

*Plant Response to Climate Change:
Integration of ITEX Discoveries*



Proceedings from the 9th ITEX Meeting



AEL REPORT 1

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***Plant Response to Climate Change:
Integration of ITEX Discoveries***



Proceedings from the 9th ITEX Meeting

Compiled and edited by Robert D. Hollister

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Foreword

This compilation from the 1999 meeting of the International Tundra Experiment (ITEX) held at Michigan State University (MSU) demonstrates the considerable progress made since the 1990 founding meeting of ITEX which was also held at MSU. In the intervening nine years ITEX has become an established and well-known project. It has been used as a model for related endeavors. This document is intended to serve as an update on ITEX activities and an encouragement for continued integration and cooperation in the study of tundra plant response, and the linked feedback of this response, to climate change.

The ITEX Steering Committee and I wish to thank Bob Hollister for his unflagging efforts as Conference Coordinator and compiler and editor of this report. The meeting was made possible with funding from the United States National Science Foundation Office of Polar Programs (grant number OPP 9714103).

Participants of the conference and readers are urged to continue their interaction and to avail themselves of the ITEX Network and its links to other endeavors that study global change. This is the way to make the best progress toward the common goal of understanding and conserving Earth's cold-dominated ecosystems.

Patrick John Webber
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ITEX Steering Committee

Philip Wookey, Chair
Thomas Berg, Secretary

Greg Henry
Kari Laine
Ulf Molau
Volodya Razzhivin
Marilyn Walker
Patrick Webber

THE INTERNATIONAL TUNDRA EXPERIMENT (ITEX)

The International Tundra Experiment (ITEX) is a collaborative research effort that is examining the response of circumpolar cold adapted plant species to environmental change, specifically to an increase in summer temperature. ITEX uses empirical knowledge based on experiments and evolutionary history, ecology, and genetics to forecast plant species response to climate change. Collectively the ITEX network is able to pool its data sets to examine vegetation response at varying levels, for example genetics (from ecotype to functional type), across space (from habitats to ecosystems), and over time. ITEX is part of the Northern Sciences Network (NSN) and is coordinated from the Danish Polar Center, Copenhagen. US projects in ITEX are also part of the Arctic Systems Science Program (ARCSS).

ITEX began in December of 1990 when researchers from North America, Europe, and Russia met at Michigan State University and agreed to undertake similar experimental studies on plants throughout the tundra biome. The primary focus of the research was to be on species responses to natural variations in climate and experimental warming, with a secondary focus on ecosystem processes and community dynamics (Webber and Walker 1991). ITEX was designed with a uniform set of protocols (ITEX Manual, Molau 1993) in order to standardize experiments and measurements all participating sites. ITEX includes several levels of complexity ranging from a basic passive warming experiment using small, clear-plastic, open-top chambers where standard observations are made on sets of circumpolar species, to more sophisticated measurements and manipulations involving whole system responses (Molau and Mølgaard 1996). The ITEX *modus operandi* for studying biotic response to climatic variation is well regarded and has been used as a model for other studies. ITEX is one of only a few truly circumarctic research programs; it currently consists of over 37 sites in 13 countries.

ITEX has provided extensive empirical data on the response of plant species, vegetation structure, physiological processes, and ecosystem processes to experimental warming. The success of the Network is demonstrated best by two recent synthesis efforts: (1) a special issue of *Global Change Biology* with papers highlighting site-specific findings and cross-site comparisons (Henry 1997); and (2) a synthesis paper based on a meta-analysis of the collective ITEX data (Arft *et al.* 1999).

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About the Conference

The 9th ITEX meeting was intended to showcase integration within ITEX and to seek to catalyze integration with the Climate Change Community. The focus of the conference was to highlight ITEX achievements and demonstrate why ITEX results are central to understanding vegetation response to global warming. While stressing the need for continued long-term data sets, the conference emphasized linkages and applications of current ITEX work within and beyond the network. In order to enrich the ITEX vision scientists who work on other taxa, other biomes and other global change programs were invited to attend. The meeting also elucidated the direction of the network and created active working groups to address ITEX related issues.

The Conference Goals were:

- to refresh and review the ITEX mission and goals;
- to review progress and renew momentum;
- to continue and enhance synthesis;
- to increase integration within ITEX and across the climate change community;
- and to elucidate continuing and new directions of the Network.

CONFERENCE PROGRAM

Plant Response to Climate Change: Integration of ITEX Discoveries

Tuesday January 5th, 1999 "Gathering "

8:00-10:00pm Welcome reception at the Marriott Hotel Terrace
(pick up registration material)

Wednesday January 6th, 1999 "ITEX Discoveries "

ALL PLENARY SESSIONS WILL BE HELD IN ROOM 105 SOUTH KEDZIE HALL

7:30- 9:00am Poster setup (105 South Kedzie Hall)

ITEX HIGHLIGHTS, Morning Session Chair: Pat Webber

9:00- 9:05am Welcome to MSU - Robert Huggett, MSU Vice-President for Research and Graduate Studies
9:05- 9:15am The Program – Pat Webber
9:15- 9:35am Opening Address – Phil Wookey
9:35-10:15am Summary of the Special Issue of Global Change Biology – Greg Henry and Ulf Molau

10:15-10:45am Refreshments and Posters

10:45-11:55am Summary of the NCEAS Synthesis paper – Marilyn Walker

PROJECT REPORTS

11:55-12:15pm A five-year ITEX study at Latnjajaure, northern Swedish Lapland – Ulf Molau
12:15-12:30pm Biotic validation of ITEX Open Top Chambers in Alaska – Bob Hollister

12:30-2:00pm Lunch

PROJECT REPORTS (CONTINUED), Afternoon Session Chair: Phil Wookey

2:00-2:15pm Norwegian Alpine ITEX – Ørjan Totland
2:15-2:30pm Linking leaf phenology and gross ecosystem production in Alaskan tussock tundra – Steve Oberbauer
2:30-2:45pm Vegetation changes in ITEX experiments in the Canadian High Arctic – Greg Henry
3:00-3:15pm Studies on ecosystem functioning at subantarctic Macquarie Island – Craig Tweedie
3:15-3:30pm Climate Change effects at the limits of plant life – Georg Grabherr
3:30-3:45pm Growth of *Betula nana* in northern Sweden and northern Alaska – Donie Bret-Hart
4:00-4:15pm Refreshments and Posters
4:15-4:30pm What can be learned from studies of key variables at many tundra sites during a single season? – Inga Svala Jónsdóttir
4:30-4:45pm Responses of soil microbial biomass and respiratory properties to artificial warming – Yukiko Bekku, Hiroshi Kanda and colleagues
4:45-5:00pm Ecosystem feedbacks to climate warming and pastoral land use change on the Qinghai-Tibet Plateau, China – Julia Klein
5:00-5:15pm Combined influence of grazing and warming in a high arctic wet meadow – Esther Lévesque
5:15-5:30pm Population genetics of *Pedicularis dasyantha* on Svalbard, relation to past and present environments – Ann Marie Odasz-Albrigtsen
5:30-5:45pm Progress of the BioBasis Monitoring Programme at Zackenberg, Northeast Greenland – Hans Meltofte

5:45-6:00pm Poster Session

CONFERENCE PROGRAM

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Thursday January 7th, 1999 " Widening the Picture "

ALL PLENARY SESSIONS WILL BE HELD IN ROOM 105 SOUTH KEDZIE HALL

8:30-8:35am Introductory comments and House keeping

GLOBAL CHANGE NETWORKS, Chair: Inga Svala Jónsdóttir

8:35-8:50am NSN/MAB – Pat Webber

8:50-9:05am GCTE/IGBP – Gus Shaver

9:05-9:20am FATE / IASC – Torben Christensen

9:20- 9:35am CALM / IPA – Jerry Brown

9:35-9:50pm ARTERI / EC – Phil Wookey

9:50-10:20am Refreshments and Posters

10:20-10:35am ETEMA / EC – Martin Sykes

10:35-10:50am NATEX / ARCSS – Steve Oberbauer

10:50-11:00am ATLAS / ARCSS – Jeff Welker

11:00-11:05am SCANTRAN – Kari Laine

COMMUNITY & ECOSYSTEM STUDIES: Chair Jeff Welker

11:05-11:50am Modeling vegetation at different scales – Martin Sykes

11:50-12:35am Biogeochemistry and Carbon Balance of Tundra and Wetland Ecosystems – Torben Christensen

12:35-2:00pm Lunch

COMMUNITY & ECOSYSTEM STUDIES (CONTINUED), Afternoon Session Chair: Marilyn Walker

2:00-2:45pm Long-term system responses to manipulation and mimicking of climate change – Gus Shaver

2:45-3:00pm Community and Ecosystem Research within ITEX – Phil Wookey

3:00-3:30pm Refreshments and Posters

PANEL COMMENTARY AND COUNSEL FOR WORKGROUPS

3:30-4:30pm Panel members - Josef Svoboda, Jerry Brown, Ulf Molau, Volodya Razzhivin

4:30-5:00pm Preliminary discussion of breakout group activities - Pat Webber

7:00-10:00 Reception and Banquet

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Friday January 8th, 1999 "Building on the Investment "

ALL PLENARY SESSIONS HELD IN ROOM 105 SOUTH KEDZIE HALL

8:30-8:40am Introductory comments and house keeping – Bob Hollister and Phil Wookey

BREAKOUT SESSION I

8:40- 9:00am Meet together to form groups

9:00-10:30am

- Group I Metadata
- Group II Community Analysis
- Group III Soils
- Group IV Climate
- Group V Modeling

10:30-11:00am Refreshments and Posters

11:00-11:15am The Computational Ecology & Visualization Laboratory – Stuart Gage

11:15-12:00pm Report from Groups

12:00-1:30pm Lunch (NATEX & NORUTEX Planning Meetings)

BREAKOUT SESSION II

1:30-1:50pm Meet together to form new groups determined by participants

1:50-3:00pm

- Group VI Editorial
- Group VII Observatory
- Group VIII Biotic Interactions
- Group IX ITEX Linkages
- Group X Functional Types

3:00-3:30pm Refreshments and Posters

BREAKOUT SESSION III

3:30-6:00pm Final Working Group Reports and Discussion

WRAP UP

6:00-6:15pm Passing of the Viking

Saturday January 9th, 1999 "Field Trip "

9:00am-11:00pm Field trip to Lake Michigan

This trip lasted all day. We toured the landscape of Southwest Michigan and visit the Warren Dunes on the shore of Lake Michigan. These are huge forested dunes. On the way to the dunes we had lunch in the Village of Paw Paw and toured the small winery St. Julian. Towards the end of the afternoon we visited the small harbor town and summer resort of Saugatuck. We had dinner there and return to East Lansing around 11:00pm having covered almost 500km!

OPENING ADDRESS

Plant Responses to Climate Change: Integration of ITEX discoveries

Philip A. Wookey
ITEX Chair

Introduction

ITEX was launched in 1990 in response to a growing awareness that environmental change in tundra regions (related to anthropogenic modifications of atmospheric composition: Leggett *et al.* 1992) is expected to be of greater than average magnitude, particularly at high latitudes (Maxwell 1992). The potential ecological impacts of such changes are hypothesized to be serious in tundra dominated regions due to (i) the relatively greater increase in accumulated heat sum (thermal time) under global warming in high latitudes compared with temperate or tropical ecosystems, and (ii) because elements of the tundra biota (including soil organisms) that may be approaching the limits of their physiological tolerances may also be particularly sensitive to an amelioration or deterioration of conditions (see Callaghan *et al.* 1992, Wookey & Robinson 1997a,b for reviews). It is now recognized that if tundra ecosystems do indeed exhibit responsiveness to environmental changes then this will not only have implications for the structure, biodiversity and functional stability of the systems themselves but it will also, through strong land-atmosphere coupling, influence surface energy budgets, water vapor, CO₂ and CH₄ fluxes (see Foley *et al.* 1994, Oechel and Vourlitis 1994).

Several key facets of the philosophy and approach underpinning ITEX have enabled the program to make a unique contribution to the debate on global change impacts on the structure and function of terrestrial ecosystems. The purpose of this address is to highlight some of the achievements of ITEX, to consider what still needs to be done, and to discuss the longer-term role of ITEX within the context of other programs relating to global change and tundra ecosystems.

ITEX characteristics and attributes

Tundra ecosystems and community types occupy a broad 'environmental space' (see Bliss *et al.* 1981), from the extreme polar deserts of, for example, northern Canada, Greenland, and the Russian Arctic archipelagos to the 'closed-canopy' tundras of the Low Arctic, and from maritime (e.g. sub-antarctic Macquarie Island) to continental and high elevation alpine tundra (e.g. Qinghai-Tibet Plateau, China and Niwot Ridge, Colorado). ITEX was launched in recognition of this diversity and of the value of establishing experiments and monitoring activities at a network of contrasting sites covering a wide swathe of 'environmental space' (Henry and Molau 1997). ITEX, through its broad coverage of tundra ecosystems (or 'extensive approach'), provides an essential counterpart for complex, technically-demanding 'intensive' experiments which, by virtue of their cost and demands for highly-developed infrastructure, are restricted spatially. Data from ITEX provides a tremendous resource for 'scaling-up' and making

generalizations about the structure and function of tundra ecosystems and their potential responses to environmental change. The data set from ITEX can also be used explicitly to draw geographical comparisons about how tundra plant species with a broad distribution react to temperature amelioration at widely contrasting positions in their range (Arft *et al.* 1999): Such information cannot be obtained at just one research site, no matter how comprehensive the experimental design, and this is one key reason why extensive networks of sites must be established to support intensive manipulations. Fig. 1, and accompanying legend, illustrates the importance of 'environmental space' and ecological responses to environmental change.

Several features of ITEX that have contributed to its implementation at many sites include (i) the focus on a suite of major circumpolar, arctic and alpine vascular plant species (the so-called 'bottom-up' approach, see fig. 2, which provides an achievable target and manageable workload in the field when personnel and resources are limited), (ii) the emphasis on an environmental manipulation (temperature) that requires no electric power, minimal maintenance and only requires moderate financial resources to set-up (Marion *et al.* 1997), (iii) the availability of a comprehensive manual of techniques (Molau and Mølgaard 1996) and a mechanism to update these when necessary, and (iv) the catalyst provided by regular workshops and the opportunities they create to exchange ideas and evaluate/synthesize data. ITEX has also benefited from being a program that can dovetail with more complex environmental manipulation experiments (e.g. at the Toolik Lake LTER (Long-Term Ecological Research) site and the ZERO (Zachenberg Ecological Research Operations) site in Northeast Greenland).

ITEX achievements and the agenda for the future

Within the last two years the original vision of the ITEX founders has materialized in the form of two major syntheses of ITEX data sets: (i) the publication of a *Global Change Biology* special issue (Vol. 3, supplement 1, December 1997), and (ii) the meta-analysis (based upon ITEX data sets from 13 sites) and synthesis meeting at NCEAS (the National Center for Ecological Analysis and Synthesis) University of California, Santa Barbara, from 4-9 December 1996. The meta-analysis work is in press and soon to be published in *Ecology*.

The special issue of *Global Change Biology* focuses on the responses of individual 'ITEX species' to experimental manipulations of temperature, together with comparative analyses of soils and climate across the ITEX sites. The contribution provides a comprehensive overview of ITEX progress over the first 3-4 years of the program, and also laid the foundation for the subsequent meta-analyses of the broader data set. Although such synthesis works have high visibility in the scientific community it should also be noted here that ITEX researchers have maintained strong publication output from work at the individual sites for which they are responsible. We take this aspect of ITEX seriously because one tenet of the philosophy of the program is that work at individual sites should stand on its own merits and be publishable in its own rights. The program has supported the scientific development and training of young researchers from 13 countries and contributed to numerous successful PhD and Masters dissertations.

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The key scientific achievements presented in the ITEX special issue of *Global Change Biology* and in the meta-analysis paper in *Ecology* are presented elsewhere at this meeting (by Ulf Molau and Greg Henry, and Marilyn Walker, respectively). One aspect of the results obtained so far in ITEX, however, that should also be emphasized here, is the growing evidence that amelioration of temperature constraints may result in significant short-term (2-4 yr) responses of individual species, but that these responses may not be maintained over the medium to longer term (arbitrarily defined here to >5 years). This pattern of decreasing response though time likely reflects the gradual imposition of an alternative resource constraint (in particular, nutrient availability), particularly if rates of nutrient recycling are insufficient to support increased plant growth and overall system productivity. This pathway is illustrated in Fig. 2 by the link between 'ecosystem/landscape/watershed' and 'individual species'.

The temporal dynamics of species responses (Arft *et al.* 1999), plus the increasing evidence to suggest that nutrient and/or water limitations may play a significant role in determining the longer-term responses of tundra communities to warming (Chapin *et al.* 1995, Robinson *et al.* 1998), both point to two fundamental factors that must be given priority: (i) it is absolutely essential to maintain the temperature manipulation experiments for as long as is possible, and (ii) it is becoming clear that individual species responses can only be objectively interpreted in relation to community characteristics and soil nutrient and water supply at individual sites. On the basis of their longer-term environmental manipulation experiments at the Toolik Lake LTER site in Alaska, Chapin *et al.* (1995) also state that "realistic predictions of the future distribution of vegetation with respect to climate must emphasize the indirect effects of climate on resource supply". Another striking lesson from ITEX to date is that, quite apart from the experimental manipulations themselves, the maintenance of ITEX measurements on 'control' (unmanipulated) plots over several years has yielded data of exceptional value in relation to natural inter- and intra-annual climatic variability.

ITEX must now address issues relating to resource supply and community dynamics in the medium to longer-term. The value of the program can be increased substantially by ensuring that we have good basic information on soil C and N pools, nutrient mineralization rates and temperature/moisture response kinetics of the decomposer communities. With this objective in mind a working group on soils was convened during the 9th ITEX Meeting (under the leadership of Gabriele Broll and Charles Tarnocai, see the Report from the Soils Working Group in the Appendix) to develop further the soils research presented in the *Global Change Biology* special issue by Marion *et al.* (1997). Recommendations for soils research will be included in an updated version of the ITEX Manual.

Finally, the philosophy of ITEX has always been based, although to some extent implicitly, on the use of a combination of approaches to answer the scientific questions being posed. These approaches can be summarized as the '3 Ms' (*manipulation*, *monitoring* and *modeling*) - see fig. 3 - and this can be increased to 4 if we explicitly include *mapping* (as suggested by Marilyn Walker). These approaches are complementary and provide several lines of evidence to strengthen our conclusions. The

OPENING ADDRESS

use of the 4-Ms is also an iterative process: the results of monitoring and experimental manipulations, for example, can refine model parameterizations, while modeling can provide a catalyst for hypothesis development and highlight key areas where further data are needed. At the current stage of development of ITEX, however, we recognize that we need to incorporate a modeling component to provide us with the ability to make objective predictions concerning rates and directions of future change. The involvement of Martin Sykes (see abstract p. 65) in the 9th Meeting was a step in the right direction, but it will be important to maintain this momentum.

ITEX links to other programs

ITEX brings together a unique pool of logistic and scientific expertise from around the world: we also welcome the opportunity to share our experience and to establish connections with interested individuals and research programs from all branches of the natural sciences and Humanities. ITEX researchers are in a strong position to inform the international scientific debate on the potential responses of tundra plant species and vegetation communities to environmental change. The circum-polar Arctic and alpine coverage of contrasting tundra environments, all underpinned by a common set of protocols and objectives, provides a broad spatial framework for interpreting responses at various points within individual species ranges.

What ITEX does not systematically address, however, is the significance of several other major facets of environmental change occurring in tundra regions (e.g. elevated CO₂ concentrations or increased fluxes of UV-B radiation at the surface). When ITEX was designed it was recognized that the inclusion of manipulations requiring sophisticated technical and logistic services would limit the spread of ITEX sites and therefore weaken its geographical coverage (and thus its coverage of 'environmental space'). As stated previously, therefore, ITEX is complementary to research programs (e.g. LTER) that deal with these other aspects of environmental change.

ITEX currently works in direct partnership with the IPA (International Permafrost Association) and we are actively exploring potential links with other programs such as AMAP (the Arctic Monitoring and Assessment Program: see <http://www.grida.no/amap/amap.htm>), CAFF (the Program on Conservation of Arctic Flora and Fauna: see <http://www.grida.no/caff>) and SCANTRAN (an IGBP Terrestrial Transect for Scandinavia / Northern Europe). ITEX has benefited greatly from the support provided by the UNESCO MAB-Northern Sciences Network over the years.

ITEX undoubtedly has a major role to play in the years to come, and the impetus will be greatly strengthened if funding that transcends national boundaries can be found to support the program. With this in mind the Canadian and US participants in ITEX have recently joined forces to write a proposal to NSF to create NATEX (the North American Tundra Experiment), while on the other side of the Atlantic the Nordic and Russian ITEX participants have recently submitted a proposal to the Nordic Council of Ministers to fund NORUTEX (the Nordic-Russian Tundra Experiment). We are acutely aware of the problems maintaining viable ITEX research in Russia, and this is an issue that can only realistically be addressed by finding support from international programs.

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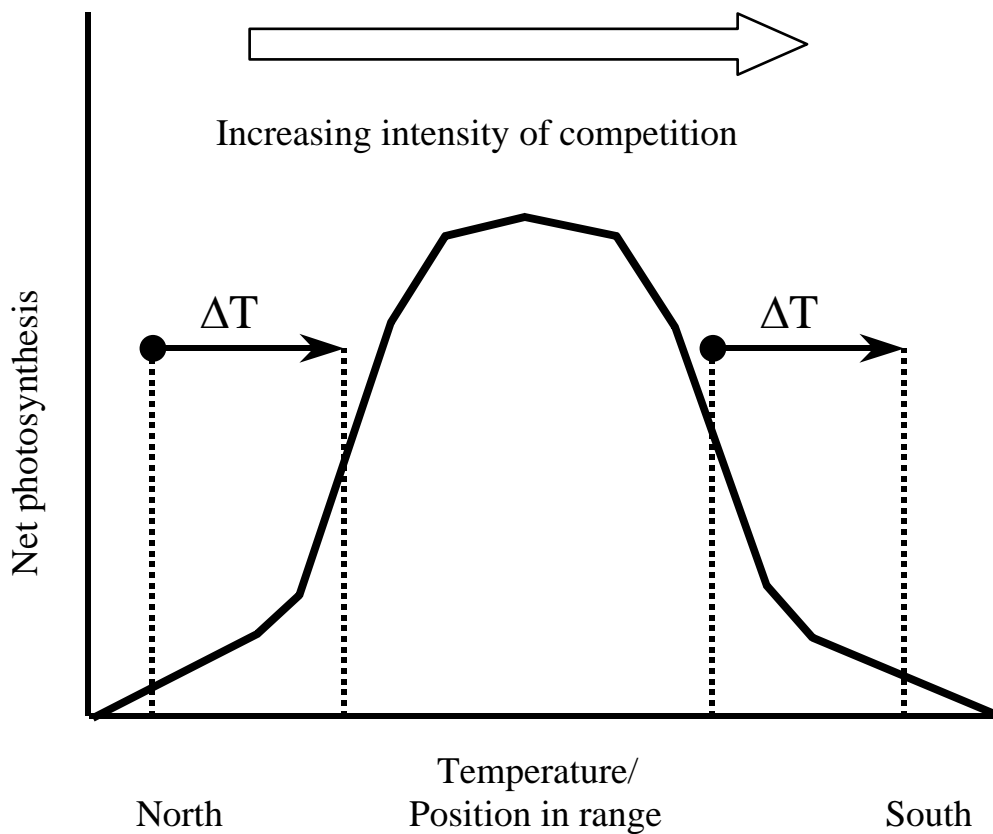


Figure 1. Spatial scale, ‘environmental space’ and ITEX manipulations. This schematic diagram illustrates the performance of a plant species (in terms of net primary productivity, NPP) across a gradient of temperature (which could be expressed as mean temperatures over a growing season, or as some other metric of thermal energy availability, e.g. growing degree days (GDDs), or in the case of tundra plants thawing degree days (TDDs), representing accumulated ‘thermal time’). Increasing temperature in tundra ecosystems will co-vary with other abiotic factors (e.g. precipitation or depth of the active layer) and also with biotic factors, such as intensity of competition or herbivory. Intensity of competition (e.g. for light or soil nutrients) is likely to increase from the extreme polar deserts and alpine fellfields to the more closed tundras of the Low Arctic and mid- to low alpine (perhaps leading to a skewed NPP curve, with values dropping more steeply at the warmer end of the distribution due to competition interactions). Note that, according to this scheme, a given temperature increase (ΔT) could produce quite different outcomes depending on where in the species’ range the warming occurs. Thus warming at the colder end of the distribution could markedly improve plant performance, while toward the warmer end of the distribution increased respiratory demands, or intensity of competition, could reduce NPP to the extent that the species dies out, or is forced-out, of the community.

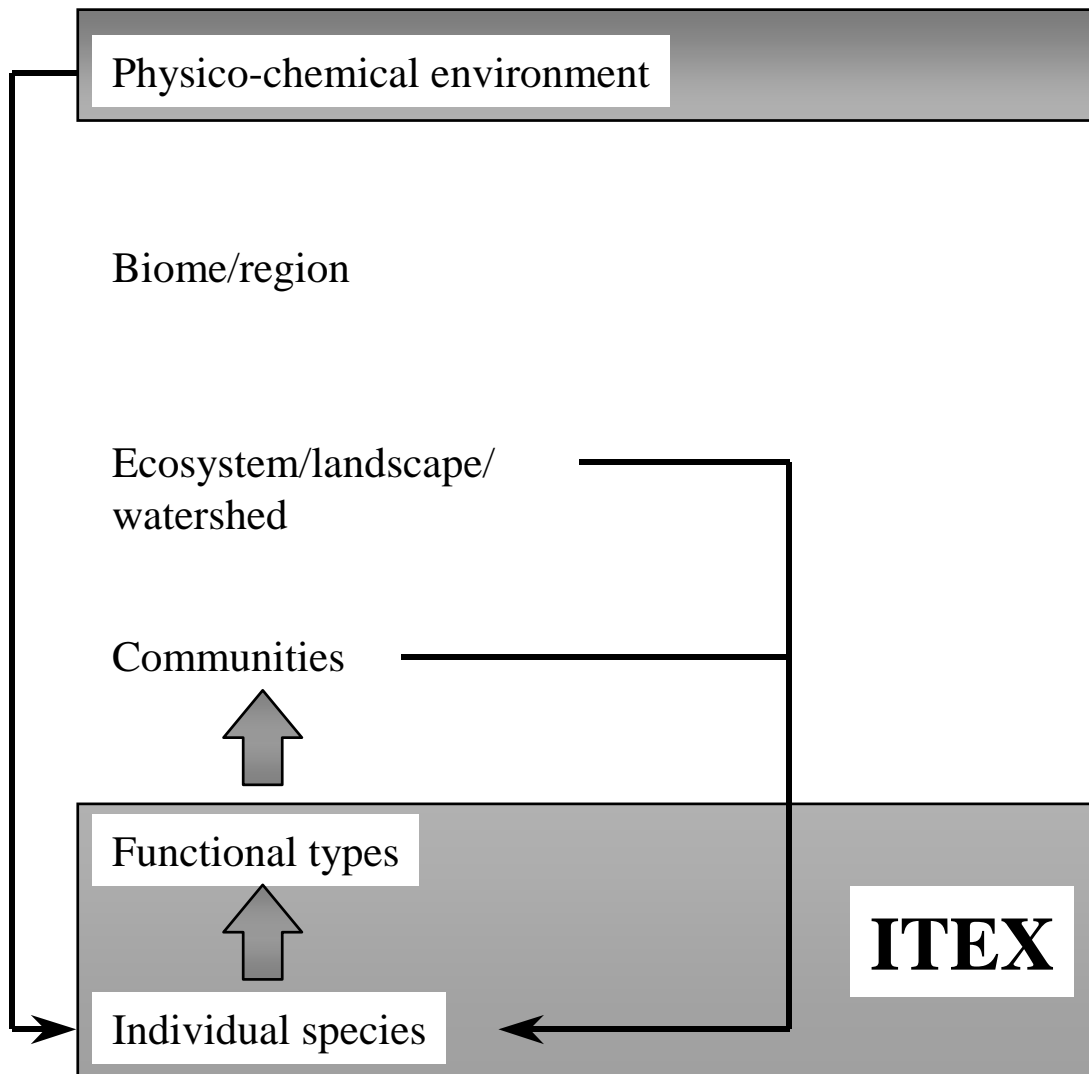


Figure 2. ‘Top-down’ and ‘bottom-up’ approaches to environmental manipulation experiments. ITEX adopts a ‘bottom-up’ approach to studying the impacts of environmental change on tundra plant species (in recognition of the fact that the responses of individual plants underpin the community and higher-level system responses to change). This diagram illustrates the way in which ITEX also considers functional types (see Arft *et al.* 1999). The arrows leading from ‘communities’ and ‘ecosystem/landscape/watershed’ back to ‘individual species’ reflect the potential for individualistic plant responses to temperature to be, in their turn, modulated by nutrient availability in the system (and responses of the decomposer communities to change) and plant interactions (i.e. the same species may not respond to the same manipulation of temperature in the same way if growing in contrasting communities with contrasting competitive interactions). Forecasting changes at the Biome / region level is a task that becomes an ultimate goal and one that requires recognition of ITEX contributions and coordination with global climate and vegetation modelers.

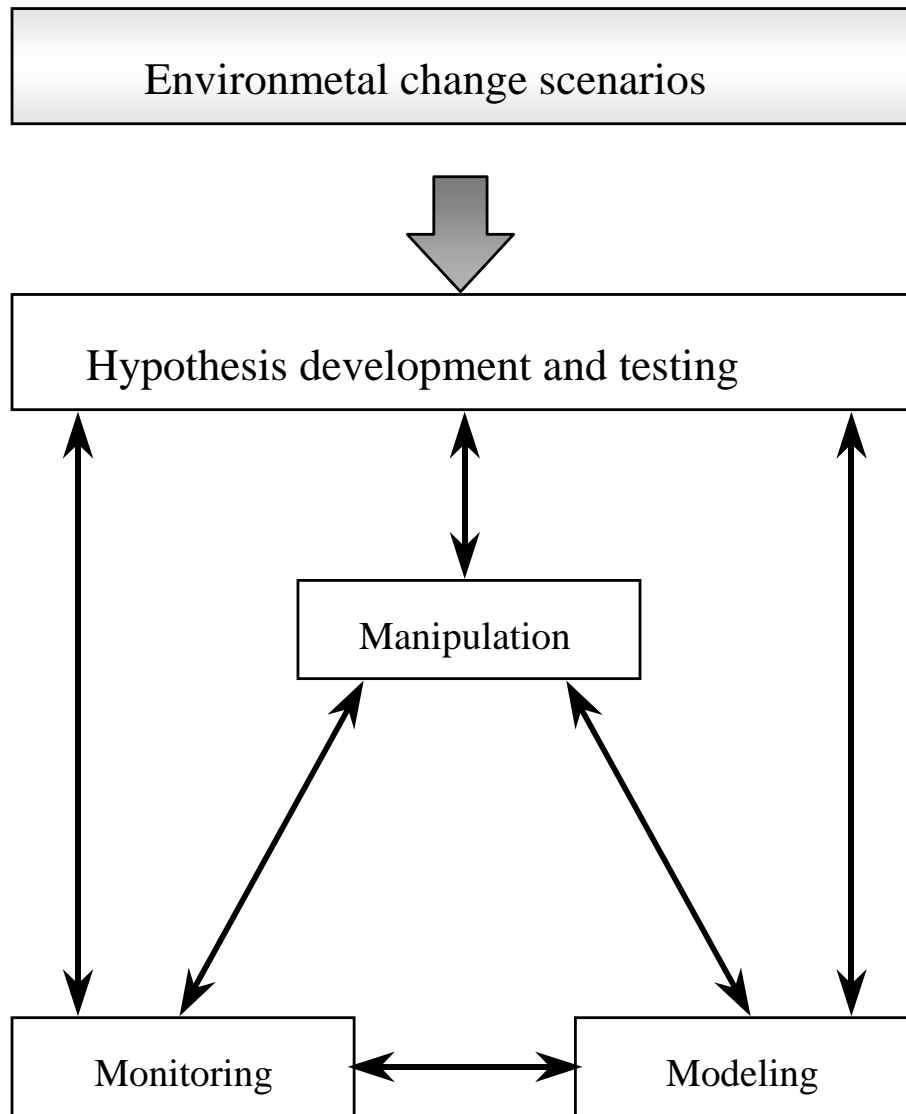


Figure 3. Rational for environmental manipulation experiments - the ‘3 Ms’. ITEX has implicitly been based upon the rationale outlined in this diagram. The environmental *manipulation* experiments and the *monitoring* activities have been central to ITEX since the inception of the program. At the current stage of development of ITEX, however, we need to strengthen the *modeling* component. The double arrows here illustrate the iterative nature of the investigative process, with the contrasting approaches reinforcing one another and allowing refinements to be made. Since ITEX also has a strong spatial element, and is based on a network of sites, a 4th M could also be added: *mapping*.

ITEX WORKING GROUPS

The following ten working groups were established during the meeting in order for ITEX members to continue to address critical issues. The membership of these groups is expanding; people interested in becoming a group member should contact the group leader. Working group reports on recent progress can be found in the Appendix.

ITEX Metadata

Leaders: R. Hollister, C. Tweedie

This working group will collect, organize, and distribute metadata on all the ITEX sites. This information will ease collaboration and is essential for synthesis. The ITEX metadata will be distributed beyond the ITEX group to increase awareness and encourage linkages with other groups particularly modelers.

Observatories

Leader: H. Meltofte

Members: J. Brown, G. Grabherr, S. Bret-Harte, I. Jónsdóttir, K. Laine, E. Lévesque, U. Molau, U. Nordenhäll

ITEX recognizes the value of basic long-term monitoring of weather, climate and ecological dynamics. This working group will encourage the continuity of existing efforts at Environmental Observatories such as the BEO (Barrow Environmental Observatory) and the ZERO (Zackenbergl Ecological Research Observatory) and the establishment of new observatories. It will also identify a minimal list of critical environmental and ecological measurements.

Climate

Leader: G. Henry

Members: U. Molau, R. Hollister, C. Tweedie

This working group will expand on earlier efforts to compile climate descriptions for each site. It will also encourage sites to set up and maintain minimal on-site climate stations according to the ITEX Manual.

Soils

Leaders: G. Broll, C. Tarnocai

Members: C. Bilbrough, J. Brown, E. Lévesque, J. Klein, R. King, P. Wookey

As ITEX expands its interests into ecosystem processes good soil information will be needed. This working group will establish a list of minimum soil descriptors to be measured at each site and the methods to obtain them. The group will also be pro-active in data gathering, compilation and analysis.

Community Analysis

Leader: F. Gugerli

Members: M. Diemer, E. Lévesque, G. Grabherr, V. Razzhivin, M. Walker, P. Webber

Preliminary classification and ordination of the ITEX sites based on plant community composition shows interesting patterns of life form distribution but reveals large gaps in the data set. This working group will continue this work and encourage all sites to provide basic community and environmental descriptions. The aim will be to relate the ordinations and classifications to results derived from plant response syntheses. The group will also encourage regular measurements of community composition using the ITEX point frame method in order to track natural and experimental changes.

Biotic Interactions

Leader: I. Jónsdóttir

Members: C. Bilbrough, S. Bret-Harte, G. Henry, O. Khitun, J. Klein, E. Lévesque, A. Odasz-Albrigtsen

Concern has been expressed that the standard ITEX open top chamber interferes with and affects plant-animal interactions such as pollination and herbivory, and plant-plant interactions such as competition, parasitism and symbiosis. This working group will design appropriate controls for substitute experiments to examine the effect of chambers on biotic interactions and include suggestions on how the effects of climate change on biotic interactions might also be examined.

Functional Types

Leader: U. Molau

Members: S. Bret-Harte, H. Kanda, K. Laine, U. Nordenhäll, A. Odasz-Albrigtsen, M. Walker, P. Webber

This working group will review and evaluate existing plant functional types (PFT) classifications and encourage the development of new *ad hoc* PFT classifications on the basis of ITEX results and on the need of various modeling activities.

Modeling

Leader: M. Walker

Members: G. Grabherr, G. Henry, R. Hollister, C. Tweedie

The purpose of this working group is to coordinate modeling activities related to species and community change in tundra and northern environments. There are a handful of various modeling approaches currently being applied to this problem, and each approach has its own strengths and weaknesses. The immediate focus for this group is to coordinate a synthesis of modeling efforts aimed at looking at species-level effects on community and landscape change.

ITEX Linkages

Members: ITEX Steering Committee

ITEX is within the aegis of the NSN/MAB. The steering committee will pursue close links with GCTE/IGBP, FATE/IASC and ARTER/EC. ITEX investigators are already interacting with these efforts and it is the goal of this working group to formalize these links for mutual scientific gain.

Editorial

Leader: P. Webber

Members: G. Henry, M. Walker, J. Welker, P. Wookey

This working group will encourage and facilitate the writing of general lay articles and synthesis papers with the twin goals of widening an awareness of ITEX and sharing ITEX discoveries with global change scientists.

About the Abstracts

The order of the abstracts is alphabetic by first author's last name. Most papers were presented as posters. Abstracts denoted with a ▲ were presented orally at the plenary sessions.

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PHENOLOGICAL AND PHYSIOLOGICAL RESPONSES OF EIGHT NORTHERN ALASKA TUNDRA SPECIES TO DECREASED SUMMER IRRADIANCE

Lorraine E. Ahlquist, Esperanza Rodriguez, Brooke Shamblin, and Steven F. Oberbauer.
Florida International University, Miami, USA.

Preliminary observations had suggested that when shaded, tundra plants delay their senescence compared to unshaded plants. Such a response to delayed senescence may function to prolong leaf carbon gain in order to maintain a balance relative to internal nutrient stores. To verify that shaded plants do delay senescence, we conducted a shading experiment by covering 1.5 x 1.5 m plots with A-frame tents made of 50% shade cloth after leaves had expanded. We monitored the phenology and physiology of eight species on the plots and compared them to nearby unshaded control plants. The results confirmed that shaded plants delay senescence and maintain physiological activity longer relative to unshaded controls.

RESPONSES OF SOIL MICROBIAL BIOMASS AND RESPIRATORY PROPERTIES TO ARTIFICIAL WARMING

Yukiko Bekku¹, H. Kanda¹, T. Nakatsubo², A. Kume², and H. Koizumi³. ¹ National Institute of Polar Research, ² Hiroshima University, ³ Gifu University, Japan.

Introduction

It is generally anticipated that global warming will stimulate soil microbial activity and decomposition rate of soil organic matter. In particular, as arctic ecosystems have large carbon pools in permafrost (Melillo *et al.* 1990), the increase in the decomposition rates may result in a large release of CO₂ and nutrients. The increase in CO₂ emission to the atmosphere could affect the regional and possibly global carbon cycle and climate (Oechel and Vourlitis 1994). The large release of nutrients could exert marked effects on plant-soil relationships in arctic ecosystems (Nadelhoffer *et al.* 1992). Thus, it is important to determine the effects of warming on decomposition processes in order to predict the response of ecosystems to global warming.

For predicting the responses of decomposition processes to warming, effects of temperature increase on soil microbial activities should be elucidated. Microbial activities depend on microbial biomass and the respiratory properties (biomass specific respiration rate and its temperature dependence). However, information on above microbial processes in arctic ecosystems remains very scarce. In the present study, we examined the responses of soil microbial biomass and the respiratory properties (the specific respiration and its temperature dependence) to warming in a laboratory experiment using three types of arctic soil.

Materials & Method

Three study sites (Site-1 to Site-3) were set on moraines representing different successional stages in the deglaciated area of East Brogger glacier in Ny-Alesund, Svalbard, Norway (79°56'N, 11°50'E). Soil carbon and nitrogen contents varied among the three sites reflecting successional ages; 2% and 0.06% in Site-1, 10% and 1% in Site-2, 20% and 6% in Site-3. Soils at the study sites were collected from 6 points in early July 1998. The six soil samples were mixed well, and passed through a 2-mm mesh sieve to remove plant roots and stones, then divided into 27 subsamples and placed in petri-dishes ($\phi = 7$ cm). The subsamples were incubated under three temperature conditions for 40 days ($n=9$ for each temperature): 2°C constant (cooling treatment), 14°C constant (warming treatment) and a control at 8°C constant (control) which was the average soil temperature in the growing season at the field. Water contents of the soil samples at Site-1, Site-2 and Site-3 were kept at approximately 20%, 70% and 100% (approximate average water contents in the field), respectively, by occasional irrigation with distilled water. After soil incubation for 40 days, microbial respiration rate and its temperature dependence were measured with closed chamber method (Bekku *et al.* 1997), changing the soil temperature from -2°C to 24°C in an incubator. Following the respiration

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measurements, ATP content which is an indicator of microbial biomass in the soil were measured with ATP-method (Jenkinson and Oades, 1979).

Results & Discussion

There was no significant difference in the respiration rate and its temperature dependence among three temperature treatments in all study sites. Total amount of respired-CO₂ during 40 days, was largest in the warming treatment, and smallest in the cooling treatment at all sites. However, in Site-1 and Site-2 where soil carbon and nitrogen contents were low, ATP contents (microbial biomass) in the warming treatment were significantly lower than the control and cooling treatment, and respiration rates in the warming treatment had been decreasing at the later stages of the experiment. These results suggested that in warming, the soil microbial respiration rate, namely decomposition rate, would be enhanced by temperature increase, maintaining the present metabolic properties. However, in soils that have less organic matter, the effect of increased temperature would be offset by substrate limitation.

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BRYOPHYTE PROPAGULE BANKS IN FELDMARKS ON SUBANTARCTIC MACQUARIE ISLAND

Dana M. Bergstrom¹ and P. M. Selkirk². ¹The University of Queensland, Brisbane, ²Macquarie University, Sydney, Australia.

Subantarctic Macquarie Island has substantial areas of feldmark on its plateau above 200m altitude. Samples of the substrate (5cm in depth) from bare areas of feldmark contained viable propagules of bryophyte species found at adjacent and distant sites on the island. In laboratory conditions propagules of 15 bryophyte taxa germinated, allowing interpretation of reasons for bare patches in feldmark: bryophytes were successful at colonizing stable ground but when surface movement was present, burial or damage of propagules and young plants prevented colonization. Spherical moss posters found in cryoturbatic areas in feldmark, however, represent a growth form that can tolerate surface movement. Ten of the 15 germinated taxa were non-local taxa which currently grow in plant communities at lower and hence warmer altitudes on Macquarie Island. The presence of viable propagules of these taxa provide an immediate and constant potential for dramatic vegetation change with climate change.

HOW WILL PLANTS AT THE POLAR FRONT RESPOND TO CLIMATE CHANGE?

Dana M. Bergstrom, Craig E. Tweedie, and Justine Shaw. The University of Queensland, Australia.

Using temperature change with increasing altitudinal as an analogy of climate warming, plant structure and function of key plants is being studied on subantarctic Macquarie Island. As with other subantarctic islands in the Southern Ocean, Macquarie Island lies in the vicinity of a significant oceanic and climatic boundary, the Antarctic Polar Front (APF). Climatic induced changes are likely to be observable first at regional margins such as the APF. In addition, subantarctic vascular plants may prove to be sensitive ecological indicators as they are at the physiological and reproductive limit of their distribution, are geographically isolated and most likely genetically impoverished. Subantarctic islands also, present relatively simple ecosystems compared with many Arctic sites. Four ITEX sites have been established on an east-facing slope on Mt Elder, Macquarie Island. In association with level II climate stations, morphological, ecophysiological and genetic studies are currently being conducted in association with a climate change scenario.

THE EFFECTS OF ELEVATED TEMPERATURE AND CHANGES IN SNOW COVER ON SOIL NITROGEN DYNAMICS.

C. Bilbrough¹, J. Welker¹, and J. Schimel². ¹ University of Wyoming, Laramie,
² University of California, Santa Barbara, USA.

Altered nitrogen (N) dynamics due to climate change are expected to affect plant N availability and soil carbon (C) dynamics and, as a consequence, affect ecosystem CO₂ flux rates and possibly community composition and production. We initiated experiments investigating the effects of climate warming and snow cover, using snow fences, on N dynamics in moist tussock and dry heath tundra. The snow fence treatments result in warmer soil temperatures during the winter and a shortened snow-free season. We are measuring N dynamics in tussock and inter-tussock subplots (moist tussock tundra), and in subplots dominated by *Arctostaphylos* or *Dryas* (dry heath). In August of this year, we began an intensive series of measurements comparing 1. gross and net rates of ammonification and nitrification (15N pool dilution technique), 2. soil organic and inorganic N pools, 3. microbial biomass C and N (chloroform fumigation-extraction), and 4. soil respiration rates, between ambient and deep snow plots and among the tundra subplots (tussock, inter-tussock, *Arctostaphylos*, *Dryas*). These measurements will be repeated in the spring during snowmelt and again during the growing season. Also in August, four replicated sets of net N mineralization cores were installed in the snow fence experiments (ambient, snow) in the moist tussock tundra (tussock and inter-tussock) and in the dry heath (*Arctostaphylos* and *Dryas*). The cores were 10 cm deep, with mixed resin bags at the bottom of the cores. One set was removed in November, and the remaining sets will be harvested in January, during snowmelt, and at peak growing season. These cores were/will be homogenized, and extracted to measure soil NH₄ and NO₃ pools for determination of net mineralization rates, and additional subsamples used to measure microbial biomass C and N, and soil respiration rates. In the November harvest, insitu soil temperatures ranged from 0 to -5 °C, and did not exceed +0.1 °C prior to extraction. We expect to find significant differences among subplots, and elevated net mineralization rates in areas of early and deeper snow accumulation.

GROWTH OF BETULA NANA IN NORTHERN SWEDEN AND NORTHERN ALASKA

M.S. Bret-Harte^{1,2}, J.P. Zoerner¹, and G.R. Shaver¹. ¹ Ecosystems Center, Marine Biological Laboratory, Woods Hole, ² Institute of Arctic Biology, University of Alaska, Fairbanks, Alaska, USA.

A key question underlying the ITEX experiment is the extent to which the capacity of individual species to respond to climate warming may differ in different parts of the Arctic. *Betula nana* is an arctic species with circumpolar distribution. In Alaskan tussock tundra, *Betula nana ssp. exilis* is co-dominant and responds strongly to increased nutrient availability and increased temperature. In long-term manipulations of nutrient availability and temperature, its abundance increases while that of other species and growth forms decline, and its growth response increases the productivity and biomass of the tundra up to 15-fold (Chapin et al. 1995, Bret-Harte et al. 1999). In contrast, in similar experiments performed in tundra in northern Sweden, *Betula nana ssp. nana* shows much less response to increased nutrient availability and increased temperature than does *Betula nana ssp. exilis* in Alaska (Graglia et al. 1997). The response of the whole ecosystem to increased nutrient availability and temperature is also much smaller in northern Sweden than in northern Alaska. We analyzed 10 years of growth retrospectively in *Betula nana* from 3 ecosystem types (riparian shrub tundra, low altitude heath tundra, and high altitude heath tundra) near Abisko in northern Sweden and 3 ecosystem types (riparian shrub tundra, tussock tundra, and heath tundra) near Toolik Lake in northern Alaska. The sites we chose fell along a natural gradient of biomass and productivity. Preliminary analysis shows that *Betula* ramets from the Swedish sites had less biomass for the same age than *Betula* ramets from similar ecosystem types in the Alaskan sites. Swedish *Betula* ramets had different branching patterns and less primary and secondary growth than Alaskan *Betula* ramets. These developmental differences may reduce *Betula*'s ability to respond to environmental change in northern Sweden, as compared with northern Alaska.

LONG-TERM PERMAFROST OBSERVATIONS AND DATA PROCESSING BASED ON THE ITEX-CALM FRAMEWORK

Jerry Brown¹, Ken Hinkel², and Frederick E. Nelson³. ¹ International Permafrost Association, ² University of Cincinnati, ³ University of Delaware, USA.

Since the development of the ITEX active layer protocol in Ottawa in 1995, additional permafrost related activities have developed. The initial set of ITEX sites has grown to a network of more than 70 sites at which the maximum depth of thaw is measured by probing on the standard 1000m or smaller sized grids (48 sites), or from other point data measured along transects, with thaw tubes, or extrapolated from temperature profiles (25 sites). The network is called the Circumpolar Active Layer Monitoring Network (CALM). Of the CALM sites, 13 sites were originally co-located or in the vicinity of ITEX sites. Most sites are equipped with soil temperature loggers, several measure soil moisture, and other obtain deeper permafrost temperatures in boreholes (23 sites). Unfortunately, some CALM sites have not reported data in the past several years or are inactive.

Starting in 1998, the University of Cincinnati received a five-year funding from the U.S. National Science Foundation to process the annual thaw and soil temperature data and provide some support and equipment for Russian sites. A web site is available for access to data and site descriptions (<http://www.geography.uc.edu/kenhinkle/CALM/>). Data will be periodically transferred to the World Data Center-A for Glaciology, Boulder, Colorado for permanent archiving. Summary data prior to 1998 and site metadata are contained on the CD-ROM Circumpolar Active-layer Permafrost System (CAPS). Although the current CALM network is confined to the Northern Hemisphere, plans are underway to add Southern Hemisphere; primarily Antarctic sites.

Presently under development is a more comprehensive program for active layer and permafrost temperature monitoring under the World Meteorological Organization and the Food and Agriculture Organization. Once approved the permafrost monitoring network will be incorporated under the Global Terrestrial Observing System (as one of its terrestrial networks) and the Terrestrial Observation Panel for Climate (TOPC). TOPC is chaired by Josef Cihlar, Canada Center for Remote Sensing. Sites will be selected based on specific spatial and temporal criteria. Many of the existing CALM, and thus some ITEX sites, will be included in the monitoring network. Belonging to the network could enhance possibilities for national or regional funding.

The existing CALM network and the proposed permafrost monitoring initiative are being coordinated through the International Permafrost Association and its several committees and working groups.

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BIOGEOCHEMISTRY AND CARBON BALANCE OF TUNDRA AND WETLAND ECOSYSTEMS.

Torben Christensen. Lund University, Lund, Sweden.

This presentation is providing a brief overview of data and results obtained through a number of studies of actual and potential trace gas exchanges in Eurasian and Greenlandic tundra ecosystems.

Long term accumulation rates of carbon in organic tundra soils, i.e. net uptake of atmospheric CO₂, have been found to be strongly controlled by simple climatic parameters (mean July temp., annual precip.). Warmer and wetter conditions are stimulating carbon sequestration rates in Arctic terrestrial ecosystems.

The release of carbon through ecosystem respiration is also strongly controlled by climate. However, the release of dead organic soil carbon as CO₂ is constrained by the lability of the stored organic compounds. This lability decreases significantly with depth (i.e. age) of the soils and further to this it also decreases the temperature sensitivity of the decomposition process.

Methane emissions from typical tundra habitats in northern Eurasia were found to be slightly lower than from seemingly similar habitats in North America although this difference probably can be attributed the colder climatic setting of the studied sites compared with the general climatic conditions at the sites of the reported North American data. There is a strong linkage between CO₂ exchange and CH₄ formation and emission rates in some wet tundra ecosystems. This linkage is currently being investigated in depth by the European Commission funded CONGAS project.

Atmospheric uptake of CH₄ occurs in some dry and mesic tundra habitats and there are indications that these uptake rates could be affected negatively by atmospheric nitrogen deposition. Emissions of N₂O are rarely seen from arctic soils but there appear to be a strong potential for denitrification and, hence, N₂O release. This might be due to high rates of denitrification during the spring thaw and possibly associated significant releases of N₂O in this period. The winter/spring releases of all trace gases from arctic terrestrial ecosystems represents an issue which needs further investigation.

VEGETATION, SOIL AND CLIMATIC CONDITIONS AT AUDKULUHEIDI, ICELAND

Ásrún Elmarsdóttir¹, Borgthór Magnússon¹, and Ingibjörg S. Jónsdóttir². ¹The Agricultural Research Institute, Reykjavík, Iceland, ²Botanical Institute, Göteborg University, Göteborg, Sweden.

In 1996 an ITEX project was started at Audkuluheidi, NW Iceland at 490 m.a.s.l. The main aim of the project is to follow changes in vegetation composition, species abundance and canopy height. The demography of *Carex bigelowii*, soil characteristics and temperature are also monitored at the site.

Ten hexagonal open top chambers (OTCs) and equal number of control plots were placed within fenced area (ungrazed). Outside the fence (grazed by sheep) are ten control plots which can be used to follow vegetation changes caused by cessation of grazing. Measurements of vegetation composition and canopy height will be repeated in 1999. Temperature was monitored in control and OTC plots from May - September 1998.

The vegetation type in the area is dwarf-shrub heathland with *Racomitrium lanuginosum*, *Cetraria islandica*, *Betula nana* and *Empetrum nigrum* as dominants. In plots inside the fence 25 vascular plant, 5 moss and 9 lichen species were recorded. The average soil pH is 6.5, carbon and nitrogen content is 4.9% and 0.4% respectively and depth of the soil to the glacial till is 63 cm.

Decorana ordination was done on the initial vegetation data collected in 1996 and 1997. A separation was not found between OTC, control and grazed plots indicating homogeneity in the vegetation. The canopy height of shoots of *Betula nana* was tested for initial difference between treatments, a significant difference was not found between OTC and control plots. Repeated sampling and ordination analysis should reveal future vegetation changes and trends between treatments.

From the middle of May until late September 1998 the OTC increased the air temperature at ground surface by 1.6°C on the average. The temperature increase was significant with respect to control plots. When comparing single days the difference between control and OTC plots was greatest in early summer.

ROYAL FERTILIZER AT THE POLAR FRONT

Peter D. Erskine, Dana M. Bergstrom, Susanne Schmidt, George R. Stewart, Craig E. Tweedie, and Justine D. Shaw. The University of Queensland, Brisbane, Australia.

Plants collected from diverse sites on subantarctic Macquarie Island varied by up to 30 ‰ in their leaf $\delta^{15}\text{N}$ values. $\delta^{15}\text{N}$ natural abundance of plants, soils, animal excrement and atmospheric ammonia suggest that the majority of nitrogen utilized by plants growing in the vicinity of animal colonies or burrows is animal derived. Plants growing near scavengers and higher food chain animals had highly enriched $\delta^{15}\text{N}$ values (mean = 12.9 ‰), reflecting the highly enriched signature of these animals' excrement, while plants growing near nesting penguins such as the abundant Royal penguin, which have an intermediate food chain position, had less enriched $\delta^{15}\text{N}$ values (> 6 ‰). Vegetation in areas affected by rabbits had lower $\delta^{15}\text{N}$ values (mean = 1.2 ‰), while the highly depleted $\delta^{15}\text{N}$ values (< -5 ‰) of plants at upland plateau sites inland of penguin colonies, suggested that a portion of their nitrogen is derived from ammonia (mean $\delta^{15}\text{N}$ = -10 ‰) lost during the degradation of penguin guano. Vegetation in a remote area had $\delta^{15}\text{N}$ values near -2 ‰. These results contrast with arctic and subarctic studies that attribute large variations in plant $\delta^{15}\text{N}$ values to nitrogen partitioning in nitrogen limited environments. Here, plant $\delta^{15}\text{N}$ reflects the $\delta^{15}\text{N}$ of the likely nitrogen sources utilized by plants.

WHAT LIMITS SEED PRODUCTION IN THE ARCTIC? AN EXPERIMENT WITH SAXIFRAGA HIRCULUS AND MONITORING OF FIVE OTHER ARCTIC SPECIES.

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Seed production is a prerequisite for recruitment in plant populations and seeds have the role of dispersion and colonization. Arctic plant populations often fail to produce seeds but the causes are not well understood. In Thjórsárver, a nature reserve in the central highland of Iceland a research was initiated in 1996 to monitor the seed production. From a human perspective, forests in mountainous areas fulfill an important task with regard to protection of *Saxifraga hirculus*, *Saxifraga nivalis*, *Saxifraga caespitosa*, *Bartsia alpina*, *Lychnis alpina*, and *Carex rostrata*. Variation in seed production between years is monitored as well as climate and the flowering time of individuals. An experiment has been conducted in 1997 and 1998 to test the following hypotheses about limiting factors on seed production in a population of *S. hirculus*: 1) the growing season is too short 2) lack of pollen 3) lack of nutrients, where a) ITEX open top chambers are raised to enhance temperature, b) individuals are hand pollinated and c) plots are fertilized. All combinations of these factors are also tested. Fruits are collected, seeds counted and classified, and their viability measured.

This research will help understand 1) the variation in seed production between years and between populations, 2) the reproductive ecology of arctic plant populations, 3) the effects of climatic global change on arctic plant populations.

RESPONSE OF *SAXIFRAGA HIRCULUS* TO INCREASED TEMPERATURE AND NUTRIENTS

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Introduction

A long term field experiment was initiated in 1996 in Thjórsárver, central Iceland, designed to assess the effects of temperature and nutrients on the phenology and quantitative parameters of *S. hirculus*, specifically date of flowering, number of flowers, shoot height, and seed weight. The factorial experimental setup comprised 40 replicates of each: a) ITEX open top chambers (OTCs) to enhance temperature by sheltering, b) N, P, K fertilized plots, and c) combinations of a) and b). Fertilization started in 1996 and OTCs were installed in 1997. The climate in Thjórsárver is oceanic, with annual precipitation of approximately 800 mm, mean July temperature of 7 °C and mean annual temperature of -0.8 °C.

Results

Plants in shelters flowered earlier than control plants (5 days difference in 1997 and 4 days in 1998), ($p < 0.001$; Fig 1). Flowering was on average 9 days earlier in 1998 than in 1997 ($p < 0.001$).

The mean number of flowers per individual was significantly different between treatments in 1998 ($p < 0.001$; Fig 2). Plants that received both shelter and fertilization had more flowers than control plants, and sheltered only and fertilized only plants. No difference in flower number was detected in 1997. More flowers were produced per individual in 1998 than in 1997 ($p < 0.001$; Fig.2).

Height of flowering shoot differed between treatments ($p < 0.001$; Fig. 3). Control plants were smallest, fertilized plants were taller, plants in shelters were taller still, but tallest were those who received combination of shelter and fertilization. Seed weight in 1997 showed similar pattern. Control plants had the lightest seeds, fertilized ones had heavier seeds and plants from combined treatments had the heaviest ones ($p < 0.001$; Fig. 4), but data are not yet available on seeds from 1998.

Discussion

Both temperature and nutrients had significant effects on *Saxifraga hirculus* but the effects differed somewhat between the characters measured. The air temperature inside shelters was on average 1.3 °C higher than outside in 1997 and 1.9 °C higher in 1998. This increase in temperature had a marked effect on the flowering phenology of *Saxifraga hirculus* which flowered 4 (1997) to 5 (1998) days earlier inside shelters than outside. The winter 1997-1998 had exceptionally little snowfall and average temperature in May was 1.8 °C higher in 1998 than in 1997. As a result *Saxifraga hirculus* flowered

on average 9 days earlier in 1998 than in 1997. These results are consistent with earlier findings on other species (e.g. Thórhallsdóttir 1998; Molau and Shaver 1997; Stenström and Jónsdóttir 1997)

Saxifraga hirculus responded to increased nutrients and temperature in increased height, greater number of flowers, and heavier seeds. Fertilizer alone had more effect on seed weight and flower number than did shelter alone but this was reversed for shoot height although there was no difference between shelter and fertilizer effect on shoot height in 1998. Combined treatments had the greatest effect in all cases (Figs. 2 to 4).

The response in shoot height and seed weight was observed in 1997 and is consistent in shoot height in 1998 (Fig. 3). The effect on flower number on the other hand was not detected in 1997 but was marked in 1998 (Fig. 2). This indicates that it takes the plants more than one year to respond to added nutrients by increased flower number and/or that higher temperature (longer growing season) is needed in addition for the effects to be expressed in the plants (see Shaver and Chapin 1995).

Favorable temperature conditions are of primary importance for phenological development but have less value for growth unless combined with nutrients where their interaction may be significant. Application of N, K, P fertilizer increased growth but the effect was greatly enhanced by temperature. The effects of temperature and nutrients need to be studied simultaneously for a long period of time in order to understand their separate contribution and interaction both in short-term and in the long-term.

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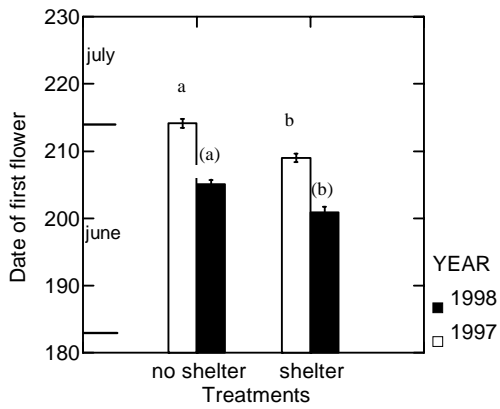


Fig.1. The date of first flower of *S. hirculus* with and without shelter in 1997 and 1998. Bars with different letter are significantly different. Letters in brackets are for 1998 but letters without are for 1997. Data are means \pm SE bars. n = 284 for 1997 and 369 for 1998.

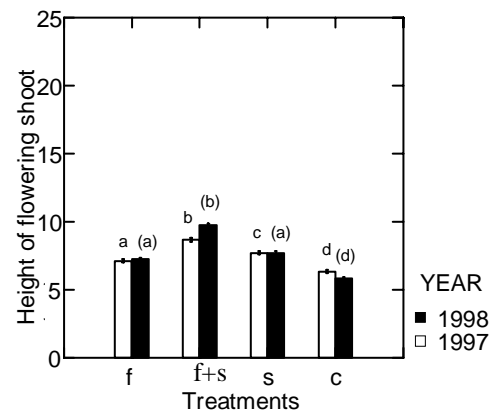


Fig. 3. The height of flowering shoot of individuals (cm) between treatments in 1997 and 1998. f=fertilizer, s=shelter, c=control. Data are means \pm SE bars. n=188.

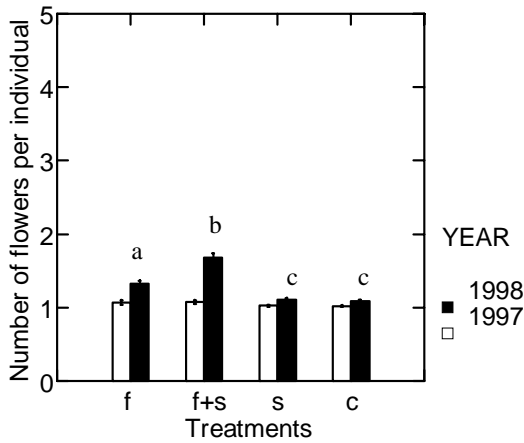


Fig. 2. Number of flowers per individual between treatments in 1997 and 1998. f=fertilizer, s=shelter, c=control. Bars with different letter are significantly different. In 1997 no significant difference was detected between treatments. n=917 in 1997 and 1710 in 1998. Data are means \pm SE bars.

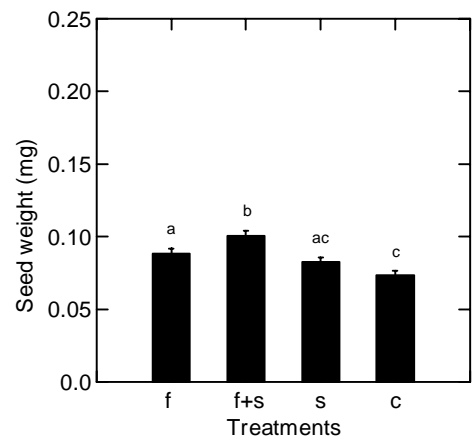


Fig. 4. Seed weight (mg) in *Saxifraga hirculus* between treatments in 1997. f=fertilizer, s=shelter, c=control. Bars with different letter are significantly different. n=533 in 1997 and 718 in 1998. Data are means \pm SE bars.

CLIMATE CHANGE EFFECTS AT THE LIMITS OF PLANT LIFE - AN UPDATING OF THE AUSTRIAN RESEARCH INITIATIVE.

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The Austrian research initiative is based on a comparative approach. Since the early nineties we have observed vegetation patterns at the low temperature limits of plant life at high Alpine summits, and in 1996 we included a polar desert site at Ziegler island (Franz Josefs Land). One activity for both sites was to establish a set of permanent plots for simple observation of vegetation. In the high Arctic we applied strictly the ITEX rules for describing sites, but also established a plot approach developed in the Alps. For summer 1997 we planned to start with ITEX-experiments based on open top chambers, and fertilizer experiments. Unfortunately we failed to get the necessary permits for the summer expedition 1997, and even for the following year. For 1999 the things are looking much better and starting a basic ITEX approach will be one of the main activities. For the time being our data set consists of several quadrats with detailed species lists as well as quantitative data according to the ITEX manual. The quadrats are marked in the field, and the coordinates of their position is known precisely.

The research at the high summits of the Alps, however, is in a much better shape. After providing evidence that alpine plants have moved towards higher altitudes as an effect of warming during this century we have developed a computer model for predicting vegetation patterns on a selected model mountain in the Tyrolean Alps (i.e. Mt. Schrankogel, 3476m). Based on a DEM with a resolution of 1 square meter, together with a detailed vegetation sample in relation to topography, we can predict now very precisely how single species, and plant assemblages, are distributed at this mountain. Computer simulations for what might happen if temperature rises indicate that the zonal structure of vegetation will disintegrate. Some plant species, and plant assemblages as well, will lose safe sites in large quantities, therefore becoming extinct long before they reach the summits which would be the ultimate extinction scenario. This model can now be improved by temperature measurements from tiny data loggers exposed close to the surface for more than 40 sites at Mt. Schrankogel. The analysis of these records has not been completed. However preliminary result show that the altitudinal temperature gradient at the immediate plant environment deviates significant from that measured by meteorological standards. Snow is certainly the critical factor. Snow depth increases with altitude, and determines frequency and duration of exposure to dangerous low temperatures, or frost drought, on ridges but also the length of the growing season. An additional important factor is the stability of the substrate. High mountains are steep, debris rain, and debris movements caused by cryoturbation destroy plants trying to set roots. For the future it might be interesting to compare vegetation pattern at steep cold environments with those from flat ones as it is the case for the sites at Franz Josefs Land.

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BIODIVERSITY IN ALPINE FOREST ECOSYSTEMS: ANALYSIS, PROTECTION AND MANAGEMENT

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From a human perspective, forests in mountainous areas fulfill an important task with regard to protection against natural hazards. Stability of forest stands, however, is increasingly threatened by air pollution, cease of management, lack of regeneration due to overabundant ungulate, and novel environmental conditions because of climate change. A joint project, funded by the European Union, addresses the biodiversity within and between carrier species of alpine forest ecosystems. The overall objective is to create a data pool which will help to better understand the function and dynamics of forest ecosystems and to transfer results into practice.

At 14 sampling locations across the Alps, each consisting of three elevations levels, populations of adult and juvenile forest tree species are screened for their genetic diversity. The target species are *Abies alba*, *Larix decidua*, *Picea abies*, *Pinus cembra*, and *P. mugo*. Nuclear (isoenzymes, microsatellites) as well as plastid markers (chloroplast microsatellites, mitochondrial tandem repeats) are investigated by respective expert groups. Knowing the distribution of variation of these different genetic markers with their specific characteristics of transfer from one generation to the other will allow us to model population dynamics within and between different stands under various environmental and management regimes.

VEGETATION CHANGES IN ITEX EXPERIMENTS IN THE CANADIAN HIGH ARCTIC

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ITEX experiments were established at Alexandra Fiord, Ellesmere Island, Canada (79°N) in 1992. OTCs were established in 5 community types along a soil moisture gradient. The vegetation composition and density were measured in and out of OTCs in 1995 using ITEX protocols for point-cover. There was a significant change in cover of major functional groups in all but the wettest community. Increases in density were greatest in mesic community and were significantly greater in the graminoids and deciduous dwarf shrubs. Species density also increased in OTCs relative to controls in all communities. These results indicate that the high arctic communities will likely respond similarly to low arctic sites (e.g. Toolik Lake) to climate warming, with a shift in composition to species with greater growth rates and higher rates of turnover for nutrients. Implications for feedbacks to ecosystem processes will be discussed.

BIOTIC VALIDATION OF ITEX OPEN TOP CHAMBERS IN ALASKA

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Twenty-four small open-top chambers (OTC) were used to passively warm canopy temperatures in wet meadow tundra at Barrow, Alaska during the summers of 1995 and 1996. Fortuitously the seasonal average temperature difference due to chamber warming and interannual variability were both approximately 1.5 °C; this allowed comparisons of species response to warming caused by the two mechanisms. The statistical significance of species responses to chamber warming and interannual warming were similar 70% of the time. These results give empirical biotic validation of the efficacy of the ITEX OTC.

SPATIAL, TEMPORAL, AND INTERANNUAL PATTERNS OF SOIL MOISTURE AND THAW DEPTH AT BARROW, ALASKA U.S.A.

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Data on active-layer thickness and near-surface soil moisture content were collected in late summer 1996 and 1997 at 100-m intervals over a 1 km area near Barrow, Alaska. The Barrow ITEX sites are located within the 1000-m grid, and time series of soil moisture and soil temperatures are monitored year-round at several sites. Both the ITEX and grid are contained within the Barrow Environmental Observatory, a 7500-acre protected research area.

The 121 thaw depth and soil moisture measurements were mapped to facilitate interannual comparisons and to evaluate the effects of terrain and parent material on moisture content. Statistical analysis indicates that: (1) substantial differences in soil moisture and thaw depth occur in dissimilar terrain units; (2) soil moisture and thaw depth are relatively uniform within terrain units; (3) spatial patterns of thaw depth are consistent within the study area on an interannual basis; and (4) patterns of soil moisture and thaw depth do not necessarily show close spatiotemporal correspondence. Time series of soil moisture show large variations near the surface in response to precipitation and evaporative drying, but the lower part of the active layer remains near saturation throughout the summer.

BRYOPHYTE GROWTH AND OPEN TOP CHAMBERS: SPECIES, SEASONAL AND SITE DIFFERENCES.

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I have studied the effects of OTCs on growth of different bryophyte species, seasonal periods and at two different sites (Latnjajaure, Sweden and Thingvellir, Iceland). Bryophytes in the Arctic and Subarctic play a significant role in the primary production, nutrient cycling and species diversity. In the face of predicted climate change it is therefore important to study the bryophytes and their responses to increased temperature.

My results show that:

1. Bryophyte species show different responses to OTC treatments.
2. Single bryophyte species can show different responses to OTC effects on different time scales.
3. The response of the same bryophyte species to OTC treatments varies greatly between sites.

Most bryophytes have an poikilohydric physiology so that growth is mainly limited by water availability or relative humidity. The study results can be explained by (1) bryophyte species have different ecology. (2) A growth measurement during the summer do not have to show the same results as measurements throughout the year. This is because during the warm summer period, the OTC plots may dry out faster or more (because of evaporation) than the surroundings, which may cause some species to grow less in the OTCs. During the rest of the year, water is no longer the main limiting factor, and there is no significant differences between treatments. (3) The site differences in bryophyte growth response to OTCs can probably be explained by differences in precipitation. When water is less limiting, the "real" response to an temperature increase is shown.

My results show that bryophytes may have complicated responses to the simple OTC design used within ITEX (e.g. the same species may show different responses, depending on the time scale and site being used). For bryophytes, not only temperature but also precipitation must be considered when studying the possible effects of predicted future climate change. However, today the GCM predictions of precipitation amount and intensities are not fully clear.

The bryophytes are an important and significant part of the communities which most people within ITEX are working with. Therefore, there is an urgent need for more information about the bryophyte responses to predicted climate change (e.g. species specific, between sites, short- and long-term).

This project is being done within my Ph.D. at Gothenburg University: Population ecology of arctic bryophytes, geographic variation, ecophysiology, interactions with vascular plants and responses to climate change.

WHAT CAN BE LEARNED FROM STUDIES OF KEY VARIABLES AT MANY TUNDRA SITES DURING A SINGLE SEASON?

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Basic knowledge on both patterns and processes among tundra organisms at the population level are needed for reliable predictions of tundra ecosystem responses to climate change and other types of environmental change. To study this intensively at a few key sites using common protocols (ITEX), or to study some key variables at many sites, are two alternative approaches to the problem. We report here on a study from the icebreaker-based Swedish-Russian Tundra Ecology Expedition 1994 where the latter approach was applied (Jónsdóttir *et al.* 1999a, b, c). A few common *Carex* species (*C. stans*, *C. ensifolia* ssp. *arctisibitrica* and *C. lugens*) were studied at 15 different sites along the entire Siberian coast during a single season. The study revealed large spatial variation in population variables (frequency of flowering and ramet production), reflecting asynchronous, between year fluctuations: The variation was largely explained by environmental factors that show temporal variation, rather than by those that vary in space. Cyclic herbivore populations (lemmings) appeared to be most important, followed by previous year summer temperatures. Climate variables that vary in space could not explain any of the variation (mean July temperature, mean annual precipitation). We were also able to estimate genet ages at two high arctic sites visited and the oldest genets were estimated to reach far over 2000 years.

This study has three messages to bring to ITEX.

1. It shows clearly the importance of plant-herbivore interaction and implies the importance of careful control for herbivore effects on plants in ITEX experiments. Open top chambers (OTC's) may function as exclosures for certain herbivores and enclosures for others. To control for such exclosure/enclosure effects is essential for plants consumed by herbivores in herbivore dense environments and may also be important for those not consumed because of possible indirect effects of herbivores through plant competition.
2. Individual genets can apparently reach very old ages, especially those with pronounced clonal growth. This may have important implications for responses of tundra vegetation, dominated by clonal plants, to environmental changes. Some of our experimental plants may belong to genets that have experienced far greater climate changes than those simulated in the experiments.
3. Studies of ecological patterns over a large number of sites in a single season can give important cues to significant ecological processes and can be considered as complimentary to experimental and more process oriented studies such as ITEX.

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The pattern of plant-herbivore interaction and plant population dynamics will be studied during a second tundra ecology expedition, Tundra Northwest 1999, following the same concept as in 1994. This time 16 different sites in the Canadian Arctic will be visited, which will enable a circumpolar study. The expedition is organized by the Swedish Polar Research Secretariat in collaboration with Canadian Coast Guard/Department of Fisheries and Oceans, Canada.

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ECOSYSTEM FEEDBACKS TO CLIMATE WARMING AND PASTORAL LAND USE CHANGE ON THE QINGHAI-TIBET PLATEAU, CHINA

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We are investigating two aspects of global change - climate warming and land use change – on the eastern Qinghai-Tibetan Plateau. The Qinghai-Tibet Plateau is situated at an average elevation of 4,000m and comprises over 2.5 million square kilometers, approximately ¼ of the Chinese land area. Over 70% of the land area has been classified as “rangeland” vegetation; pastoralism as a livelihood has persisted on the Plateau for millennia. Ice core data and measures of soil thermal regime indicate that warming has occurred on the Plateau over the past few decades. This pastoral system is also experiencing changes in the traditional land use dynamic. Our research questions include: how do climate warming, historic and current grazing levels, and the interaction of warming and grazing affect: a) ecosystem properties which feedback to climate, such as carbon storage; and b) ecosystem properties critical to pastoralism, such as the quantity, quality and timing of forage availability?

In order to address these questions, we have established an US-Chinese collaborative research project on the eastern Qinghai-Tibet Plateau. We have established experimental plots at the Haibei Alpine Research Station in Menyuan County, Qinghai Province, China (latitude 37°29'N, longitude 101°12'E). Mean annual temperature at the site is –2°C. Mean annual precipitation is 500mm/year, over 80% of which occurs during the summer monsoon season. In September 1997, we established experimental plots in two main vegetation types: a winter grazed *Kobresia humilis* dominated meadow and a summer grazed *Potentilla fruticosa* dominated shrubland. Together, these alpine meadow and shrub communities comprise approximately 35% of the vegetation cover of the Qinghai-Tibet Plateau.

Within each vegetation type, we have identified sites with low and high grazing histories, for a total of 4 main study areas. Within each study area, we have four-fold replication of a complete factorial study design with two treatments: warming and grazing. Warming is achieved by using ITEX conical open top chambers (OTCs) which remain on the plots year-round. Grazing is simulated through clipping. We are monitoring a suite of micro-climate, vegetative and soil properties in order to address our research questions.

Both habitat type and grazing history are important because they establish the initial vegetative composition and micro-climate conditions on which we have superimposed our treatments. For example, the shrub site soils are both cooler and wetter than the meadow site soils. In both the meadow and shrub habitats, the high grazing history soils are warmer and drier than the low grazing history sites within the same habitat type.

Within both meadow and shrub habitats, forb cover is significantly greater ($p < .05$) than graminoid cover in the high grazing history sites as compared to the low grazing history sites.

Preliminary data from the plots reveal that the amount of soil and air warming caused by the OTCs differ by habitat type and by grazing history. These data also indicate the OTCs are significantly warming the soil and the air of the plots as compared to the controls. For example, data collected on a sunny day in August in the high grazing history meadow site reveal that the mean daily air temperature at 3cm aboveground in the OTC was 2.9°C warmer than the control. The mean daily air temperature of the combined OTC x graze plot was 3.2°C warmer than the control. The mean daily soil temperature at 12cm depth in the OTC was 0.7°C warmer than the control. The mean daily soil temperature at 12cm depth for the OTC x graze plot was 1.3°C warmer than the control. More replicated measurements taken over the duration of the growing season for multiple years will provide stronger evidence as to the effects of the treatments on the plots and how they differ with respect to grazing history and habitat type.

Our study site on the Qinghai-Tibet Plateau employs the basic warming experiment of the ITEX program. Large herbivore grazing has been acknowledged as an important factor in other ITEX sites. It continues to be a predominant form of land use on the Qinghai-Tibetan Plateau. Consequently, in addition to the basic warming experiment of the ITEX program, we have included current and historic grazing levels to examine the interactive effects of global change drivers at our site. Our very preliminary data suggest that grazing, both historic and current, may play an important role in mediating how the system responds to climate warming. It also highlights the need to control for the ITEX chambers' exclusion of large herbivore grazing - where grazing is an important factor in the system. This latter point was discussed at the Ninth ITEX meeting in January 1999.

Due to some of the unique properties of the Qinghai-Tibet Plateau, we anticipate that our system's response to OTC warming, or the mechanisms responsible for the responses, will differ from those reported in other arctic and alpine systems. For example, in the eastern Qinghai-Tibet Plateau, the majority of the precipitation falls during the summer - winters are generally cold and dry. Thus, phenomena like early snowmelt, which is an important consequence of climate warming in many tundra sites, is not an important factor in this system. We hope that our research on the Qinghai-Tibet Plateau will contribute to the broader ITEX goal of understanding the tundra biome-wide response to climate warming.

SEED DISPERSAL AND SEEDBANKS IN LATNJAJAURE, SWEDEN

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To make a contribution to the understanding of arctic seed bank an investigation was performed at Latnjajaure field station, situated in the mountains 15 km west of Abisko in north Swedish Lapland. Soil samples were taken from the tree-line at 700 m.a.s.l. to the highest top in the area at 1560 m.a.s.l. A reference site was chosen in the birch forest. On each location, samples were taken from three different layers. Both total seed bank and germinable seed bank were analyzed. The number of species in the total + germinable seed bank decrease with altitude. The same trend is observed both concerning the number of seeds in the total seed bank as well as the number of seedlings in the germinable seed bank. The total number of seeds varies with soil depth, at all altitudes decreasing downwards. Although the number of seeds in the bottom layers is very low at high altitudes, a substantial proportion is germinable. The graminoids are represented at similar amounts from 900 to 1200 meters. At a climate change, models predict that graminoids will increase. The results in the present study show that they may be recruited from the seed bank.

COMBINED INFLUENCE OF GRAZING AND WARMING IN A HIGH ARCTIC WET MEADOW.

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The bird sanctuary on the southern lowland of Bylot Island (73°N, 80°W) is the main breeding ground of the greater snow goose (*Chen caerulescens atlantica*). Breeding snow geese graze and grub intensely in the wet meadows dominated by *Eriophorum scheuchzeri* and *Dupontia fisheri*. A block design standard ITEX experiment joined with an exclosure treatment was established in 1995 in wet meadows of the lowland (n = 9) to measure the impact of low level warming and of geese grazing on the vegetation. As expected, results of the fourth year of treatment show that flowering (especially of *E. scheuchzeri*) is much more intense in the exclosures and OTC's than in the controls and it occurs earlier in the OTC's than in the exclosures. There is less litter in the control plots (>2% cover) than in the OTC's (15 ± 7 % cover) and exclosures (13 ± 10% cover). The density of shoots for all graminoids is similar in all treatments (approx. 7000 shoots/m² in 1998) but the proportion of *E. scheuchzeri* is inferior in the controls which are heavily grazed (39.5%) than in the OTC's and exclosures (46% for both). Heavily grazed sites have a higher proportion of *Dupontia fisheri* and *Carex aquatilis*. These results suggest that in this system the impact of grazing is stronger than the effect of warming and reinforces the need to study the impact of biotic interactions in combination with warming.

PROGRESS OF THE BIOBASIS MONITORING PROGRAMME AT ZACKENBERG, NORTHEAST GREENLAND

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The main elements of the 'BioBasis' monitoring programme, running under Zackenberg Ecological Research Operations (ZERO) in Northeast Greenland since 1995, are presented together with examples of results obtained so far on flowering, invertebrates, bird populations and mammals.

SOIL SEED BANKS ON SUBANTARCTIC MACQUARIE ISLAND

Wieslawa M. Misiak, Dana M. Bergstrom, and Justine D. Shaw. The University of Queensland, Brisbane, Australia.

Soil seed banks were investigated on subantarctic Macquarie Island, in terms of their similarity to the standing vegetation, variability, and size, in six communities: herbfield, mire, feldmark and three grasslands. The soil seed banks strongly reflected species composition of the standing vegetation. Of 19 taxa recorded in total, only two taxa were not found in the soil seed bank at the time of sampling. It could, therefore be anticipated that with climate change, contribution from the soil seed bank would not alter species composition of the standing vegetation. Local heterogeneity of the standing vegetation and the soil seed bank was pronounced at all sites. Soil seed bank size was extensive at all sites, ranging from an average of 667 seeds m² in the species poor feldmark, to 96,333 seeds m² in a short grassland community. Sampling was conducted in early summer, prior to the season's seed rain. Further work is required to understand seasonal variation within the soil seed banks.

A FIVE-YEAR ITEX STUDY AT LATNJAJAURE, NORTHERN SWEDISH LAPLAND

Ulf Molau. Botanical Institute, Göteborg University, Göteborg, Sweden.

In this study, I present extended data sets for five of the "ITEX species" (sensu Murray) from one of the keystone sites in ITEX, the Latnjajaure Field Station in northern Swedish Lapland (subarctic-alpine). Temperature enhancement was brought about by using standard ITEX Open-Top Chambers (OTCs). Five-year data sets (1993–97) on phenology, growth, and reproduction are provided for *Cassiope tetragona*, *Dryas octopetala*, *Eriophorum vaginatum*, and *Ranunculus nivalis*, and a four-year data set (1994–97) for *Polygonum viviparum*. In addition, a seven-year monitoring (1992–98) of flowering in the cotton grass *Eriophorum vaginatum* is presented.

In general, the short-term (2–3 years) responses published in the ITEX Special Issue of *Global Change Biology* 1997, are maintained also in the longer term. Good examples are flowering phenology, leaf size, and seed weight. Other responses, e.g., ovule number in *Ranunculus nivalis* and *Eriophorum vaginatum*, that were constantly increasing in the temperature enhancement experiment during the first three years of manipulation, have now leveled out at the higher level reached on the 3rd year of the experiment. Two species, both evergreen dwarf shrubs (*Cassiope tetragona* and *Saxifraga oppositifolia*), do not - even after five years of manipulation - show any response to enhanced temperature in vegetative growth.

Responses are now, after five years, also showing up at the community level, mostly brought about by plant-plant interactions. In the sedge-rich moist-wet meadow, the number of *Ranunculus nivalis* individuals in the OTCs have started to decrease, out competed for the light resource by vigorously responding *Carex bigelowii* and *C. lachenalii* sedges. In the dry acidic heath, deciduous dwarf shrubs (mainly *Betula nana*) are slowly shifting to a more bushy habit, with increased long-shoot production; in this case out competing the bryophytes for the light resource. In the calcareous scree, *Saxifraga oppositifolia* individuals die more rapidly in the OTCs than in controls, and recruitment is small or absent; the reasons for this are not fully understood.

There was a huge variation in climate among the years, and this is easily seen from the annual variation in the responses in the control plots. Also, several ITEX species have clear temperature optima above which enhanced temperature experiments do not induce any further responses. Thus, in the warmest year (1997), there was little difference between the data from OTCs and controls.

LINKING LEAF PHENOLOGY AND GROSS ECOSYSTEM PRODUCTION IN ALASKAN TUSSOCK TUNDRA

S. F. Oberbauer, G. W. Starr, E. W. Pop, and L. E. Ahlquist. Florida International University, Miami, USA.

Tussock tundra consists of species of different growth forms reflecting a range of leaf phenologies. The timing of leaf development and leaf activation of different species potentially have important consequences for ecosystem production. To evaluate the relationship between species leaf phenology and gross ecosystem production, we followed leaf development and ecosystem carbon fluxes over three growing seasons in undisturbed tussock tundra at Toolik Lake Alaska. On treatment plots, we shifted leaf development earlier in the season by removing snow cover before general snowmelt. Our results suggest that early season production is largely supported by *Eriophorum vaginatum* over wintered and newly expanded leaves. Nevertheless, production is slow to develop and does not attain maximal rates until deciduous species have leafed out and graminoids have expanded substantial leaf area. End of season gross production is again dominated by *Eriophorum*, which depending on timing of hard freezes, can maintain photosynthesis late in the season.

GENETIC VARIATION IN POPULATIONS OF THE ARCTIC PERENNIAL *PEDICULARIS DASYANTHA* (SCROPHULARIACEAE), ON SVALBARD, NORWAY

Ann Marie Odasz-Albrigtsen. University of Tromsø, Tromsø, Norway.

Isozyme variability was examined in 13 geographically isolated populations of the endemic arctic hairy lousewort (*Pedicularis dasyantha*) in the Svalbard Archipelago, 80° N latitude, Norway. Of the 23 enzyme systems screened on five buffer systems 18 were interpretable. Of the 31 reliable loci, only 6-phosphogluconate dehydrogenase (6-Pgd), was polymorphic. However, no heterozygotes were detected. Frequencies for allele 1 among the populations varied from 1.00 in the north to 0.00 in the south and 0.53 in the central "overlap" region. At the species level the mean number of alleles per locus (A) was 1.03. Percent of polymorphic loci (P) was 3%. Expected heterozygosity (H_e) was 0.016. At the population level the mean number of alleles per locus was 1.01, and 1.1% of the loci were polymorphic. H_e was 0.004. These values are low compared to endemic, widespread, selfing, and outcrossed species.

Flower color morphs were distinct. They varied within and among the 13 populations. The frequency of color morphs coincided with allele frequencies of 6-PGD: allele 1 was found in dark purple morphs, and allele 2 was found in light morphs. This species shows more isozyme genetic variability than the five other species reported in the genus but generally less variation than other species with limited regional distributions. Low-level genetic variation in this diploid species may be a result of colonization events coupled with genetic drift, founder effects, and strong natural selection. Additional factors include the self-compatible reproductive system and the long-lived perennial habit.

Results will be compared to genetic variation in other arctic species and in the context of the ITEX program of research.

ROLE OF INVERTEBRATES IN NUTRIENT CYCLING ON SUBANTARCTIC MACQUARIE ISLAND

Tore K. Pedersen and Dana M. Bergstrom. The University of Queensland, Brisbane, Australia.

Soils on subantarctic islands are cool and wet year-round, resulting in relatively low rates of microbial mineralization. On subantarctic Marion Island, this slow mineralization of litter and peat is insufficient to sustain the high primary productivity found in some vegetation types. Certain macro-invertebrate taxa have been found to play an important role in litter and peat breakdown and nutrient release by "short-circuiting" the microbial mineralization process. Macquarie Island has similarly cool and wet soils and high rates of primary production, but differs from Marion Island, particularly in terms of distance from other land masses, flora and invertebrate fauna composition. Investigations are currently underway into the role of macro-invertebrates in the breakdown of and nutrient release from litter and peat at four ITEX sites along an east-facing altitudinal gradient on Mount Elder, Macquarie Island.

PREDICTING VEGETATIVE BUD BREAK IN TWO ARCTIC DECIDUOUS SHRUB SPECIES, SALIX PULCHRA AND BETULA NANA

Eric W. Pop, Steve F. Oberbauer, and Greg Starr. Florida International University, Miami, USA.

The controls of bud break in two arctic deciduous species, *Salix pulchra* and *Betula nana*, were investigated using field observations and growth-chamber studies. A bud-break model was calibrated using the experimental observations and was used to predict bud break under current and potential future climate regimes. The two species responded similarly in terms of bud break timing and response to air temperature in both field and controlled environments. In the field, the timing of bud break was strongly influenced by air temperatures once snowmelt had occurred. Growth chamber studies showed that a period of chilling is required before buds break in response to warming. Model simulations indicate that under current conditions, the chilling requirement is easily met during winter and that even with substantial winter warming, chilling will be sufficient. In contrast, warm spring temperatures determine the timing of bud break. This limitation by spring temperatures means that in a warmer climate bud break will occur earlier than present.

CYCLIC SUCCESSION OF ZONAL TUNDRA PLANT COMMUNITIES IN CHUKOTKA

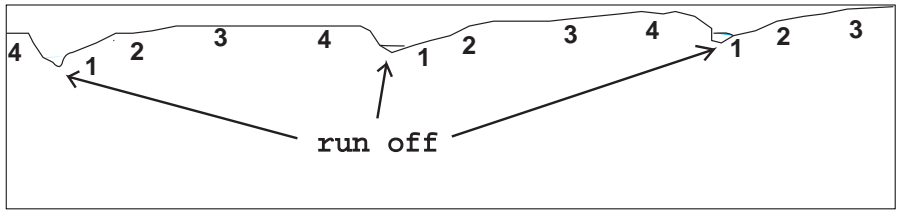
V. Yu. Razzhivin. Komarov Botanical Institute, St. Petersburg, Russia.

Diversity of plant communities on flat and slightly inclined areas with acidic loam soils under relatively uniform environment is a result of succession dynamics. The following series of plant communities is well established: *Eriophorum polystachyon*-*Carex stans* moist tundra (1st stage) -> *Rubus chamaemorus*-*Sphagnum* spp. tundra (2nd stage) -> *Betula exilis*-*Salix* spp.-*Sphagnum* spp. - *Eriophorum vaginatum* tussock tundra (3rd stage) -> *Betula exilis*-*Salix* spp. - *Eriophorum vaginatum* - green mosses tussock tundra with bog mosses and fruticose lichens (4th stage).

The community of the first stage borders streams of snow and rain run off. As soon as water-borne organic matter and fine grained soil accumulates, this habitat changes and bog mosses gradually increase. Change in environment leads to the second stage with dominance of cloudberry and bog mosses. The active layer diminishes. On the next (third) stage *Eriophorum vaginatum* tussock and subarctic dwarf shrubs become dominant and the role of green mosses increases along with the bog mosses. On the next (fourth) stage bog mosses decrease whereas dwarf shrubs (up to 45-65%) and green mosses increase. Tussocks are depressed.

Bog mosses provide an effective thermo-insulating effect and as they decrease bare patches between tussocks are formed and active layer increases. Bare patches increase gradually and form a single net. Water runs along the net, which leads to intense erosion and the formation of running water streams.

The observed endoecogenetic cyclic succession with the suppression of tussock and bog mosses takes place because of increasing of hypoarctic dwarf shrubs and green mosses. Each succession stage transforms the biotope and it becomes favorable for appearance of new growth forms. The described scenario deviates in different ways depending on peculiarities of local environment: in flat areas with no incoming running waters the community stabilizes in the third stage almost without a dwarf shrubs; for habitats with snow accumulation dwarf shrub-green mosses community with no tussocks is common. The cyclic succession will probably turn to the more pronounced dwarf shrub stage under global climate change.



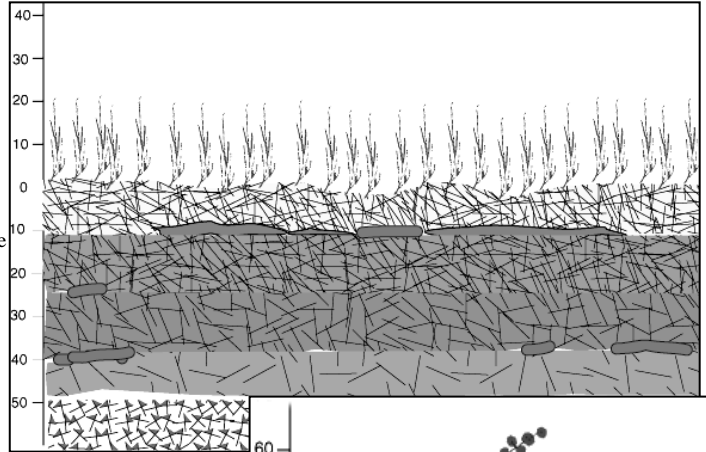
Stage 1: *Eriophorum polystachyon* – *Carex stans* moist tundra

The community borders streams of snow and rain run off. Soil is well stratified, and multilayered. The active layer is about 50 cm from late August to early September.

Stage 2: *Rubus chamaemorus* –

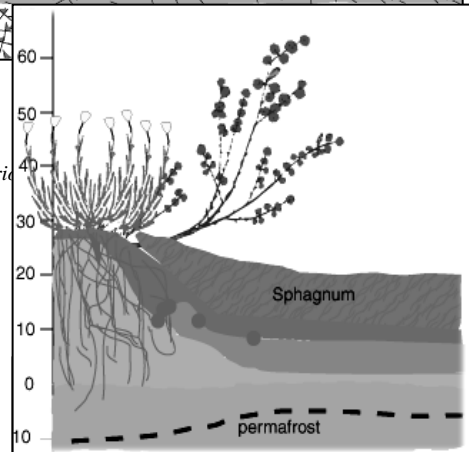
Sphagnum spp. tundra As soon as water-borne grained soil accumulates, the habitat of Stage 1 changes and bog mosses gradually increase. The active layer diminishes.

Simultaneous change in environment and species composition leads to the stage with dominance of cloudberry and bog mosses (sometimes with visible juvenile *Eriophorum vaginatum* tussocks).



Stage 3: *Betula exilis* - *Salix* spp. - *Sphagnum*

spp. – *Eriophorum vaginatum* tussock tundra *Eriophorum* shrubs become dominant and the role of green mosses increases along with the bog mosses. Pattern in active layer reflect the pattern of bog mosses.



Stage 4: *Betula exilis* - *Salix* spp. –

Eriophorum vaginatum - green mosses tussock tundra with bog mosses and fruticose lichens Bog mosses decrease whereas dwarf shrubs increase. Tussocks are depressed. Active layer increases especially under bare ground.

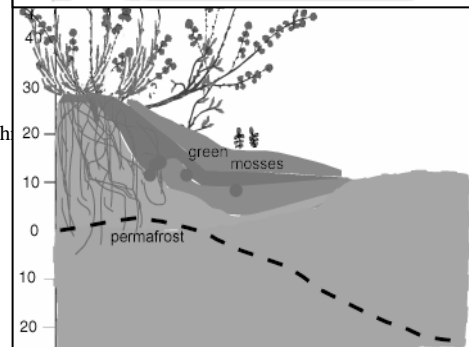


Table 1. Species coverage (%) in relevés, representing stages of cyclic succession in the east of Chukotka Peninsula (“+” indicates coverage less than 1%; sample plot size is 10 x 10 m).

Stage #	1	2	3				4			
Relevés #	1	2	3	4	5	6	7	8	9	10
Dwarf shrubs										
<i>Betula exilis</i>	+		5	10	10	10	20	20	30	30
<i>Salix pulchra</i>	+		3	5	2	7	1	5	5	1
<i>Ledum decumbens</i>		2	10	10	18	4	40	30	5	30
<i>Vaccinium vitis-idaea</i> var. <i>minus</i>		+	5	5	15	2	8	5	3	20
<i>Vaccinium uliginosum</i> ssp. <i>microphyllum</i>		+	2	+	3	4	+	+	5	
<i>Empetrum subholarcticum</i>		3		+	+	+	+	+		5
<i>Rubus chamaemorus</i>		15			1				2	
<i>Cassiope tetragona</i>				+		+				4
Graminoids										
<i>Calamagrostis holmii</i>	+		+	+	+				+	1
<i>Arctagrostis latifolia</i>	+	+			3	3	+	+	+	
<i>Poa arctica</i>		+	+			+				
<i>Eriophorum vaginatum</i>			70	70	40	25	30	40	10	20
<i>Eriophorum polystachyon</i>	90	+	+	+		2				
<i>Carex lugens</i>						3	+			
Forbs										
<i>Pedicularis labradorica</i>			+	+	+	+			+	+
<i>Pedicularis capitata</i>		+		+			+			
<i>Polygonum tripterocarpum</i>		+			+		+	+	+	
<i>Petasites frigida</i>					+	+				
Green mosses										
<i>Aulacomnium turgidum</i>		10	3	2	+	5	2	5	+	5
<i>Aulacomnium palustre</i>						+		+	5	
<i>Hylocomium alascanum</i>		1	5	5	10	10		3	20	60
<i>Drepanocladus uncinatus</i>					10	5	40	45	15	
<i>Ptilidium ciliare</i>		2	2	+		2	3	2		5
<i>Dicranum elongatum</i>		+	+	+	+		3	5	5	7
<i>Dicranum angustum</i>			+		+	3	2	+	2	3
<i>Polytrichum strictum</i>				+			+		+	+
<i>Polytrichum piliferum</i>							+	1	3	+
Bog mosses										
<i>Sphagnum warnstorffii</i>		20	5	5		15		+	10	+
<i>Sphagnum nemoreum</i>				15						
<i>Sphagnum balticum</i>		30	10							
<i>Sphagnum angustifolium</i>							10			
<i>Sphagnum girgensohnii</i>		20			5	5				
<i>Sphagnum russovii</i>				10				+		+
Lichens										
<i>Thamnomia vermicularis</i>		+	+	+	+	+			+	+
<i>Dactylina arctica</i>			+	+	+	+	+	+	+	+
<i>Peltigera aptosa</i>					+	+		+		
<i>Peltigera scabrosa</i>			+					+		
<i>Cetraria cucullata</i>				+	+		+			+
<i>Cetraria islandica</i>						+	+	+	3	+
<i>Cetraria laevigata</i>						+		+	+	
<i>Cetraria nivalis</i>		+		+				+		
<i>Cladina arbuscula</i>			+					+		
<i>Cladina rangiferina</i>				+						+
<i>Cladonia squamosa</i>										+
<i>Cladonia chlorophaea</i>									+	+
<i>Cladonia pleurota</i>			+					+	2	
<i>Cladonia amaurocraea</i>				+	+					+
<i>Cladonia coccifera</i>			+			+				+
<i>Cladonia deformis</i>		+			+					+
<i>Cladonia macroceras</i>					+					+
<i>Cladonia alascana</i>								+	+	
<i>Ochrolechia frigida</i>						+	+			

SPATIAL DISTRIBUTION OF SURFACE TEMPERATURES IN ITEX CHAMBERS.

Steve P. Rewa, Robert D. Hollister, and Patrick J. Webber. Michigan State University, East Lansing, USA.

This study examined the spatial variability of surface temperature distribution in the ITEX open top chambers. Temperatures were recorded in two chambers and two control plots in both the dry heath and wet meadow community in Atkasuk, Alaska. Surface temperatures were recorded with a Raytek Ranger ST infrared temperature meter. Canopy and soil temperatures were measured with Hobo Pro series data loggers manufactured by Onset Company.

The overall temperature was higher in the chambers than the control plots. There is usually a definite temperature gradient within the chamber which appears to be related to the amount of direct sunlight. The temperature distribution also appears to be modified by the time of day, sky conditions, micro-topography and vegetation type.

LONG-TERM SYSTEM RESPONSES TO MANIPULATION AND MIMICKING OF CLIMATE CHANGE

Gus Shaver. Ecosystems Center, Marine Biological Laboratory, Woods Hole, USA.

This talk will focus on both the pitfalls and the opportunities provided by long-term experimental manipulations of whole ecosystems. The principal examples will come from long-term experiments Toolik Lake, Alaska, with additional comparisons with other long-term experiments. Important opportunities for future research include opportunities to distinguish the effects of individual species on ecosystem properties, and to explain how changes in species composition interact with changes in climate and resources to determine element cycles and energy balance of ecosystems.

SOME RESULTS 4-YEAR ITEX OBSERVATIONS IN NORTH-EAST RUSSIA (SITE MEKS, MAGADAN REGION)

N. Sinelnikova and A. Berkutenko. Institute of Biological Problems of the North, Magadan, Russia.

ITEX site Meks was established in 1995. The climate station is situated 10.8km SW of the Orotuk settlement, Tenkinsky district, Magadan region (62°05'N, 148°40'E, 548.9 m.a.s.l.). Site Meks is situated in the *Larix cajanderi* open forest subzone of taiga zone. The predominant soils are gray, peaty cryozems, silty loam (Pergelic cryoquept). A standard set of thermometers, psychrometer, thermograph and precipitation gage is used at the climate station. Field measurements are carried out from March 15 to November 1. The vegetation period lasts about 140 days. Usually stable snow cover forms from September 27 to October 14 and disappears from May 10 to May 15. The snow depth is 35- 40 cm. In 1995-1996 ITEX Corners were used on *Eriophorum vaginatum* and *Empetrum nigrum*. Since 1997 *Empetrum nigrum*, *Ledum decumbens* and *Betula nana* are investigated in Plastic Tents.

Eriophorum vaginatum. The first bud and first flower appear 3-5 days earlier than in control group. Number of flowering stalks and flowers increase in experimental group (1-4 stalks more), but according to our observations in 1995-1996, the whole number of seeds, seed productivity and the date of seed dispersal are the same as in the control group.

Empetrum nigrum. No effect of ITEX device was detected on phenological dates of *Empetrum nigrum*. The analysis of seed productivity and fruit/flower ratio showed more stable development of fruits in the experimental group (fruit/flower ratio is 0.7 in the experimental group and 0.2 in the control group). Total number of seeds in control group is 10-30% less compare to experimental group. Annual stem elongation in experimental group increases from 5 up to 10 mm.

Betula nana. Experimental plants suffer from overheat inside the Plastic Tent (2-4°C more then daily maximum). It leads to poor seed productivity (30-50% below normal), very low number of catkins (50-70% below normal), low annual increment (30-50% below normal). Some branches in 1998 had only a few leaves.

Ledum decumbens. Our measurements showed no direct influence of the ITEX device in all parameters.

According to our 4-year ITEX measurements the influence of the ITEX devices varies with species. Among investigated species the effect of ITEX devices is favorable for *Eriophorum vaginatum* and *Empetrum nigrum* and destructive for *Betula nana*. From our 2-year observations we can preliminary conclude that *Ledum decumbens* is indifferent to ITEX warming.

MODELING VEGETATION AT DIFFERENT SCALES

Martin T. Sykes. University of Lund, Lund, Sweden.

Predicting the past, present and future response of vegetation to a changing environment has led to the development of a range of state-of-the-art simulation models for application at local, regional and global scales. These new models are more realistic than earlier as important physiological processes such as photosynthesis are modeled more mechanistically through new approaches linking carbon and water cycles.

A suite of models developed within the Lund-Potsdam-Jena (LPJ) consortium of researchers are now available to be applied within most types of vegetation. The models can be run in both equilibrium and dynamic mode and have within them similar core processes. The models operate at the species, plant functional type (PFT) or biome level using monthly mean climate and soil texture data.

The equilibrium regional to global model BIOME3 successfully links biogeography and biogeochemistry through a linked carbon and water cycle and outputs potential vegetation as dominant and secondary PFT, biome type, NPP etc. PFTs and their attributes required by the model can be defined according to the region being simulated. Initial work on modeling arctic biomes by defining plant functional types appropriate for northern ecosystems has been done.

STASH 3 based on BIOME3 physiology defines individual species equilibrium distributions. It can be used to predict potential regional range limits of tree, shrub and herb species using only three bioclimatic variables, winter temperature, growing degree days amended by chilling requirement and a measurement of drought response. It has been used in Europe and North America to predict natural and future distributions of native and alien species. It can also be used in reverse modeling mode to predict past climates.

LPJ, a regional to global dynamic vegetation model again includes the basic physiological ideas from BIOME 3 and simulates grid-scale vegetation population dynamics including tissue turnover, allocation, light competition, mortality and establishment. These processes occur annually at the grid cell level. Daily processes such as photosynthesis, maintenance respiration, water balance and carbon and water fluxes are modeled at the PFT level. Time-series monthly temperature, precipitation and cloudiness data drive the model. Disturbances such as fire are dynamically determined based on climate and litter availability. Typical outputs include vegetation descriptions, NPP, NEP, AET, vegetation litter and soil carbon, runoff, fire return times etc. It has been used in various global comparisons of vegetation and carbon changes under different climates and is one of the models used in the VEMAP phase 2 comparisons of vegetation of the USA. Further developments include simulating nitrogen cycling and better representation of land use.

GUESS a generalised ecosystem model of vegetation dynamics is very similar to LPJ but models the response of separate individuals of species or PFTs and can be used at the very local patch to regional scale. It has been tested in forest, shrub and savanna- type communities. It is likely to be an element in one of the core modules of the EU funded project the European Terrestrial Ecosystem Modeling Activity (ETEMA), a modular approach to modeling European ecosystems.

Clearly these different but related models can be applied with modifications to most types of vegetation, species or PFTs in many different biomes, under a wide range of climates. As yet only one or two applications of these models in Arctic biomes has been attempted. However many of the extensive datasets that are becoming available within the ITEX program are precisely what is required to parameterize and validate vegetation models of this type.

Understanding what has happened in the past and what may happen in a uncertain future in the cold-adapted ecosystems of the Arctic is vital for their survival. The successful integration of good quality data as collected under the ITEX programme with the types of vegetation models described here is an absolute requirement if we hope to really understand the processes in these landscapes.

PROGRESS REPORT FROM THE ALPINE ITEX SITE AT FINSE, NORWAY

Ørjan Totland. University of Bergen, Bergen, Norway.

ITEX research at Finse in alpine Norway was initiated in 1994 at Finse. Since then studies on more than 10 species are completed or in progress. Most studies have been done in middle alpine meadows and snowbed communities on the performance of individual species. In addition, studies have been initiated to explore the effects of climate change on the low-alpine willow belt at Finse. This ecosystem form an ecotone between the low and the middle alpine zone in Fennoscandia. We examine how the dominant willow species at Finse, *Salix lapponum*, will respond to environmental change by manipulating temperature and nutrient availability. Secondly, we examine how this willow effects plant performance and population dynamics of other species in the willow belt, in order to enable predictions on the future dynamics of willow dominated plant communities.

TIME SERIES ANALYSIS OF 50 YEARS OF SURFACE AIR TEMPERATURES RECORDS FROM SUBANTARCTIC MACQUARIE ISLAND: A BASELINE STUDY FOR PREDICTING CHANGES TO TERRESTRIAL ECOSYSTEM STRUCTURE AND FUNCTION.

Craig E. Tweedie and Dana M. Bergstrom. The University of Queensland, Brisbane, Australia.

The effect of climate change on terrestrial biota at high latitudes will most likely be profound within the vicinity of regional margins. One such important margin is the Antarctic Polar Front to which the subantarctic islands are adjacent. Here, where current climatic conditions are limiting to biota, climate change will probably alter plant and ecosystem function and plant community composition. Our studies on Macquarie Island are currently trying to predict these likely effects. We present a statistically valid, and biologically relevant climate change scenario for the Macquarie Island region which aims to improve the predictive power of our studies.

Fifty years of meteorological data have been analyzed using ARIMA time series analysis and forecasts made. Data from four automatic weather stations (AWS's) positioned along a 400 masl altitudinal gradient on the east coast of Macquarie Island has then been regressed with simultaneous meteorological observations collected during the same time frame. The climate of the AWS sites along the altitudinal/temperature gradient for the last 50 years has then been reconstructed and the future climates at the sites forecast using the ARIMA time series analysis. Using the analogy of an altitudinal gradient being akin to a temperature gradient, temperature differences between sites along the altitudinal gradient are then converted to years using the forecast rate of climate warming calculated for the island.

This study hopes to serve as a foundation to ongoing studies of terrestrial ecosystem structure and function on Macquarie Island and may allow for predicted changes in ecosystem processes with climate change to be quantified.

HOW WILL PLANTS AND ECOSYSTEMS ALTER WITH CLIMATE CHANGE IN HIGH SOUTHERN LATITUDES? ITEX ON SUBANTARCTIC MACQUARIE ISLAND

Craig E. Tweedie and Dana Bergstrom. The University of Queensland, Brisbane, Australia.

Oceans play an integral role in the regulation of climate, especially in the Southern Hemisphere where 81% of the Earth's surface is ocean (Linacre and Hobbs 1991). At high southern latitudes, the Southern Ocean links with most major oceans in the world and has an important role in transmitting climate anomalies around the globe (White and Peterson 1996). As such, terrestrial island ecosystems in the Southern Ocean are model systems for examining the effects of global climate change (Bergstrom and Chown in press; Frenot *et al.* 1997). The effects of climate change on terrestrial biota in these latitudes are likely to be most profound within the vicinity of regional margins (Smith 1990, Selkirk 1992, Smith and Steenkamp 1990). One such regional margin is the Antarctic Polar Front, a dramatic oceanic and latitudinal climate boundary where Antarctic waters are subducted by warmer and less dense subantarctic waters (Selkirk *et al.* 1990).

Subantarctic Macquarie Island (54°30'S, 158°56'E) lies close to the Antarctic Polar Front (Belkin and Gordon 1996; Sparrow *et al.* 1996; Fig. 1) and has one of the most equable and oceanic climates in the world (Jenkin 1972; Troll 1960). The flora of this remote and small island is species poor, treeless and close to the southerly limit of vascular plant physiological and reproductive fitness. Most plant species appear to have arrived via long distance transoceanic dispersal (Bergstrom and Selkirk 1987) and are likely to have low genetic diversity that may limit their adaptive and competitive ability to adapt to climatic change (Huenneke 1991; Bradshaw and Mc Neilly 1991). For these reasons, Macquarie Island offers a model system for examining the effects of climate change on high southern latitude terrestrial ecosystems.

Macquarie Island is tectonically uplifted ocean floor and rises steeply (35° to 80° slopes) from the sea to an undulating plateau 180 to 350 *masl* (Selkirk *et al.* 1990). A permanently occupied Australian National Antarctic Research Expedition (ANARE) base is located at the northern end of the island and includes a meteorological station operated by the Australian Bureau of Meteorology (continuously since April 1947). The climate of the island is generally described as cool wet and windy. Mean annual surface air temperature is 4.8°C (warmest month is February 7°C and coldest month is July 3.4°C – mean of 04/1947 – 04/1998 records). Precipitation falls on an average of 341 days a year and the mean annual precipitation is 865mm. Radiation is low with mean daily direct sunshine is greatest in February (3.5 hours) and lowest in June (0.6 hours – calculated from 04/1947 –04/1998 records).

Tweedie and Bergstrom (submitted manuscript) analyzed 50 years of surface air temperature records using ARIMA time series analysis. They found mean monthly surface air temperature had increased between 1947 and 1998 by 0.3°C and forecast a 0.2°C increase by 2030. This forecast is conservative but within the range of temperature increases predicted by coupled Global Change Models incorporating an aerosol component (Houghton *et al.* 1996, CIG 1996). ARIMA time series analysis also allows for backcasting. Backcasts from 1947 to 1912 correspond well with meteorological records collected between 1912 to 1914 and suggest surface air temperature in this time has increased by 0.3°C. These time series analyses including the forecast from 1998 to 2030 and the backcast from 1947 to 1912 suggest surface air temperature on Macquarie Island have increased by 0.8°C in 118 years (1912-2030). Considering the low diurnal and seasonal range of climatic conditions experienced on the island (Adamson *et al.* 1988), even such a small change in climate is significant and represents 16% of the 1947 – 1998 50 year mean. Other climate and biologically relevant indices are currently being analyzed and will form the climatic basis of terrestrial plant and ecosystem climate change related research on the island.

ITEX related experiments commenced on Macquarie Island in the summer of 1995/96. As an analogy of climate change we are using a 370 meter east facing altitudinal temperature gradient. Under a warming scenario, this analogy proposes that sites at low altitude (comparatively warm) are forecasts of sites at high altitude (comparatively cool). The analogy has been quantified by Tweedie and Bergstrom (submitted manuscript) who combined ARIMA time series analyses and forecasts of surface air temperature with air temperature differences recorded by Automatic Weather Stations (AWS) spaced along the altitudinal gradient. The final scenario forecasting the number of years before surface temperature climates at high altitude sites are representative of respective low altitude sites is presented in figure 2. This scenario forms the basis of our prediction of the effects of climate change on plant and ecosystem composition, structure and function.

A variety of plant and functional ecological studies have been coupled to the altitudinal temperature gradient analogy. Most studies to date focus on six species that are widespread and are structurally important in the vegetation communities on the island. These are *Stilbocarpa polaris* (Araliaceae), *Acaena minor*, *A. magellanica* (Rosaceae), *Luzula crinita* (Juncaceae), and *Agrostis magellanica* and *Poa foliosa* (Poaceae). Studies include examinations of plant morphologies, growth and reproductive phenology, photosynthetic capacity and patterns of nutrient acquisition and turnover. All species exhibit strong morphological and phenological variation over the altitudinal gradient. In particular there is strong temporal separation in reproductive development with increasing altitude. Results from Australian based common garden experiments indicate the presence of ecotypic differentiation with a decrease in plant stature, leaf morphology and phenological development with increasing altitude. Various scaling up studies are currently underway and will link plant level processes to the ecosystem level. When combined with the climate change scenario described above predictive plant and ecosystem models will be developed and tested through long term monitoring.

A major part of our studies involves examining plant nitrogen utilization and the nitrogen cycle on Macquarie Island. Using ¹⁵N natural abundance showed that plants from diverse

sites on Macquarie Island varied by up to 30 ‰ in their leaf $\delta^{15}\text{N}$ values (Erskine *et al.* 1998). ^{15}N natural abundance of plants, soils, animal excrement and atmospheric ammonia suggest that the majority of nitrogen utilized by plants growing in the vicinity of animal colonies or burrows is animal derived. Plants growing near scavengers and higher food chain animals had highly enriched $\delta^{15}\text{N}$ values (mean = 12.9 ‰), reflecting the highly enriched signature of these animals excrement. Plants growing near nesting penguins and albatross, which have an intermediate food chain position, had less enriched $\delta^{15}\text{N}$ values (> 6 ‰) while highly depleted $\delta^{15}\text{N}$ values (< -5 ‰) of plants at upland plateau sites inland of penguin colonies, suggested that a portion of their nitrogen is derived from air borne ammonia (mean $\delta^{15}\text{N}$ = -10 ‰) lost during the degradation of penguin guano. Vegetation in a remote area had $\delta^{15}\text{N}$ values near -2 ‰. These results contrast with Arctic and Subarctic studies that attribute large variations in plant $\delta^{15}\text{N}$ values to nitrogen partitioning in nitrogen limited environments. We are presently studying the uptake of inorganic and organic nitrogen forms under different temperature conditions to assess species nitrogen use characteristics and the effect of climate change on plant nitrogen uptake and availability.

Nutrient cycling in subantarctic environments could be unique compared with other high latitude terrestrial ecosystems. On subantarctic Marion Island Smith and Steenkamp (1992) documented several common and widespread invertebrate species 'short circuiting' microbial mineralization processes. Similar to Marion Island, Macquarie Island soils are cool and wet year round resulting in low rates of microbial mineralization that are insufficient to sustain the high productivity found in some vegetation types, especially at low altitudes. The role of invertebrates in nutrient cycling on Macquarie Island and the likely effects of climate change on these processes is currently being investigated. This study is also located at sites along the altitudinal gradient.

To investigate the potential of vegetation communities to alter with climate change on Macquarie Island, a series of soil seed (Misiak 1998) and bryophyte propagule bank studies (Bergstrom and Selkirk in press) have been conducted. Preliminary studies differ for the vascular and non-vascular flora. Although local heterogeneity has been pronounced throughout all studies so far, soil seedbanks were representative of standing vegetation at all sites and differed markedly between sites across the altitudinal gradient. This suggests that, with climate change, the species composition of standing vegetation will not be altered by contributions from soil seed banks. Interestingly, some of the highest seed bank sizes ever recorded were documented (up to 96 333 seeds/m²). Contrary to soil seed bank studies, germination of bryophyte propagules in soil cores from feldmarks around the island have shown the presence of viable taxa from distant and warmer locations (lower altitudes) compared to the site of collection (Bergstrom and Selkirk in press). Bryophytes were successful at colonizing stable ground but when surface movement was present, burial and or damage of propagules and young plants prevented colonization. These suggest soil bryophyte propagule banks could provide feldmarks on the island with an immediate and constant potential for dramatic vegetation change with climate change.

To advance this study we are expanding to other periantarctic locations to establish sites along a latitudinal temperature gradient. International links have been established for this.

New sites will not only be added as ITEX sites but also link with a new international climate change collaboration RiSCC (Regional Sensitivity to Climate Change in Antarctic Terrestrial Ecosystems) which will meet at Madrid in June 1999 to establish a science plan. Further information on RiSCC will be circulated within ITEX following the workshop in June.

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Figure 1.

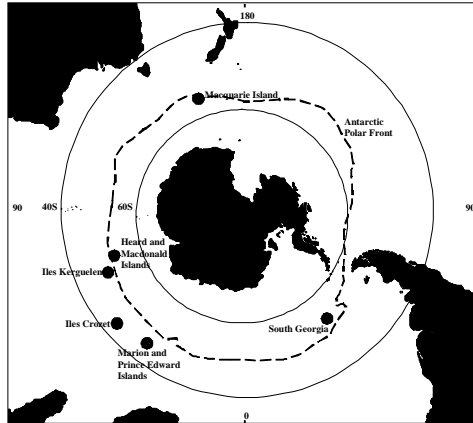


Figure 1. Location of Macquarie Island to the southeast of Australia and located close to the Antarctic Polar Front. Other treeless subantarctic islands are also named.

Figure 2.

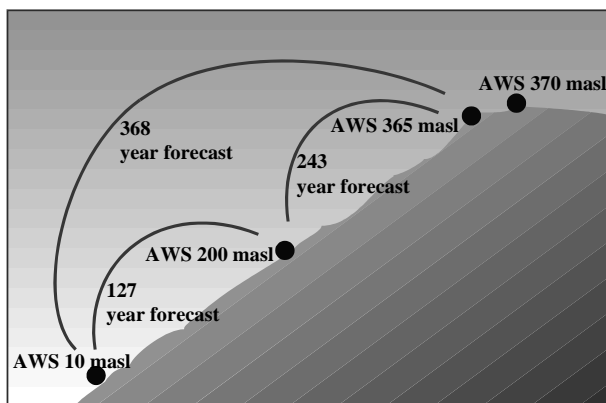


Figure 2. Climate change scenario for the altitudinal temperature gradient. Values are forecasts (in years) based on calculations which divide the mean annual difference in surface air temperature between AWS sites (1 year time series) by the forecast rate of warming modeled using ARIMA time series analysis of 50 years of continuous meteorological records (Tweedie and Bergstrom submitted manuscript). This scenario suggests that, based on the current rate of warming, the 200masl AWS site will have a similar mean temperature environment in 127 years as the 10masl AWS site.

VARIATIONS OF FLORAL TRAITS AND GENDER EXPRESSION OF *DRYAS OCTOPETALA* IN A SMALL-SCALE ENVIRONMENTAL DIFFERENCE AND IN A SIMULATED ENVIRONMENTAL MODIFICATION

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The floral traits and gender expression of arctic plants may vary among populations, in response to large-scale environmental variations, along a latitudinal gradient. Wada *et al.* (1999) demonstrated that flower weight and floral sex allocation to the female organs (= femaleness) significantly decreased along a latitudinal gradient from the Subarctic to the High Arctic, in hermaphrodite flowers of *Dryas octopetala*. The aim of this study is to describe and clarify how floral traits such as flower weight and femaleness vary between populations, in a small-scale environmental difference, near a glacier (*ca.* 0.5 km from the edge of the glacier = site A) and far from a glacier (*ca.* 1.5 km from that = site B), in the High Arctic Ny-Alesund, Svalbard in Norway. We also examined flower size and gender expression in a simulated environmental modification using by an open-top chamber at site A.

In 1998 snow melt was in mid- to late-June at site A and in early-June at site B. We collected twenty-four flowers in late July at site B, and twenty-four flowers in early-August at site A. The dry weight of flowers was significantly higher in the population at site B (mean \pm sd: 16.9 ± 2.3) than the population at site A (15.1 ± 2.3) ($P = 0.02$ by Student *t* test). Femaleness (gynoecium weight / gynoecium and androecium weight) was also significantly higher in the population at site B (mean \pm sd: 0.51 ± 0.17) than at site A (0.46 ± 0.07) ($P = 0.02$ by Student *t* test). Thus, gender of *Dryas* hermaphrodite flowers significantly differed between the populations, and the femaleness obviously decreased under a more severe condition even in a small-scale environmental variation.

In order to confirm the high plasticity of gender variation of *D. octopetala* in a simulated environment modified stressful factors such as low temperature and strong wind, we installed an open-top chamber (OTC) on the *Dryas* dominated vegetation at site A on August 8, 1997. The OTC was hexagonal, made by six plastic boards, and its upper and basal area were 0.3 m^2 and 0.6 m^2 , respectively. The height of the OTC was *ca.* 20 cm. We also measured temperature on the ground at a hourly interval inside (at the center of the chamber) and outside the OTC, with Optic StowAway temperature data loggers (Onset Computer Co.). The OTC increased temperature *ca.* 1°C from 1st to 31st July 1998.

We collected twenty-two flowers inside the OTC in mid-July and twenty-four flowers outside the chamber, the same as flowers collected as the mentioned above in a population at the site A. The dry weight of flowers was 14.6 ± 2.3 mg in the OTC-manipulated shoots, and was 15.1 ± 2.3 mg in the control, with no significant difference ($P > 0.1$, by Student *t* test). However, femaleness showed a significant higher value in the

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OTC-affected shoots (mean \pm sd: 0.65 ± 0.09) than in controls (0.46 ± 0.07), analyzed by Student *t* test ($P = 0.0001$), mostly because of an increase of gynoecium weight within the flowers inside the OTC (mean \pm sd: 3.8 ± 15 mg) as compared to outside the one (2.4 ± 0.9 mg).

Thus, we experimentally demonstrated that flowers of *D. octopetala* had high plasticity and performance of floral sex allocation and gender expression in response to an environmental change, and the hermaphrodite flowers changed their gender from male-biased to female biased expression under less stressful conditions. These flowering performances may strongly affect the seed production and the reproductive success of *Dryas octopetala*.

CO₂ FLUX IN ARCTIC AND ALPINE DRY TUNDRA: COMPARATIVE FIELD RESPONSES

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We compared growing season CO₂ flux patterns between botanically similar arctic and alpine dry tundra ecosystems in Alaska and Colorado under ambient and experimentally warmed conditions. Measurements were taken during the 1997 growing season, three years after the warming treatments were begun. Under ambient weather conditions, arctic dry tundra was a net source (4 g CO₂-C m⁻²) of CO₂ to the atmosphere, while alpine dry tundra was a net CO₂ sink (-7 g CO₂-C m⁻²) during the growing season.

Experimental warming of arctic tundra by 1-3°C, resulted in a 7-fold (30 g CO₂-C m⁻²) increase in this ecosystem's carbon source activity. Similar warming in alpine tundra changed this ecosystem from a net carbon sink to a net carbon source of 8 g CO₂-C over the growing season (Figure 1). In the Arctic, increased CO₂ efflux with warming was largely the result of increased rates of gross respiration throughout the entire growing season, while in the alpine ecosystem respiration was only increased early in the growing season. Rates of photosynthesis were generally not affected by experimental warming at either site. Global warming will likely accentuate the carbon source activity of arctic dry tundra, and will change the net CO₂ exchange of the similar alpine dry tundra ecosystem from a net CO₂ sink to a net CO₂ source to the atmosphere.

Figure 1. Integrated estimates of net growing season CO₂ flux (g CO₂-C m⁻² season⁻¹) under current ambient weather conditions (○) and under an experimentally warmed climate scenario (●).

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Summary: 8th ITEX Workshop

Royal Holloway Institute for Environmental Research

19-22 April 1997

1. Introduction & Objectives

The 8th Annual ITEX Workshop attracted 44 delegates from a total of 14 countries and convened at the Royal Holloway Institute for Environmental Research, Surrey, England. The format for the meeting was based upon a combination of:

1. key-note **Plenary Presentations**, designed to prompt critical discussion,
2. **Working Group** sessions (concurrent),
3. **Plenary Discussions** based on 1 and 2 above, and
4. **concise reports** (both oral and in poster format) from individual ITEX sites.

Strong emphasis was placed on informal discussions within the Working Groups, and the programme was designed to foster active participation by all delegates. The principal objectives of the Workshop were:

- to review progress made during the NCEAS Synthesis of ITEX Data, Santa Barbara, CA, 4-9 December 1996;
- to evaluate critically the results of the meta-analyses;
- to make a start interpreting the results in mechanistic terms and to use this as a foundation for refining hypotheses and developing new approaches;
- to consider future directions within ITEX and to devise new protocols (for incorporation into updates of the ITEX Manual) where appropriate or necessary.

This document, which has been circulated via the ITEX e-mail list, presents a brief progress report from the meeting (Section 2), written reports from some of the Working Group sessions (Section 3) and a draft protocol for measuring growth rate in bryophytes and lichens (Section 4). The authors of the reports and protocols are identified below, although I have made some minor editorial changes, in places, to ensure that the format is as consistent as possible, without (I hope) changing the emphasis or balance of the individual reports. Comments relating to this summary are welcome so please use the ITEX e-mail lists if you wish to discuss any aspects with the ITEX research community and list subscribers. I have included all the materials submitted to me by 7 October 1997 (Abstracts from posters and oral presentations will appear separately).

My thanks to all the participants in the 8th ITEX Workshop for making it a great success (and for being so patient with some of the logistic problems): please continue the dialogue and debate over the ITEX e-mail list.

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2. Progress:

An enthusiastic team of ITEXers (comprising of Donie Bret-Harte, Laura Gough, Dean Morewood, Kent Schwaegerle, Marilyn Walker and Sarah Woodin), who did not have to rush away immediately after the formal close of the Workshop, stayed behind to draw up a summary statement of the progress made: this is presented below. It should be emphasised at this point, however, that the conclusions relating to the meta-analyses must still be considered preliminary and the analyses on-going. For further information about specific points relating to meta-analysis contact Anna Arft and/or Marilyn Walker on arft@raastro.colorado.edu or mwalker@taimyr.colorado.edu.

1. The meta-analysis has provided sufficient data for preparation of a paper (co-ordinated by Anna Arft), with the main conclusions being:
 - the most consistent effect of the experimental warming treatment was advancement of early season phenology;
 - there is a vegetative growth response that is strongest in the low Arctic and either weak or absent in the high Arctic;
 - there is a minimal and inconsistent reproductive response (in terms of reproductive ‘effort’ and ‘success’, but not for flowering phenology; the latter was consistently accelerated in the warming treatments);
 - there are important differences in responses among growth forms;
 - these data represent a relatively short-term transient response and may not be easily extrapolated to predict long-term changes;
 - in many cases the effects of the OTCs relative to natural variation were small.

2. The meta-analysis was used as the basis for discussion of future development of the ITEX programme, with the following recommendations:
 - all sites need community characterisation (detailed point quadrating: see note below);
 - characterising changes in community composition is essential because the response of individuals strongly depends on community composition;
 - biological processes underpinning the trends must be examined in detail, and the ITEX programme should retain the focus on the response of individuals as the building block for integrating physiological, developmental, population and community level processes;
 - overall site characterisation should be improved - e.g. soils, climate (longer-term records) and other species groups and/or trophic levels (lichens, mosses, fungal fruit bodies, invertebrate and vertebrate herbivores);
 - variables to be measured should be assigned an order of priority, based upon their usefulness in meta-analysis, the logistics and effort required to measure them, and the requirements for site-specific data (e.g. for PhD dissertation work);
 - measurements of some facets of vegetative growth require further critical evaluation and revision where necessary;
 - the biological meaning of ‘reproductive growth’, and the key variables used to assess it, should be considered further;
 - the meta-analyses should be used as a catalyst for the development of mechanistic hypothesis-testing and novel experimentation;
 - recognise that short and long-term responses may differ, and long-term experiments are therefore essential.

3. A “wish list” was developed for ‘ITEX II’ (the next phase of ITEX):

- additional replicates for destructive plot sampling for below-ground parameters, chemical analyses and invertebrate sampling;
 - incorporate new expertise into the ITEX network.
4. The dates and venue for the next ITEX Workshop (the 9th) are subject to confirmation, although we propose, at this stage, to meet in East Lansing, Michigan, from 3-9 January 1999. Pat Webber and Bob Hollister will host and organise the workshop. At the Royal Holloway meeting a proposal to conduct the 9th Workshop as a symposium to which non-ITEX scientists will be invited was discussed. The exact format of the workshop, however, and the major themes to be considered in Michigan, remain as flexible as possible: please mail suggestions to the ITEX list to ensure that there is an opportunity to discuss these well in advance of the meeting.

Note: ALL ITEX CORE SITES MUST, AS A BASIC REQUIREMENT FOR DATA INTERPRETATION AND SCALING-UP, PERFORM MEASUREMENTS OF COMMUNITY COMPOSITION AS INSTRUCTED IN THE ITEX MANUAL.

3. Individual Working Group Reports:

Meta-analysis - Working Group I:

Rapporteur (and report author): Felix Gugerli; **Chair:** unappointed; **Members:** Matthias Diemer, Ingibjörg Jónsdóttir, Eric Pop, Karl Reiter, Mikael Stenström, Shizuo Suzuki, Jeff Welker.

In this working group we focused on the results from the overall analyses (only separated by treatment years) and on the results with the categorical variables 'azone' (high arctic, low arctic, alpine) or broad and narrow functional type (woody/herbaceous; deciduous, evergreen/forb or graminoid).

Our objectives were (i) to develop broad mechanistic hypotheses, and (ii) to assess whether the data from meta-analysis provided support for such hypotheses and aided in their interpretation.

Hypothesis	Observations	Possible explanations	
Phenology accelerated by warming	<i>leaf bud burst</i> <i>flower open</i> <i>dispersal</i> <i>leaf colour change</i> : no response	significant response	<ul style="list-style-type: none"> • responding variables seem temperature-dependent • lack of response not necessarily due to inconsistencies among categories, but other biological factors (e.g., deterministic, frost, light-regime, extreme events)
Woody species are more conservative than herbaceous species	<i>veg. growth</i> : no effect in woody strong effect in herbs <i>repr. growth</i> : both show effect (stronger in herbs) <i>repr. effort</i> : no effect		<ul style="list-style-type: none"> • leaf size may be more plastic in herbs than in woody species → monitor abundance, not just size • woody species need more time to respond → long-term observations

<p>Vegetative growth responses in the order graminoids > forbs > dec. woody > evegr. woody</p>	<p>but: forbs > graminoids (evergreen > deciduous)</p>	<ul style="list-style-type: none"> • competition? • allocation to below-ground structures? • short-term effects?
<p>Response stronger at high-arctic (HA) than at low-arctic (LA) or alpine sites</p>	<p><i>veg. growth:</i> almost no effect in HA strong effect in LA (after 1st year) medium effect in alpine</p> <p><i>repr. growth:</i> effect reduced with time in HA effect increased with time in LA alpine: strongest effect in 1st year</p> <p><i>repr. effort/success:</i> practically no effect</p>	<ul style="list-style-type: none"> • lower above-ground competition in HA • different degree of plasticity of species in different zones (see, e.g., Grime's triangle: stress-tolerant vs. competitor) • veg. growth only due to cell elongation? • repr. effort/success influenced by pollinator limitation

Wishes/proposals for further monitoring or with respect to a manuscript about meta-analyses:

- identify functional groups from other than the traditional perspectives (e.g., clonality, storage-capability)
- change the direction of approach: Which species do respond, and what characteristics do these have in common?
- look at some of the old theorems about tundra ecology – support or re-consider them?

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Meta-analysis - Working Group II:

Rapporteur (and report author): Bob Hollister; **Chair:** Ørjan Totland

This group suggested that, for the purposes of meta-analysis, the weather conditions during any particular year could be categorised, very simply, into two types: above the average temperature and below the average (i.e. 'good' and 'bad'). We also considered that the previous year's weather should be an additional factor in the analyses. After some discussion, however, the group concluded that the adjustment for weather would ideally involve the current year's conditions coupled with those of several previous years and that this would probably involve modelling (and perhaps prove more effort than is useful at this time).

The group then looked at the output from the NCEAS Workshop:

- Phenology was accelerated in the chambers (with the exception of first colour change). The lack of response at the close of the growing season may be because colour change is deterministic (i.e. responsive not to temperature but to day length or changes in light quality).

- There was an increase in reproductive growth in response to the warming treatments. We rejected the knee-jerk criticism that this is simply etiolation due to reduced wind speeds (or to shading) by pointing to similarities between OTC responses in cool years and controls in warm years (thus emphasising the need to maintain monitoring over several growing seasons within ITEX if possible). We agreed that there were three lines of evidence that show that increased reproductive growth was a result of temperature increase: the results of our short-term manipulations with OTCs, spatial differences due to micro-climate and regional climate, and year-to-year variability. We also concluded that the trend in reproductive growth over the first three years in the High Arctic appeared to be different and that this should be explored.
- The broad original assumption (or hypothesis) that the High Arctic vascular plants should respond more to warming than the Low Arctic is not supported by the meta-analyses. We proposed that actual leaf temperatures, even in the High Arctic, may not be limiting in comparison with other factors, such as moisture or nutrient availability.

The group then went on to consider the 'uncoupling' of canopy and soil temperatures that sometimes occurs in the OTCs. The chambers do not always warm the soil, due to factors such as the size of the plots (and lateral heat fluxes), the effects of restricted air mixing within the OTCs, the canopy type (cover) and soil properties. This uncoupling of air and soil temperatures could be a major limitation of the chambers and may need to be accounted-for in our analyses (including the meta-analyses).

ITEX response variables are also currently restricted in terms of quantifying vegetative reproduction and proliferation. This was seen as a significant limitation, especially bearing in mind the paradigm of strong dependence of the Arctic (and, to a lesser extent, alpine) flora on vegetative reproduction. We suggest several criteria should be used when modifying our variable lists: thus, (i) variables should be important to ITEX as a whole even if they do not appear to be pertinent at some individual sites, (ii) just because we have already measured a response variable in the past does not justify retaining that measure if a more suitable alternative exists, or if the measurement is of limited value, (iii) the time investments and costs are important, and (iii) the variables should, as far as possible, be consistent across sites.

We concluded this working group with some cautionary comments about the meta-analyses. We must examine each analysis by taking a detailed look at the sites, species and variables that the analysis is based upon in order to ensure that the conclusions we make are consistent with our knowledge of the system and that results are not misinterpreted due to cryptic errors in the analysis.

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Meta-analysis - Working Group III:

Rapporteur (and report author): Anna Stenström; **Chair:** Matthias Diemer; **Members:** Felix Gugerli, Annika Jägerbrand, Gaku Kudo, Borgthor Magnusson, Richard Ring, Marilyn Walker, Pat Webber

We discussed the meta-analysis results and came to the following conclusions.

Positive (things working well)

- This is a great study of the biology of global change.
- We show that species-level responses can be scaled-up to the level of growth forms or functional groups.
- This is a new way of using meta-analysis.

Problems and new ideas

- ‘Genetics’: instead of some narrow functional groups we can maybe use clonality / non-clonality, or the inconsistency of variance, as criteria for further analysis.
- ‘Space’: should we consider devising an integrated variable for soil and community-data? We also have to differentiate between weather and climate and we really need long term climate data (although this might be difficult to obtain at all sites): Young’s floristic zones also need climate data, not weather data.
- ‘Time’: we could possibly use weather data to see if we get the same responses in a ‘warm’ year as in a ‘cold’ year. But that is a new analysis to be made later. We could also divide the data set after the Chapman & Walsh map.

Some more thoughts

- How ‘representative’ are our species, sites and functional groups?
- How many species do we have in each family and functional group (i.e. are our comparisons ‘balanced’)?
- Is there a stronger trend in flowering and reproduction than in vegetative growth?
- The ‘year 4 effect’ (i.e. the observation of clearer or ‘new’ response patterns in the 4th year of treatment) needs to be based on observations from more sites (at present it is based on only 1-3 sites, depending on the response variables analysed).
- Could we use bare (unvegetated) ground as an indicator of the intensity of competition?
- Is there a greater vegetative growth response in high-competition environments?
- Do certain functional groups invest in reproduction instead of growth in response to warming?
- Could we interpret narrow functional types in terms of nutrient use patterns?
- Are reproductive and vegetative growth more responsive than reproductive effort and success?

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Meta-analysis - Working Group IV:

Rapporteur (and report author): Ørjan Totland; **Chair:** Greg Henry; **Members:** Gaku Kudo, Volodya Razzhivin, Karl Reiter, Anna Stenstøm, Ørjan Totland

We decided that our tasks were: i) to distil the data presentation (e.g. the quantity of graphs) to a number consistent with publication in a journal article, and ii) to interpret the data presented.

1. Data reduction:

- a) Site type vs. high-, low-arctic, alpine: we recommend to remove the site type classification because it is partly redundant with high-, low-arctic and alpine. Site type is also not entirely representative for each site. Detailed climate data from each site should be used instead, in combination with high-, low arctic and alpine.
- b) We found site type precipitation very useful.
- c) Remove secondary graphs (e.g. Herbaceous divided into forbs and graminoids) if they do not add anything to the results presented in the primary graph (e.g. herbaceous).
- d) Remove 'redundant' variables if they show similar results.
- e) Remove family level responses from the main paper: present these in a subsequent paper.
- f) Remove guerrilla/phalanx classification. These are strategies that only apply to clonal plants. We suggest, instead, to use a clonal/non-clonal classification of species.
- g) We suggest that summer thawing degree days TDDs are replaced by the July mean temperature instead. TDDs may be redundant (in the view of this Working Group), and July mean temperature is more readily understandable than thawing degree days.
- h) In general we suggest to condense or remove 'redundant' variables when similar responses are found.
- i) The breaking-up of some of the variables needs to be justified, because results may be dependent on the break-point.

Brief interpretation of results:

- a) Phenology accelerated in the OTCs, but termination of the growing season (senescence) appears fixed. Warming speeds-up phenology and there is great phenotypic plasticity. There are obvious advantages to start growth/flowering early in the thaw period. Termination of growth, however, is not delayed in the OTCs because there may be diminishing 'returns' (e.g. if an economic analogy is used) with prolonged growth coupled with an increased risk of frost damage late in the season.
- b) Effects of warming on vegetative growth decrease over experimental time, whereas effects on reproduction increase over time. It appears that a shift in resource allocation from growth to reproduction occurs under warmed conditions. However, there are many limitations in the data: i) small, insignificant, differences across years, ii) fourth year poorly represented, and iii) lack of independence between years.
- c) Small effects of warming on vegetative growth at high arctic sites. It may be that plants are constrained from responding to increased temperature if other factors, such as nutrient

availability, limit growth. It could also be that high arctic species have a more conservative growth strategy because of high mortality risks associated with increased growth.

- d) A precipitation class < 50 mm includes mainly studies from high arctic sites. Thus it may be difficult to isolate the effects of severe conditions and little precipitation.
- e) We believe that the small growth response in woody plants is mainly caused by the opposing effects of warming on deciduous and evergreen species. When comparing these groups, and others as well, it is important to know which growth parameters have been measured for each species, since the result may depend on whether, for example, leaf number or leaf size have been measured.

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Summary of Working Group to discuss expanding ITEX and consider additional trophic levels

Rapporteur (and report author): Laura Gough; **Chair:** Phil Wookey; **Group Members:** Gabriele Broll, Peter Crittenden, Annika Jägerbrand, Borgthór Magnússon, Wm. Dean Morewood, Ulf Molau, Steve Oberbauer, Tom Powers, Richard Ring, Gus Shaver & Sarah Woodin

This group spent most of the afternoon discussing additional measurements that need to be made at each site to better characterise the site and measurements that could be added for 'ITEX II'. Throughout the Workshop the importance of classifying sites by soil characteristics was emphasised. We discussed adding three baseline measurements to the ITEX Manual to be conducted at all sites and used in the meta-analysis: (1) pH, (2) bulk density, and (3) thickness of organic/peat layer. Gabriele Broll has been preparing a protocol for the Manual and this is being considered prior to formal adoption (the draft form, which is available upon request - brollg@uni-muenster.de - is also worth consulting). In addition, N mineralisation protocols will be added to the Manual so that site personnel wishing to conduct these measurements would follow a standardised procedure. Gabriele suggested classifying the soil types at each site and will obtain information on soils in the region at an international meeting of soil scientists later this year.

To address additional trophic levels Richard Ring will co-ordinate a small group to devise a sampling protocol for insects and Tom Powers will do the same for nematodes. Annika Jägerbrand, Ingibjörg S. Jónsdóttir and Peter Crittenden have written a protocol for more detailed measurements of growth rates in bryophytes and lichens (this has already been circulated on the ITEX list and reproduced below). Several suggestions were made to increase our understanding of vascular plant response, including recording tiller or meristem density in the plots.

It is generally agreed that the ITEX experiments should be maintained as long as possible in order to obtain good long-term data. As ITEX expands it is important that a procedure for integrating new sites and investigators be developed: we had several new people at the Workshop who found it difficult to determine their role within the ITEX network. This will require more consideration in the future.

Destructive plots are desperately needed in order to sample adequately soils and soil fauna. If destructive plots were available additional measurements could be made including: root phenology, mycorrhizal characterisation, buried bags (for N, and possibly N and P, mineralization studies), moss physiology, lichen lysimeters and further soil description. In planning for ITEX II, the sample area must be increased either by increasing the number of replicates or increasing the size of chambers.

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4. Preliminary protocol (for subsequent adoption in the ITEX Manual)

Reproduced below is the protocol developed by Ingibjörg S. Jónsdóttir, Peter Crittenden and Annika Jägerbrand for bryophyte and lichen studies within the ITEX programme. I have included it here because I believe that this protocol could be added to the ITEX Manual with little or no amendment (I would, however, value some feedback on this from ITEXers, so please use the ITEX lists to make any views you have available for consideration; I am sure the authors would also value comment).

Measuring growth rate in bryophytes and lichens

**by Ingibjörg S. Jónsdóttir, Peter Crittenden
and Annika Jägerbrand**

Bryophytes and lichens are important vegetation components in most tundra vegetation types and they may respond either directly to temperature change or indirectly through interaction with vascular plants. It is, therefore, important to include these groups in ITEX-studies at least in those at community level. Although bryophytes and lichens are quite distinct organisms, in many cases they play a comparable role in plant communities and it is thus appropriate to include both groups under the same protocol. This is particularly true for mat forming mosses and lichens with large cover in the bottom layer. Studies have shown that both mat forming mosses and lichens are extremely efficient in immobilising all atmospheric nutrient input making it unavailable for vascular plants (Crittenden 1989; Lee et al. 1987; Jónsdóttir et al. 1995).

We strongly recommend including bryophytes and lichens in studies at ITEX-sites. This can be done at different levels and we provide some detail on measurements at two of them:

1. Community level measurements.
2. Growth rate of individual shoots.

1. Community level measurements.

In the "point framing" analysis that is recommend in the "Community baseline measurements for ITEX-studies" it is important to record two hits at each point if possible: 1) first hit in the field layer and 2) first hit in the bottom layer (called "ground surface" in the Community

baseline-protocol). If you have mat-forming bryophytes or lichens you should try to record the thickness of the mat. This is done by making one additional recording at each point: the distance from the bottom string intersection to the soil surface underneath the mat. It may be difficult to find the surface for two reasons: first, you have to be careful not to disturb the mat and secondly, the interface between the bryophyte/lichen mat and the soil surface is not always obvious. The thickness of the mat is then calculated as the difference between the distance to the soil surface and the distance to the surface of the mat ("ground surface"). In this way valuable information on the responses of mat thickness to the OTCs can be obtained.

If you find it too difficult or impossible to identify species or higher taxa in the bottom layer even a recording of a "functional group" will be informative. We suggest the following groups:

- Crustose lichens
- Foliose lichens
- Fruticose lichens
- Thalloid liverworts
- Leafy liverworts
- Acrocarp mosses (erect, ascending), other than *Sphagnum* and Polytrichales.
- Pleurocarp mosses (prostrate, for example *Hylocomium splendens*)
- Semi-prostrate mosses (for example *Racomitrium lanuginosum*)
- *Sphagnum* mosses
- Polytrichales

These groups can also be used in later meta-analysis of responses at the next level.

2. Growth measurements.

There are several methods available and different methods are suitable for different functional groups (see above). Clymo (1970) gives a detailed overview of methods used for measuring growth of *Sphagnum* species some of which have also been used for other species. Below we describe some of the methods that have proved most successful or promising in terms of accuracy and labour intensity and we mention one new method (c).

The first three methods (a-c) use reference marks outside the plant, and the two last methods are based on transplantation of plants cut to known length and/or of known mass. Some of the methods (b,d and e) involve removal and replacement of tagged target plants in a moss or lichen mat. In all these methods the target plants may either be placed back directly into the bryophyte/lichen mat or be first placed in a cage. Whether to use cage or not has to be decided from one case to another after evaluating potential disturbances and errors. By using a cage the damage to the "test" plant is minimised.

Especially for lichens, but also for some mosses, pushing a dry plant into, or pulling it out of a lichen/moss mat would do extensive damage. Under method e) there is a description of a cage that can be used for both bryophytes and lichens to decrease risk of such damage. A potential error in using cages is that a physical separation of a moss shoot or lichen thallus from the remainder of the mat can change the micro-climate of the caged plant.

a) Cranked wire.

Suitable for various *Sphagnum* species and other dense, mat forming acrocarp or semi-pleurocarp mosses. A number of ca 15-18 cm long stainless steel wires are cranked twice so there will be two vertical sections and one ca 1-2 cm long horizontal section somewhere in the middle. At time zero (t_0) one end is pushed into the mat until the horizontal section

is level with the moss shoots, while the free end projects into the air. It is important that the free end is of exact known length. The difference between this length and the portion still above the moss shoots at a given time (t_1) gives the increase in shoot length during a time interval ($t_1 - t_0$). By measuring the average dry mass of different length increments in a separate study the increase in shoot length during a time interval can be related to the species specific average mass of plant in unit depth to give an estimate of increase in dry mass. *Advantages* of the method: an easy-to-use and low-disturbance method; non-destructive and so repeated measurements possible; relatively accurate for the right type of mosses provided that many wires are used. *Disadvantages*: difficult to find all wires if not properly marked; risk of disturbance by grazing animals.

b) *Tied thread.*

Suitable for a range of mosses, but preferably mat forming. A thin thread is tied around the stem at a known distance from the apex of a number of shoots that are then placed back into the carpet at time zero (t_0). The shoots are collected at a given time (t_1) and the length increase measured. If the shoots are to be placed back for another time interval an estimate of dry mass increase can be done as in the previous method. If measurements are not to be continued, the dry mass of the new increment can be measured directly. *Advantages*: Suitable for a range of moss growth forms. *Disadvantages*: time consuming; risk of disturbing the moss shoots too much in repeated measurements; difficult to find all shoots if not properly marked.

c) *Fluorescent spray.*

This is a relatively new method that we have not tried, but should be rather accurate for a range of both bryophyte and lichen species forming dense mats (Russel 1988). A layer of fluorescent chemicals is sprayed on the mat at t_0 . Shoots are collected at t_1 and the length increment above the fluorescent layer and its dry mass is measured. *Advantages*: low-disturbance method; spraying of the mats can be repeated at intervals without disturbing the mats and at the final harvest the growth could be analysed retrospectively using the different fluorescent layers as markers. *Disadvantages*: there may be a problem finding the right chemicals that will stay in the plant tissue without harming them.

d) *Plants of known length and known mass.*

This method can be used for a range of mat forming mosses, but is probably not suitable for Polytrichales because of the primitive vascular tissue they possess. A number of moss shoots are cut to constant length (ca 5 cm) and weighed (fresh mass). The shoots are divided into two groups, one is tagged and placed back into the moss mat at t_0 , while the dry mass is measured in the other half. The ratio average dry mass : fresh mass is used to calculate the dry mass of the transplanted shoots at t_0 . The shoots are collected at t_1 , their length and weight measured. This method is very similar to the next method which is mainly designed for lichens. While the shoot length of most mosses is easily measured and can be related to dry mass, this is usually impossible to do in most lichen species. The details of the weighing procedure and calculations given under method e) for the lichens can also be followed for mosses. The greatest *advantage* of both these methods is that they are relatively accurate. *Disadvantages* are that there is risk of disturbance and it may be difficult to find transplanted shoots again.

e) *Plants of known mass*

General principle

The dry mass of a lichen is measured at time zero (t_0), the lichen is secured in the field to grow and then dry mass measured again at the end of the growth period (t_1).

Experimental

Test thalli should be selected, trimmed in size if necessary, cleaned of extraneous debris and placed in the field until they dry naturally during a rain-free period. The air dry thalli are then transferred to a laboratory and allowed to equilibrate with laboratory air for *c.* 12 h and weighed (t_0) using a 4 decimal place analytical balance. The weighed thalli are tagged for identification purposes and then returned to the field to grow. At the end of the growth period the lichens are recovered, air dried under laboratory conditions, weighed (t_1), oven dried (80 °C for 12h) and weighed again.

On both occasions (t_0 and t_1) procedures similar to those above are carried out on a duplicate set of "dummy" thalli (but these are not tagged) for which both air dry mass and oven dry mass are determined. The air dry:oven dry mass ratio for dummy thalli is then used to estimate the oven dry mass of the test thalli. Oven dry mass of test thalli at t_1 can then be measured both directly (by drying the test thalli) and indirectly (by using data for dummy thalli): this provides a check on the accuracy of the "dummy" lichen approach.

The suggestion above is that lichen thalli are selected, cleaned etc. in the wet state. This will reduce damage since dry lichens are brittle. It is probably desirable to deviate from natural conditions as little as possible and, thus, to avoid artificially rewetting lichens, especially during periods with strong evaporative forces (e.g. when exposed to strong direct solar radiation). Of course, occasions may arise when there is no other option and spraying with deionized water or simulated rainwater becomes necessary in order to select intact lichen thalli. To avoid errors it is essential that (i) after weighing at t_0 lichen thalli are handled with the greatest of care (e.g. watch-makers forceps) and (ii) thalli are wet when they are recovered from the field at t_1 : if thalli in the field are dry on this occasion then they *should* be artificially re-wetted to minimise the likelihood of mechanical damage.

Tags can be made from small pieces of acetate or polyester sheet (e.g. 4 x 3mm) attached to the lichen with polyester thread. I have found it useful to photocopy numbers onto acetate overlays for this purpose. Some lichens (e.g. foliose species) do not lend themselves readily to having things tied to them, instead tags might be tied to their securing mesh (see below).

Securing lichens in the field

Useful materials for this purpose are fine woven stainless steel (s.s.) wire mesh (or fine nylon mesh) and s.s. wire strong enough to be pushed into the soil.

Lichens should be oriented in the field in a manner comparable with undisturbed specimens of the same species. A suggestion for mat-forming species that grow vertically upwards (e.g. species of *Cladonia*, *Stereocaulon*, *Cetraria*) is to construct small cylinders from s.s. mesh which are then inserted into otherwise undisturbed lichen mats thus creating a recess or well. These cylinders should be wide enough to allow air dry thalli to be gently "dropped" into place. It may be desirable to add some material to the bottom of the cylinder to raise the apex of the test thallus to those of the surrounding lichen (suitable material might be dead basal parts of lichen thalli or inert black plastic beads). Foliose lichens (e.g. *Peltigera*, *Nephroma*) can be placed under fine mesh which is pinned to the soil with s.s. wire. Thalli of *Thamnolia vermicularis* might be held in position using s.s. wire bent like a shepherd's crook.

Relative growth rate

Mean RGR = $(\log_e M_1 - \log_e M_0) / (t_1 - t_0)$ (unit mass per unit mass per unit time)

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Report: Working Group on ITEX Metadata

C. Tweedie (Brisbane) and R. Hollister (East Lansing)

Background

It is common for large international scientific organisations and affiliations to become overwhelmed and enveloped by the complexity associated with the accumulation of large, multifaceted and dispersed datasets. At the 9th ITEX meeting in East Lansing, Michigan, it became apparent that ITEX is becoming symptomatic of this scenario. The result is that increased effort is needed to initiate and maintain collaborative relationships. Accurate representation of the organisation also becomes increasingly difficult as one can never be certain that they have all relevant information on a particular subject within the organisation. Subsequent to widespread consensus at the recent meeting a working group has been established that will initiate the construction of a metadata database for ITEX.

Metadata

A Metadata database by definition is not a depository or archive of raw or processed data. Quite simply, it is data about other data. In the context of ITEX, metadata is data of how, what, where and when raw data is or has been collected and the content, quality and condition of that data. There is, therefore, no fear of others analysing or publishing data without the approval of the intellectual owners. Other descriptions, values, benefits and examples of metadata and metadata databases can be found at and via the following web sites (full addresses located in reference section below):

- <http://geology.usgs.gov/tools/metadata/standard/metadata.html>
- <http://www.ukoln.ac.uk/metadata/>
- <http://www.antdiv.gov.au/datacentre/index.html>
- <http://lternet.edu/ecoinformatics/>
- <http://www.esdim.noaa.gov/NOAA-Catalog/NOAA-Catalog.html>

Increasingly, metadata databases are being used to consolidate the spatial, temporal and organisational complexity associated with multidisciplinary international research consortiums (try a search on the World Wide Web with 'metadata' as the key word for example). Researchers are provided with a simple yet concise directory to the data that is, has or will be collected by colleagues within the organisation. Valuable information on research personnel and publications is often included also. Metadata databases make the search and synthesis of information within an organisation much more efficient and accurate and are also a useful advertisement tool to other international organisations as well as funding and reviewing bodies. In order to retain international recognition, ITEX needs to reinforce these latter elements.

The ITEX metadata database

We understand that the compilation of a metadata database is a complicated and lengthy process involving a great deal of effort on behalf of all contributors. The longterm benefits, however, far outweigh short term inconvenience. Some advantages to contributors include increased:

- Research efficiency – metadata datasets help to identify missing links in research effort, reduce the risk of research duplication and maximise the number of collaborative links available.
- Research exposure, recognition and collaborative opportunity.
- Competitive ability – the enhanced research capability metadata datasets offer is increasingly being recognised and awarded by granting and reviewing bodies.
- Publication record – metadata datasets are regarded as a contributable non refereed publication. As such, you may include your metadata dataset contribution in your curriculum vitae or resume.

At present, the ITEX metadata database is being constructed in Microsoft Access (Access 97) but ultimately, it is planned that an upgrade to a fully interactive web based browser will be possible (e.g. <http://www.esdim.noaa.gov/NOAA-Catalog/NOAA-Catalog.html>, <http://www.antdiv.gov.au/datacentre/index.html>). Our primary aim will be to keep the metadata database simple, fully expandable, user friendly and freely available to all ITEX researchers in a variety of formats (eg. via File Transfer Program (FTP), compact disk, zip disk, hard copy). Although the database will not correspond directly to international metadata protocols (eg. <http://geology.usgs.gov/tools/metadata/standard/metadata.html>), these have nonetheless been taken into account wherever possible.

To ease the workload on contributors, we have planned several stages to the construction of the database. An excellent response to the first questionnaire has been received and a trial database has been designed. After first round data entry is complete a second questionnaire will be circulated to contributors of the first questionnaire. After data entry and compilation of the second questionnaire is complete the database will then be offered to the ITEX steering committee for testing prior to widespread circulation. Following this, it is hoped that the database can be updated annually. This process will also allow for database revision, improvement and expansion to incorporate new or altered ITEX protocols and information required by new or advancing working groups and scientific collaborations within ITEX.

Metadata from sites no longer in operation will also be included where possible from information in past ITEX records, web pages etc. These data, however, will not be granted the same data quality as data supplied by researchers directly and listed as 'unconfirmed'. In this way the data integrity and quality of the database will be maintained.

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Report: Working Group on Observatories

H. Meltofte (København) and E. Lévesque (Québec)

This working group met briefly and initiated a discussion that will be pursued on the Internet in the future. The group has focussed primarily on phenological studies at observatories thus far.

Some of the key points discussed were:

- 1) The long-term nature of datasets (more than 5 years) within ITEX is extremely valuable in order to address questions relating to the interannual variations and long-term trends of tundra ecosystems. Every effort should be made to maintain sites as long as possible.
- 2) The broad range of sites studied in this network is a great asset of ITEX and we should continue obtaining data in these varied habitats. Sites may still be added since the regional variability is large and not all vegetation types are as well represented within the network.
- 3) The standard protocols followed by ITEX researchers ensure that data are comparable among all these years and sites and this should be maintained since it represent another strong asset of ITEX.
- 4) In order to maintain sites for extended periods of time it is important to limit the disturbance of our plots (*e.g.* by frequent measurements and trampling) and to ensure that reliable comparable data are collected (and archived) regularly.
- 5) The ITEX manual is an extremely useful tool and should remain the basic reference for the monitoring of all sites (choice of species and of parameters to measure, protocols for different aspects of our studies). However some basic observations could be made of parameters that have integrative properties (*e.g.* timing of ice melt on a lake). In this respect the chapter of the ITEX manual: Intersite monitoring (ITEM) of interannual variations should be revisited.
- 6) After the initial intensive studies performed at many sites (many of which are published) it may not be possible (lack of funding) or suitable (disturbance effect *vs* the amount of new information gathered) to continue with the intensive measurements (recording of all reproductive and vegetative parameters). It is also important to note that many participants are already taking measurements to answer other types of questions (*e.g.* community level, population genetic level) which reduces the time available to the measurement of basic phenological parameters. **However, it is clear to those present that comparable basic measurements should be taken in order to maintain the high level of compatibility among our datasets.** This group will further discuss the best approaches to recommend for people who wish to reduce the intensity of their basic monitoring. The key words are: **fast, low impact, flexible in timing of the measurement, and inexpensive.**

Many suggestions were made during this initial meeting. Below is a list of some concerns and ideas that should be addressed by this group (the order does not reflect any order of priority):

- a) Do we need to take all measurements every year? Can we come up with a scheme of yearly simple measurements and of other measurements that could be made at regular intervals (*e.g.* every 5 years like the plant community data) and which require more effort?
- b) Another element to examine is time and expertise required to make good quality measurements, three levels were suggested: simple measurements (which can be done by non-specialists qualified people), measurements requiring a professional botanist, measurements that can be made when time is limiting (limited person-power).
- c) Not many species are studied everywhere, maybe we should make an effort to have representative of all functional types represented.
- d) It is important not to expand the list of species monitored (except when totally new areas are added, *e.g.* Tibet Plateau in China or regions in the Sub-Antarctic).
- e) Are we taking the right measurements to answer the questions in the long-term? Should we add or eliminate some (*e.g.* biomass estimates, measurements taken per area rather than per individuals)? Of course time is limited and it is important to keep the basic minimum measurements manageable, however, we should always remain careful not to miss something important!
- f) Using the results of the NCEAS and London workshops we should highlight the variables to choose (best indicator of reproductive or vegetative performance) if we have to choose some variables in order to continue to take measurements over many years. This should be done for all ITEX species and keep in mind the key words: **fast, low impact, flexible in timing of the measurement, and inexpensive.**
- g) In addition to standardizing our measurements, steps should be taken to facilitate the use of the manual for qualified non-experts who wish to take vegetation measurements and may contribute to extend our network.

In view of the long term monitoring of our sites the main recommendations are:

- 1) Reduce impact.
- 2) Maintain high quality of datasets (long-term, continuous, uniform).
- 3) Continue to use the ITEX manual as the reference for standardized protocols and highlight the minimum variables to measure for all species.
- 4) Revisit ITEM (Intersite Monitoring of interannual variations) protocols.

Report: Working Group on Soils

G. Broll (Muenster) and C. Tarnocai (Ottawa)

Introduction

The purpose of the working group on soils is to determine the minimal soil information needed to characterize, describe and sample the soils according to accepted methods and standards. This data will provide information about the nutrient status, pH and other chemical and physical properties necessary to study the soil-vegetation relationships on the ITEX vegetation plots.

The first goal is to provide information about the minimum types of soil data that should be collected from a representative soil site adjacent to the ITEX plot. It was decided that the type of information should include site and soil profile descriptions as well as field measurements such as monitored soil temperatures and soil moisture; soil samples should also be collected for laboratory analyses (see list of site and soil attributes in Appendix). It is planned that a field data sheet will be designed to facilitate collection and recording of these data and to ensure that all of the necessary data is collected in a systematic manner.

The second goal is to provide soil information by collecting samples for ecological studies using permanent plots adjacent to the ITEX plot. The size of these permanent plots and the layout of the sample sites within these plots are shown in the Appendix. A method is also provided for sampling plots associated with microtopography (e.g., tussocks).

The working group members recommend that, although the sampling and soil data collection could be carried out by people with some field experience with soils, if possible, the soil work should be carried out by soil scientists.

Methods

The first part of the report (A) provides brief information about methods for collecting the minimum soil data from a single representative soil site (A1-4). This soil is located adjacent to the ITEX plot, but it has the same soil as occurs on the ITEX plot.

The second part of the report (B) outlines the types of soil analysis carried out on the representative soil collected adjacent to the ITEX plot (B1). Other samples collected from new plots for the ecological studies (B2) are shown in Figures 1-3.

A. Site and profile description

(according to Schoenenberger *et al.* 1998)

Selection of a representative site adjacent to the ITEX vegetation plots

1. Site information

- Site name
- Site history
- Location (latitude/longitude)
- Landform
- Elevation
- Slope (aspect, gradient, shape, hillslope-profile position)
- Microrelief
- Soil parent material
- Bedrock
- Active layer depth
- Patterned ground
- Drainage class

2. Soil profile description

- Depth of horizon
- Colour
- Structure
- Coarse fragments
- Texture
- Roots (quantity, size, location)

3. Soil classification

- USA (Soil Survey Staff 1998)
- Canada (Soil Classification Working Group 1998)

4. Field measurements

- Soil temperature (depth: 2.5, 5, 15, 50, 100 cm)
- Soil moisture
 - TDR (point measurement or monitoring by data loggers)
 - Gravimetric measurement from core samples

B. Soil sampling and soil analysis

(according to Soil Survey Staff 1996)

1. Soil horizons of the profile

- Composite samples
 - air-dry
 - particle size analysis, pH(H₂O), pH(CaCl₂), organic carbon, total nitrogen, calcium carbonate
- Core samples with steel cylinders (usually 100 cm³) and gravimetric measurement or Saran method
 - bulk density

2. New plots for soil ecological studies

(according to Crepin and Johnson 1993)

- Plots should be established near the vegetation plots and adjacent to the soil profile.
- The plant cover and the soil (e. g. texture, parent material, drainage) of the new plots should be similar to the vegetation plots.
- Suggestion for the size of the plots: 4m x 4m
- The plots should be subdivided into parts which are as homogeneous as possible. The dominant vegetation type or microtopography can be used for horizontal subdivisions (Fig. 1, Fig. 2).

2.1 Stratified random sampling for composite / mixed samples

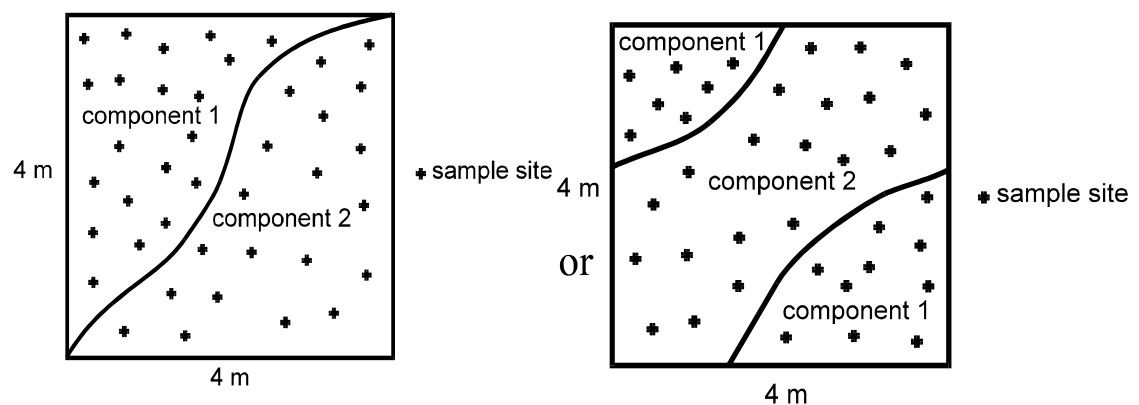
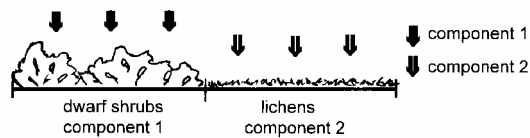


Figure 1.
Example for sampling in



stratified random
the Arctic: dry heath.

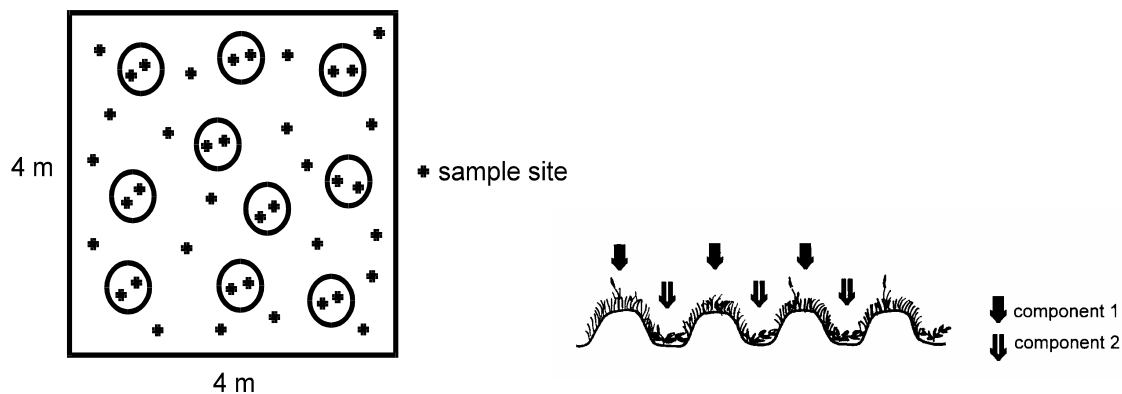


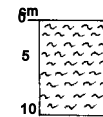
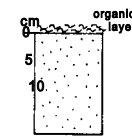
Figure 2. Example for stratified random sampling in the Arctic: tussock tundra.

- Analysis of pH (CaCl₂), pH (H₂O), organic carbon, total nitrogen, other nutrients etc. (data which are absolutely necessary for interpretation of soil ecological processes). Stratified sampling allows a statistical analysis of

variability within and between strata.

Methods for composite depth sampling

- Take corers with a small diameter (suggestion 2 cm)
 - number of cores in each component: suggestion 20
 - replicates in the field: suggestion 3
- Sampling of mineral soils
 - suggestion for moist sites: 0-5 cm sampling depth
 - suggestion for dry sites: 0-2 cm sampling depth
 - if an organic layer (soil organic matter > 30 %) exists sample it separately
 - do not mix organic layers with mineral horizons
 - do not mix major horizons (for example A and B horizon)
- Sampling of organic soils
 - Those soils are very often wet soils.
 - Samples should be taken beginning at the surface of the organic material .
 - suggestion for wet sites: 0-5 cm or 0 - 10 cm sampling depth



2.2 Stratified random sampling for undisturbed soil cores

bulk density for calculation of carbon storage, for example

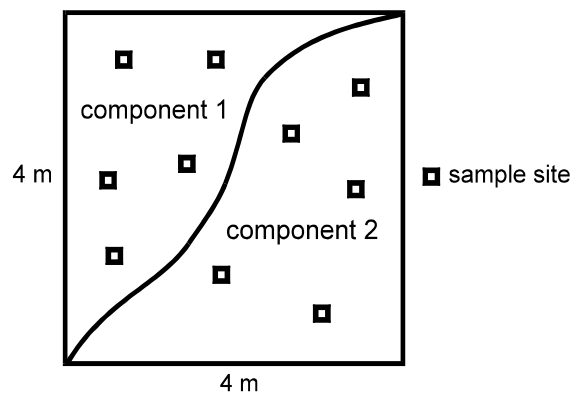


Figure 3: Example for sample sites for undisturbed soil cores

- Size of the steel cylinder usually: 100 cm³, 4 cm height (disadvantage: destruction of the soil surface). Smaller cylinders (e. g. 2 cm height) are possible, especially recommended for dry sites.
- Replicates: suggestion 5

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APPENDIX VI Report: Working Group on Soils

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