PPS Arctic Canada: **P**resent day processes, **P**ast changes and **S**patiotemporal variability of biotic, abiotic and socio-environmental conditions and resource components along and across the **Arctic** delimitation zone in **Canada**

As Robert Correll said at the closing ceremonies of the Second International Conference on Arctic Research Planning in Copenhagen in November 2005, we have entered a new paradigm: global change forces us to see humans and environments as inextricably interconnected. This paradigm is clearly apparent in the arctic region, and provides a strong underpinning of our proposed research on dynamics of the forest-tundra ecotone. Using field and GIS-based data display and analysis, our multidisciplinary research team will develop methods for integrating data from a wide range of quantitative, qualitative and anecdotal data on change across treeline, or the arctic delimitation zone. Our research will focus on the interconnections between different components of change, and will aim to communicate our findings clearly and understandably for maximal use to a broad audience in and outside of the North. By actively interweaving research themes from ecological, environmental, and social sciences with northern cultural perspectives and community priorities, we are framing environmental change research in new ways, adopting new approaches to doing science in partnership with northerners, and developing new methods of cross-scale enquiry. Our research is ground breaking because it begins with an expectation that there are important new relationships involving climate, environmental change, human health and well-being that we need to understand. By using methods familiar to natural and social science in order to understand change in the northern landscape as well as its meaning from ecological, social and cultural perspectives, we will provide policy relevant knowledge about environmental change and its human dimension in the tundra-taiga transition zone. We will also integrate this research with northern priorities at specific sites to create opportunities for hands-on involvement by scientists from diverse disciplines, Elders, local knowledge holders, community people, youth and agents from multiple sectors.

Our research team is the Canadian component of the international PPS Arctic IPY cluster, and comprises a major portion of the PPS Arctic team. Our objectives have been inspired by those of the international group and we will implement common protocols developed by PPS Arctic wherever possible. Research in this project will not only advance Canadian knowledge and expertise, but will also enable Canada to be a research leader in research on changes and their consequences in the circumpolar forest-tundra ecotone.

Project description and research workplan

<u>Introduction</u>

The magnitude of global warming is predicted to be greatest in the Arctic (ACIA 2004) and there is evidence that significant warming has already affected the region (Serreze et al. 2000). One of the most prominent biogeographical boundaries in the region is the arctic treeline and its altitudinal equivalent, the timberline. There is evidence that this boundary is shifting (Lloyd et al. 2003; Hinzman et al. 2005). Researchers have suggested a relationship between thermal regime and the position of treeline (Payette and Filion 1985; Hobbie and Chapin 1998; MacDonald et al. 2000; Ogurtsova et al. 2005) and timberline (Körner and Paulsen 2004). Thus, as temperature continues to warm, treeline is expected to shift, and there is abundant evidence of more advanced treelines during warmer periods of the mid-Holocene to support this (Payette and Morneau 1993; MacDonald et al. 2000). In addition to localized effects on land cover and habitat structure, widespread change could have important consequences for the earth's climate in terms of surface albedo and carbon cycling (Chapin et al. 2000).

The impacts of climate change on the Northern treeline ecotone will be complex and may vary among climatic regions due to interactions between numerous endogenous and exogenous factors that control temporal and spatial treeline distributions and function. In some cases treeline responses may be expressed by migration into or away from colder zones (i.e., higher latitudes and elevations). In other cases migratory responses may be small, and the capacity of extant populations to adapt to changing conditions will be more important. Despite a long history of research, the factors and mechanisms limiting the distribution of trees at high latitudes and altitudes are still not fully understood (Grace et al. 2002; Körner 1998; Sveinbjörnsson 2000). Several functional explanations have been offered, including growth-related factors such as limited seed development, germination, and recruitment; a negative balance between photosynthesis and respiration; and structure-related factors such as frost damage, winter desiccation, and mechanical damage by wind, snow, and ice during extended winters (Körner 1998; Sveinbjörnsson 2000; Tranquillini 1979). Some key general factors can be identified: 1) The ***autecology and adaptive strategies*** of treeline populations and species may express the unique conditions in which they occur. Treeline populations at Northern margins (particularly disjunct populations at the taiga-tundra ecotone) may be ecologically and genetically distinct compared to contiguous populations, due to severe selection pressures created by marginal climates and as a result of reduced gene flow in isolated treeline populations. These factors may alter the genetic variation and adaptability to climate change in treeline populations. 2) Numerous ***biological associations*** may play critical roles in treeline patterns and function. Cryptogamic assemblages, shrubby vegetation and mycorrhizal fungi may be vitally linked to the germination, establishment and growth of trees at the taiga-tundra ecotone. Current understanding of the importance of these biological associations remains weak. 3) ***Disturbance patterns*** within the taiga-tundra transition zone are diffuse and patchy, and their impact on tree stand dynamics is largely unknown. It is possible that disturbance can either accelerate or hinder treeline movement, depending upon regional conditions and disturbance type. Predicting responses of Northern treeline populations to climate change requires a much better understanding of these three general factors.

The magnitude of these changes in the environment of the Arctic and Sub-arctic regions will have enormous implications for northern peoples, for northern economies and for the ecosystems on which Aboriginal Peoples depend heavily for food, medicines and resources for cultural practices. Addressing and understanding climate change and human impacts requires both social science and natural science in order to understand not only what change is occurring and what the mechanisms and impacts are, but also to address the questions of causes and potential mitigatation and adaptation measures. In addition, climate induced stress can be expected to exacerbate impacts on species already affected by contaminants and other environment threats. Aboriginal Peoples have deep concern about the nature of these changes, about the implications of climate change for their way of life, and their health and well being. In addition to an awareness and concern about being immediately vulnerable to climate induced environmental changes, because of their direct dependency on that environment for survival, Aboriginal Peoples also have much to contribute to our understanding of the nature and meaning of the changes that are occurring and of the effects of these changes (Bielawski 1992). This knowledge is sometimes called "traditional ecological knowledge" (TEK), local knowledge or indigenous knowledge. Inuit refer to it as Inuit Qaujimajatuqangit or IQ. Research is increasingly interested in incorporating this knowledge, but the methods and processes by which this can be done successfully are still under development (Freeman and Carbyn 1988; Huntington 2000). Part of the challenge faced by researchers during IPY is to find new means to build mutual understanding through research that considers TEK and is able to communicate complex results to a wide audience.

<u>Research overview: long-term goals</u>

Our focus in PPS Arctic Canada is to examine and predict treeline responses to directional climate and environmental change and its effects on ecosystems and communities. Our research program aims to improve our understanding of the mechanisms driving ecosystem change within the forest-tundra zone and the implications for human communities and ecosystem processes. Within this program, we have identified four Long-term objectives that provide the conceptual foci for our research:

I. To model temporal and spatial treeline dynamics.
II. To assess the impacts of climate change on patterns and processes within the treeline ecotone.
III. To determine ecosystem services of the treeline ecotone and their vulnerability with climate change and land use impacts.
IV. To develop conceptual models of the long term relationship of environmental change and human health and well-being in the Arctic and Sub-Arctic.

Our goal for Objective I is to develop conceptual or synthesis models of treeline dynamics for the coming century, based on current biological understanding and data collected from our Short-term objectives. One of the unique contributions of PPS Arctic Canada (and the broader PPS international research team) will be a broad geographic focus and integrated assessment of different components of treeline ecosystems, and a synthesis of these results in a visual media that can be directly assimilated and used by northern communities. Objective II requires enhanced knowledge of ecosystem function and environmental controls on treeline populations including endogenous and exogenous driving factors. This objective also integrates the effects of climate change with other components of global change such as natural and anthropogenic disturbance. Objective III concerns the role of the arctic delimitation zone in providing ecosystem services to people in Canada's North, but also applies more globally. It will be accomplished in part through engagement of local participants. For Objective IV, patterns of treeline dynamics (Objective I) and processes (Objective II) will be situated within a comprehensive conceptual framework of environmental change that addresses ecological, social and cultural factors. This will result in the development of general ecological-social-cultural conceptual models of the long term relationship of environmental change and human health and well-being in the Arctic and Sub-Arctic. Progress towards these objectives will be advanced during IPY through our Short-term objectives (detailed below) which form the scientific underpinning and development of these Long-term objectives. This will be supplemented by additional research that will be conducted during and/or following IPY within our proposed long-term network on the forest-tundra ecotone (Section 16).

Our Long-term objectives are clearly related to four IPY themes, both Canada IPY research priorities and five areas of focus. All four objectives relate to the IPY themes 2) Change in the polar regions and 4) Exploring new frontiers. Objectives I and III specifically address the IPY themes 1) Current state of the environment and Objectives III and IV address the theme 6) The human dimension in polar regions. All of our objectives consider the Canada IPY priority Science for climate change impacts and adaptation and the sub-themes 1) Process studies and impact modeling related to climate, the physical environment and society and 4) Ecosystem and community vulnerability, resilience and adaptive capacities. The Canada IPY priority Health and well-being of northern communities is considered directly by Objectives III (through ecosystem services) and IV, and indirectly by Objective II since processes can affect the distribution of native species used by northern communities for food or medicine. The following sub-themes are considered: 5) Reducing health disparities, 6) Building and sustaining healthy resilient communities and 7) Links between climate change and well-being.

Our Long-term objectives integrate well into the international PPS Arctic project by relating to 3 of 4 scientific modules, all 3 main aims, 6 of 7 objectives and 9 of 10 tasks related to unifying themes (Hofgaard et al. 2005). PPS Arctic Canada fits into three of the four scientific modules of PPS Arctic: I) Global change effects on the arctic-boreal transition zone and modelling structural changes, II) Past history and broad scale temporal variations of the transition zone, IV) Land use and development of the Arctic-Boreal transition zone - local traditional and scientific knowledge in joint perspective. Our Objective I combines PPS Arctic objectives 1) To develop effective techniques and carry out quantitative spatial and temporal analysis of the location of transitional ecosystems within the circumpolar arctic-boreal transition zone and 3) To build realistic models of transition zone dynamics; and relates to PPS Arctic main aims i) The controls on the location and pattern of the zone and ii) The effect of global change on the location of the zone. Two PPS Arctic main aims are implicit in our Objective II: ii) The effect of global change on the location of the zone, iii) The feedback effect of the character and location of the zone on the global climate. Four PPS Arctic objectives are related to our Objective II: 2) To understand ecosystem and geosystem controls and responses in different compartments of the zone, both resilient and sensitive; 3) To build realistic models of transition zone dynamics; 4) To validate the models by ground level observations, dependent on scale and land use history; 5) To use them to implement a program of ecosystem, geosystem, and landscape analysis, examining the effects of global and local change on species, communities, and ecosystems. Our Objective III is similar to PPS Arctic objective 6) To assess the socio-economic impacts of potential future changes in the transitional zones. Our final Objective IV is closely related to PPS-Arctic module IV) Land use and development of the Arctic-Boreal transition zone - local traditional and scientific knowledge in joint perspective. Through our similar long-term objectives, PPS Arctic Canada can contribute to the objectives of the international PPS Arctic research program.

Study sites

We have study sites in treeline environments within the latitudinal taiga-tundra transition zone, in altitudinal treeline environments within the boreal forest zone and one low tundra site from South Baffin (for comparison with other sites) (Figure 1). Our sites are well distributed across Canada and representative of their respective regions. A unique aspect of this proposal is that we are establishing sites with common measurements and methodologies across regions that are likely to encounter very different climate change scenarios. A comparison of findings and interpretations of the implications for treeline response to climate change in these different areas will be a particularly important outcome.

Nearly all study sites have been used in the past, and research proposed at many of the sites builds on decades of past work. Some sites (A, L, N, S) are associated with permanent research stations and many others are associated with large seasonal camps with some limited permanent facilities or long-term research infrastructure. For example, a climatological network exists across many of the sites in Quebec and Labrador and several of the sites in the Yukon and Northwest Territories are associated with long-term vegetation plots.

Several of the sites are linked by way of researchers, objectives being addressed, or as part of projects with shared logistical efforts. Geographically, four clusters of sites are evident (Table 1). In addition to the methodological grouping of study sites, this spatial clustering will provide an informal means of organization among researchers. The human dimensions of environmental change and health and well being will be addressed by subsets of researchers at specific study sites, and will be related to but not defined by the geographic clusters. Environmental impact forms, including site descriptions, are attached for each site in Section 19, with the exception of site C (Whitehorse). No new field work is proposed at this site, though it is included here as data from this site will be incorporated into the project.

1. The subarctic-alpine cluster is comprised of sites A-E, located in southern Yukon and southwestern NWT. These sites are comprised of elevational treelines that form distinct landscape boundaries resulting from strong altitudinal gradients. *Picea glauca* is the dominant conifer at most sites with *Abies lasiocarpa* co-occurring at others. Most sites have a prominent tall shrub component consisting of *Salix* spp. and *Betula glandulosa*.

2. The central cluster is comprised of sites F-L and spans the forest-tundra ecotone west of Hudson Bay. *P. glauca* is the dominant conifer at these sites, though *P. mariana* also occurs. Deciduous shrubs are important components of the ecotone at each site. The transition from forest to tundra at these sites is gradual, typically extending over many kilometres. Some sites within this cluster are controlled by elevation at a local scale but all sites are located within the latitudinal taiga-tundra transition zone.

3. The Quebec cluster of sites is comprised of sites M-R and X, and spans the forest-tundra ecotone east of Hudson Bay. *P mariana* is the dominant conifer, though *P. glauca* does occur. The terrain is generally flat with rolling hills and the latitudinal transition can be characterized as hilltop tundra areas surrounded by forest that increase in size from south to north. Cape Dorset (X) provides an end point for cross-transition gradients and contrasts markedly with western sites at similar latitudes.

4. The Labrador cluster of sites is comprised of sites S-W. Treeline is controlled by altitude in the highland plateau of central Labrador, though these sites are still within the continental transition forest zone. The treeline here is comprised of several species intermixed in complex patterns controlled by abiotic and biotic factors. Thick *B. glandulosa* shrublands with some *Salix* are interspersed. Nain (V) is a low tundra site included for comparison with other eastern sites.

Figure 1. Proposed field study sites, and transects (Q & R) for PPS-Arctic Canada in relation to arctic treeline (heavy black line; as mapped by Timoney et al. 1992), the boreal-tundra transition forest (light gray), and subarctic alpine tundra (dark gray) (as mapped by Palko et al. 1996).

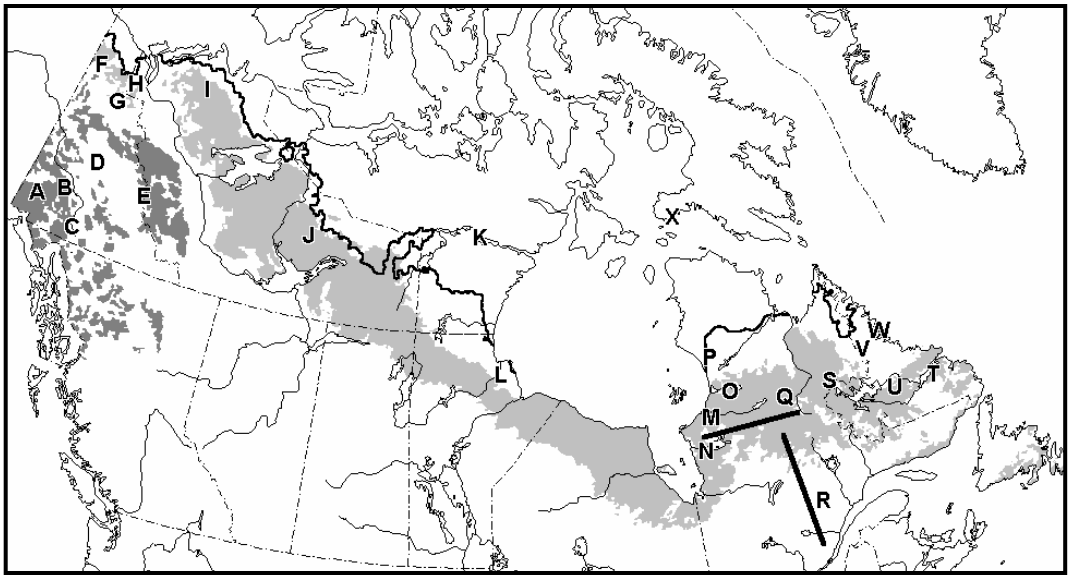

Table 1. Geographical clusters of study sites, including names of sites and researchers associated with each cluster. (Danby and Donaldson are post-doctoral fellows, Boudreau is a research associate).

Cluster	Sites (Figure 1 identifier and name)	Researchers
(1) Subarctic Alpine	A (Kluane), B (Carmacks), C (Whitehorse), D (Mayo-Keno), E (Macmillan Pass)	Hik & Danby, Savidge, Green, Kershaw
(2) Central	F (Old Crow), G (Dempster), H (Aklavik), I (Inuvik-Horton), J (Central NWT), K (Baker Lake), L (Churchill)	Johnstone, Green, Henry, Kershaw, Doubleday, Hik & Danby, Van Oostdam & Donaldson
(3) Quebec	M (Radisson), N (Whapmagoostui-Kuujuarapik), O (Lac à l'Eau Clair), P (Boniface River), Q (Reservoir Transect), R (Quebec Transect), X (Cape Dorset)	Harper, Berninger, Payette & Boudreau, Hik & Danby, Doubleday, Van Oostdam & Donaldson
(4) Labrador	S (Schefferville), T (Mealy Mountains), U (Red Wine Mountains), V (Mistastin Lake), W (Nain)	Hermanutz, Jacobs, Laroque, Simms, Marino, Bell, Hik & Danby, Berninger, Doubleday, Van Oostdam & Donaldson

Short-term objectives, methods and recent progress

Our primary question is: What are the causes and consequences of ecosystem change of the tundra-taiga ecotone? We have seven Short-term objectives for research during the IPY period. These objectives are complementary, with individual projects contributing to multiple objectives, and follow a common theme of spatial gradients and temporal trends. Wherever possible, we will strengthen linkages between project components by the use of existing common protocols (e.g. CANTTEX manual, see linkages below) or new protocols that we develop with our international cluster to achieve specific objectives (Section 17). Our general sampling design is based on two scales: broad scale sampling of sites located at different latitudes within the forest-tundra ecotone, and fine scale sampling focused on forest edges within the forest-tundra ecotone. Remote sensing and GIS analyses will be used to integrate these two scales (Short-term objective 4).

Short-term objective 1. *To analyze recent change in tree and shrub distributions within the forest-tundra ecotone.* (Group leader: **Kershaw**). Widespread, northward shifts in latitudinal treeline have been predicted in numerous biogeographic models linking vegetation zones to ongoing changes in climate (Kaplan et al. 2003). However, sparse empirical data on recent treeline dynamics has left considerable uncertainty as to the rate, magnitude and mechanisms of treeline responses to shifts in climate. Recent research on latitudinal and altitudinal treelines in Alaska and Yukon led by post-doctoral fellow **Danby** and collaborator **Lloyd** indicates that treeline advance is likely to occur in discrete pulses and often in association with disturbance (Lloyd 2005). In this objective, we will use detailed investigation of recent vegetation dynamics within the forest-tundra ecotone to evaluate patterns and processes of treeline change across a broad range of sites in Canada. Research will be conducted based on common scientific protocols developed by our group, including stand age reconstruction, traditional ecological knowledge and repeat photography. This objective addresses Long-term objective I and will link directly with research under the international PPS Arctic Task 3) Study the history of tree distribution patterns more comprehensively using multiple techniques.

Methods: We will perform detailed analysis of recent treeline changes using standard dendrochronology techniques (Lloyd et al. 2003) to develop stand age reconstructions for multi-site comparisons of past tree establishment and growth (**Bell, Danby, Green**, **Henry, Hermanutz Johnstone**, **Kershaw, Laroque**). Sites will be selected to capture a range of tree densities across the forest-tundra ecotone, from woodlands to isolated tree islands. Detailed studies at sites in Labrador will include developing an extensive series of long-term, high-resolution records of tree growth (**Laroque**) that will be used to reconstruct temperature or precipitation records (**Bell**). In the Labrador Highlands, tree-ring records will be extended further into the past by using submerged subfossil wood from ponds currently above treeline, which will be radiocarbon-dated and used to infer climate conditions when treeline was higher than at present. In addition to stand age reconstructions, permanent plots established at treeline sites will provide long-term information on current and historic vegetation change (**Danby, Harper, Henry**, **Hermanutz, Hik, Johnstone, Kershaw**). The establishment of permanent plots will follow protocols developed at the first PPS Arctic methods workshop (Section 17) and will include measures of species composition and abundance, plant biomass, and soil carbon and nutrient concentrations and dynamics. We will make use of permanent plots that have already been established at treeline sites (**Hermanutz, Hik, Johnstone, Kershaw, Savidge**), and will use repeat photography developed from historic photos to provide information on past spatial dynamics. Repeat photographs will provide visual documentation of change that can be used to link and share science observations of ecosystem change with the traditional knowledge systems more common in northern communities and will be coupled with participatory mapping of land use and landscape change (**Doubleday**). Repeat photograph series will be developed at sites where historic photos are available and their locations can be identified and re-photographed to provide a record of recent vegetation change (**Danby**, **Doubleday, Harper, Hermanutz, Hik, Kershaw, Marino**). At one site in Yukon, permanent plots established in 1947 will be used to assess recent changes in treeline dynamics from both ground-based vegetative measurements and repeat aerial photography (**Savidge**). Photographic techniques will also be applied to a sub-set of permanent plots in order to link ground-based measurements with aerial photos or remote sensing. Nested digital and Normalized Difference Vegetation Index images of permanent plots will be taken on the ground and with a balloon based camera system so that ground observations can be more clearly linked to air photos or satellite observations (**Henry**). The establishment of a series of permanent plots, linked to the past through repeat photography and to the future through long-term measurements with common protocols, will establish a legacy of information on ongoing environmental change that will provide a unique baseline for assessing change across the forest-tundra ecotone.

Short-term objective 2. *To collect environmental and microclimate data to correlate with treeline change.* (Group leader: **Jacobs**) Patterns of treeline shifts reconstructed for the Holocene vary considerably across different regions of the circumpolar North (for example, see summaries in ACIA 2004). Variations in local climate conditions and species-specific vegetation responses to climate have been suggested as a likely cause of this variation (ACIA 2004). Data on local environmental conditions and microclimate collected across multiple sites in PPS Arctic Canada will allow us to assess the role of local conditions in driving variations in recent treeline dynamics. Basic site-specific climate data will also be correlated with long-term regional climate and used to downscale scenarios of future climate to local sites. Collection of data on local environmental conditions is also the aim of the international PPS Arctic Task 4) Study environmental conditions across the forest-tundra zone, and these data are needed to feed the ecosystem level models outlined in our Long-term objectives.

Methods: In order to investigate and model relationships between climate and treeline ecosystems in the context of global and regional climate change scenarios, we require climate data at regional, local and micro-scales. A basic suite of environmental data will be collected at all sites with stand reconstruction data (**Harper, Hermanutz, Jacobs, Johnstone, Kershaw, Laroque, Savidge**). This will include data on soils and physiographic conditions, as well as short-term deployment of automatic climate stations to provide data representative of the study area as well as the basis for establishing statistical relationships with the long-term regional record. This project will make use of longer term records of microclimate available in northern Quebec and from ecological studies at Churchill, Kluane, Macmillan Pass, and Old Crow, as well as existing weather data available from Environment Canada to obtain detailed records of climate factors such as near-surface soil and air temperatures, wind, snowpack and precipitation. Detailed studies of microclimate variation in central and northern Labrador (**Jacobs**) will use data from a permanent meteorological station network that provides a database of regionally representative data of over 50 years length. Local spatial variability of air and soil temperatures, relative humidity and soil moisture is assessed using networks of inexpensive sensors, while snow cover is determined from satellite–derived snow cover maps and a spring snow survey. At the proposed new field site in north-central Labrador (Mistastin Lake), an additional automatic climate station will be installed and a network of snow-survey courses and soil temperature stations will be set up and operated for the duration of the project. Regional GCM scenarios will be adapted to landscape level using statistical downscaling methods. Tree ring chronologies, in conjunction with historical climate records, will allow for a suite of paleoclimatic reconstructions (temperature, precipitation, perhaps snowfall) which can then be mapped at a variety of spatial scales (**Bell, Laroque**, **Savidge**). Relationships developed will illuminate ecological relationships between tree growth and climate, and will allow future predictions of tree growth under future climate scenarios.

Short-term objective 3. *To investigate biotic influences on treeline dynamics as the mechanisms of vegetation change in the forest-tundra ecotone.* (Group leader: **Green**) We will relate treeline dynamics to causal mechanisms associated with early life history stages such as regeneration potential, genetic and substrate limitation and soil ecology in order to understand the physiological dynamics of later stages of key tree species and other vegetation within the transition zone and to determine triggers and consequences of treeline migration. Recently, **Green** has characterized ecological distinctiveness of populations of northern conifers genetically adapted to different climates (Green 2005, *in review*). The proposed IPY research builds on his research, as the treeline populations will provide a comparative baseline to examine the uniqueness of disjunct treeline populations across Canada including Yukon and Labrador. **Berninger** developed process based modelling approaches to analyse tree rings from subartic treelines in Finland. He found that there was a shift in limitations from resource to growth limitations (Berninger et al. 2004). Ongoing experimental research on Finnish treelines attempts to understand the relative importance of different limitations on tree growth using manipulation experiments (Susiluoto and Berninger *in review*). The results of this objective will contribute to Long-term objectives I and II and to PPS Arctic task 7) Build process based models and predictions for effects of environmental change, that have greater degree of realism than current models.

Methods: This objective relies on a combination of observational and experimental evidence to assess the current factors driving observed changes in species distributions across our study sites. Life cycle component analysis will determine the critical and limiting stage(s) in recruitment process of trees and key shrubs across the taiga-tundra zone for comparisons along both altitudinal and latitudinal gradients. The impact of pre- and post-dispersal seed predation on seed production, viability and resulting recruitment limitation will be assessed by tracking the level of invertebrate and vertebrate herbivory via seed collections, seed removal rates using exclosures and seed addition experiments (**Hermanutz, Savidge, Marino**). Seed productivity and recruitment of key conifer and shrub species across an altitudinal gradient will be determined by assessing seed viability and temperature dependent seed germination and by using seed addition experiments to determine seed availability and early survivorship, including under shrube canopies to determine if shrubs act as facilitators for treeline expansion. Pre- and post-seed predation will be quantified by harvesting and screening cones/seeds, and by seed removal experiments and exclosures. Conifer needle, bud and seed consumption by white-tailed ptarmigan (*Lagopus leucurus* Richardson) at three crown positions will be investigated at georeferenced fixed-area permanent sample plots. The extent of embryo consumption by seed-mining insects will be determined from collected seeds. The role of cryptogamic seed beds in directing successful tree and shrub recruitment along an altitudinal gradient will be examined using permanent plots to establish baseline database for future change. To assess the role of soil biota in tree establishment, the influence of the below ground microbial community on the establishment of tree seedlings will be assessed at different distances from forest edges using greenhouse bioassays (**Harper, Kernaghan**). **Green** will use latitudinal transects to examine ecological/genetic differences between contiguous and separated populations at the margins, including adaptive capacities of both mature extant treeline populations and juvenile populations. Disjunct treeline populations will be compared to populations moving progressively south from the treeline toward more moderate climates using dendroecological techniques and a common-garden study using collected seed to characterize quantitative differences in seedling traits thought to be important in climate responses. Experimental manipulative studies have been initiated at Churchill to assess the effects of temperature, wind and snowpack on recruitment (**Kershaw**). Seedlings have been planted and subjected to different environmental treatments to assess limiting factors on recruitment. Additional stands will be similarly assessed and similar studies are being formulated for Macmillan Pass (**Kershaw**). The reproductive potential of clonal spruce "tree islands" in the forest-tundra will be determined as potential nodes of treeline expansion (**Henry**, Tuktoyaktuk and Daring Lake). Tree islands used in a previous study in 1993-96 (MacLeod 2001) will be re-located for measurements and seed collection for seed viability and seedling survivorship experiments. Seed will be sown directly into common garden experimental plots at sites along latitudinal transects and followed for germination and survivorship; and seedlings grown from seed in greenhouses will be planted into experimental plots at the same sites. These studies will allow an assessment of the potential for the important conifer tree species to reproduce and survive in the forest-tundra and low arctic tundra, under experimental conditions that simulate predicted changes in temperature and snow conditions. **Berninger** will use manipulation experiments to discriminate and quantify the effects of different limitation processes at the treeline and then integrate the results into process based models that predict the growth and success of trees in the treeline determination zone. Treatments will include increasing nutrient availability through fertilisation, changing the carbon balance of trees through partial defoliation, increasing root zone winter stresses through manipulation of snow depths and changing the source sink balance of trees using debudding and girdling treatments. Tree growth and the physiological functioning of trees will be followed using campaign based photosynthesis, fluorescence and phonologic measurements, and functioning of trees will be monitored using sapflow sensors and dendrometers.

Short-term objective 4. *To determine the spatial structure of species' populations across the forest-tundra gradient and in tundra islands within the circumboreal forest zone, to predict movement of these populations and to develop scenarios for future environmental change across the gradient and possibly beyond.* (Group leader: **Harper**) Research under this objective will focus on the spatial structure of tree populations, as well as non-tree populations (shrubs, herbs, fungi, animals, etc.) within the forest-tundra transition zone. In Quebec, the treeline is a wide, fragmented region with a mosaic of natural forest edges, and has been described as a 'constellation of subarctic tree lines' (Payette et al. 2001). Data on the configuration of different species distributions will provide information on which factors investigated under Short-term objective 3 influence treeline position (e.g. covariation in distribution of mycorrhizal fungi and shrubs), as well as to assess the impact of treeline dynamics on other species including medicinal plants and isolated tree or tundra islands (Long-term Objectives II and III). Plants above the subarctic tree line across the circumboreal forest are potentially at risk because of the on-going major change in climatic conditions and human activity. If the warming scenario is realized within the next decades, there is a high probability that upland tundra islands will be transformed into new forest communities. This research links with PPS Arctic Tasks 2) Determine current location and characteristics of the forest-tundra zone and 5) Study population dynamics, population ecology, developmental phenology, and physiological ecology of present tundra taiga species.

Methods: Transects will be established perpendicular to forest edges within the treeline ecotone to sample above and below-ground vegetation structure and composition at different distances on either side of the edge in order to predict the effects of treeline movement on the spatial distribution of other species. Spatial surveys of vegetation change along the forest-tundra edge will be conducted at sites in western Nunavik, Labrador, central NWT, and in northern and central Yukon (**Harper, Henry, Hermanutz, Kernaghan, Johnstone, Savidge**). Spatial configuration of trees will be analyzed at a broader spatial scale among different treeline sites in western Nunavik and Labrador. Spatial configuration will be related to past, current and future treeline movement. An analogous study will be carried out across a range of sites using data from remote observation and mapping, and we will generate a national map of the treeline ecotone (**Danby, Hik**). The spatial pattern of the treeline ecotone will be characterized using landscape metrics and the interaction between pattern and process will be analyzed through the development of statistical models. The influence of physical environmental variables such as temperature and moisture availability (as derived from MSC and field climate station data in combination with digital terrain models) on the composition and structure of the ecotone will be determined from the influence of biological variables such as competition and reproduction. Changes in productivity (height, above ground biomass, seed output and viability) of key shrub species will be determined over the altitudinal gradient in Labrador (**Hermanutz, Marino**). Multi-disciplinary methods will be used to monitor the fate of the arctic-alpine flora of the tundra uplands within the circumboreal forest including dendroecological analysis to assess the rate at which tundra uplands are colonized by tree species, as well as vegetation, soil and geomorphological surveys and analysis of aerial and satellite photos (**Payette** and research associate **Boudreau**). Several tree islands will be intensively investigated to develop stem origin dates in both a temporal and spatial context (**Kershaw**). Local and indigenous knowledge will be integrated using three case studies of land use, landscape, and environmental and social change to investigate impacts of climate change on human well being (**Doubleday**).

Short-term objective 5. *To assess the role of disturbance in driving vegetation change within the forest-tundra zone* (Group leader: **Johnstone**). Recent research in northern ecosystems has demonstrated that many tundra and boreal communities show substantial resilience to climate change when they are undisturbed, but may rapidly shift to a new community state following disturbance (Chapin et al. 2004; Payette et al. 2001). PPS Arctic Canada will investigate the role of both natural (fire, insect outbreaks, or mammal herbivory) and human disturbance (oil exploration, mining, or hydroelectrical development) in driving shifts in species distributions and community structure in the forest-tundra zone. Research under this objective contributes to PPS Arctic Tasks 7) the nature and effects of disturbance on the forest-tundra zone, and 8) ecosystem management conditions and human impacts on treeline.

Methods: Research on the effects of disturbance will combine site-specific research on the effects of locally important disturbances with an integrative assessment of the role of disturbance in controlling treeline changes across the forest-tundra zone. Research on fire effects will be conducted in the north Yukon, where large wildfires constitute the dominant natural disturbance, and will use as a case study a 2005 burn in taiga woodland along the Dempster Highway (**Johnstone, Green**). Seedling trials with and without protective greenhouses will be combined with surveys of natural tree regeneration to evaluate the effects of substrate availability and climate on tree recruitment potential. In northern Quebec, new techniques for mapping and aging trampling scars developed in **Payette**'s lab (Morneau and Payette 1999) will be used to assess the impacts of hydro-electric reservoirs and climate change on caribou activity and subsequent vegetation change (**Boudreau**, **Payette**). Trampling scars, formed on surficial roots and low branches of woody shrubs, can be aged using dendroecological methods to provide an index of caribou activity over time in relation to climate variations and hydrological development. Vegetation surveys, reconstruction of past tree establishment, and seedling trials similar to those applied on the Dempster Highway will be used to link caribou activity to impacts on the cover of ground lichens, tree recruitment success, and potential changes in altitudinal treeline. In central Yukon, the impacts of direct human disturbance (bulldozer trenching) on permafrost thaw and subsequent tree growth will be assessed using stem analysis, dendrochronology, and active layer monitoring in disturbed trenches and undisturbed controls (**Savidge**). In Labrador, where little information exists on disturbance in the forest-tundra zone, detailed dendrochronology records collected across a range of sites will be used to estimate the frequency and intensity of various disturbance agents and their impacts on regeneration patterns across the altitudinal treeline (**Hermanutz, Laroque, Bell**). Across all sites, the role of disturbance agents in driving treeline dynamics will be assessed from dendrochronology records collected under Short-term objective 1. Data on stand age distribution and the timing of tree recruitment will be used to distinguish between past patterns of tree establishment that were episodic and most likely linked to local disturbance events, or gradual over time and more strongly related to climate or other slow changes (e.g., Lloyd and Fastie 2003). Additional information on disturbance events will be obtained from the analysis of charcoal and insect remains deposited within organic soil layers (e.g., Jasinski and Payette 2005). Comparisons of age structure and regeneration patterns across different tree species that coexist will provide information on how species with contrasting life history vary in their response to disturbance. Information on disturbance effects on treeline dynamics will be integrated in predictive models developed in other Short-term objectives.

Short-term objective 6. *To develop conceptual models for the assessment of environmental change on landscape ecosystems, processes and resource availability.* (Group leader: **Simms**) These models will also examine the linkages between changing environmental conditions, socio-economic factors, health and well being. This synthesizing objective will focus on developing a knowledge based GIS Expert System (**Simms**) such that data from other objectives will be integrated into an expert system. Scientific data and traditional knowledge in the form of past, present and predicted events can be used to assess, track and monitor environmental as well as social cultural changes. The expert system will also provide a method to standardize disparate data as well as provide a platform for non-experts to query and evaluate environmental change within the context of scientific and traditional knowledge. Within the context of the knowledge bases, this system provides a platform for developing "what-if' scenarios and comparing analysis of results from other studies. For this objective, we will use the results of Short-term objective 3 to predict the effects of vegetation change on biodiversity and the distribution and abundance of subsistence resources such as medicinal and food plants. We will also conduct additional studies to assess the impact of treeline change on permafrost dynamics, snow capture and energy exchange. This objective will contribute to all of our Long-term objectives and it is similar to PPS Arctic Tasks 6) the effect of tree cover on ecosystem ecology including greenhouse gas fluxes and energy balance across the boreal-arctic interface (feedback effects), 7) process based models and predictions for effects of environmental change, that have greater degree of realism than current models and 8) socio-economic and ecosystem management conditions across the zone.

Methods: The results from other short objectives will contribute to this objective by providing scientific and traditional data from studies on biodiversity, plants and animals that can be used for eating, medicine and as other resources. This will provide insight into ecosystem process (e.g. below-ground mycorrhizal colonization, snow accumulation, permafrost melt). Permanent plots established for short-term objective 1 will allow us to survey and monitor the long-term health of medicinal plants of interest to First Nations peoples. **Van Oostdam** will develop a framework for understanding the gender specific ways that the interactions between economic, social and environmental change (such as contaminants and climate) affect access to local food and store food in everyday life by comparing results from Inuit communities. Understanding food access requires not fixating on a particular unit of analysis (the individual, household, community), but an in-depth understanding of the dynamics among the units. It takes a multi-disciplinary approach by integrating in-depth, semi-structured interviews and a comprehensive literature review of published public health data. The results of this research are a necessary prerequisite on which to base culturally acceptable policy initiatives to improve access to and availability of culturally acceptable foods. Qualitative methods will be employed to collect and analyse the interview data according to a constant research process (Strauss and Corbin 1990). Other data in the knowledge base will include scientific data and traditional knowledge collected for the Mealy Mountain climate change study (**Simms**). Discussions will be held with northern people living at or near the Labrador study sites to explain what the research data are designed to show, with the aim of getting feedback on their values, traditions and customs in relation to land use and how the people would cope with change. The final modeling system will consist of an expert system, learning algorithms, ARCGIS and visual basic code. Visual basic provides the two-way linkage mechanism that integrates the information from the expert system with GIS or any external statistical or modelling tools.

<u>Project realization</u>

The timeframe for PPS Arctic Canada consists of two phases: 1) field data collection focused on our Short-term objectives during the International Polar Year (2007-2009), and 2) data synthesis and the continuation of a long-term network in conjunction with our international PPS Arctic cluster. The first phase will contribute towards the legacy of knowledge and expertise as part of the International Polar Year. We will use this opportunity of collaboration within the international PPS Arctic to develop an international long-term network of sites and monitoring within the forest-tundra ecotone for future research towards our Long-term objectives. In this current proposal, we ask for funding for the first phase during IPY during which we will pursue options for additional funding for the long-term research network. Our collective past research experience in the north provides us with knowledge of the logistics required for our proposed research (Section 14) and our budget justification (Section 6) shows how our objectives can be achieved given the resources requested.

Competence of investigators and collaborators

The research team for PPS Arctic Canada is composed of **Harper** as the leader, **Doubleday** as co-leader, 17 other co-applicants, 22 collaborators, 3 post-doctoral fellows or research associates who have helped prepare this proposal (**Danby, Boudreau, Donaldson**) and many supporting organizations. Our participants are from colleges or universities, government agencies, northern communities, institutions or agenices and from other countries. Our diverse research team embodies youth and experience, and includes members who are returning to the North by IPY as well as those with an ongoing involvement in northern research. Sites across Canada are represented with links to the circumpolar region. Our team provides not only complementary but also integrative expertise in social and natural science and provides both depth and breadth of research expertise.

PPS Arctic Canada research team: applicant and co-applicants

The PPS Arctic Canada team is a group of motivated, enthusiastic researchers who are poised to take advantage of the opportunity of new research and collaboration that IPY has to offer. Several co-applicants are recent tenure-track or adjunct faculty members (**Harper, Berninger, Green, Johnstone, Kernaghan, Laroque**), and our team also includes post-doctoral fellows or research associates who have been very active in developing our proposed research (**Boudreau, Danby, Donaldson**). Our youth and enthusiasm is matched and supported by other co-applicants who have extensive expertise and research experience (**Doubleday, Bell, Henry, Hermanutz, Hik, Jacobs, Kershaw, Marino, Payette, Savidge, Simms, Van Oostdam**). All team members have proven track records with numerous publications appropriate for their level in prestigious journals (Section 21). Overall, our combined expertise should inspire confidence that our research will be a success.

Our team includes members who have been lured back to the North by the opportunity provided by IPY. As primary applicant, I (**Harper**) have been especially encouraged by the research opportunities for IPY. Indeed, IPY has already been successful in encouraging my return to the North after conducting research in the boreal forest. I have previous research experience in revegetation following disturbance in shrub tundra. My most recent experience in the North includes both research experience and interaction with a northern community in a project on restoration in the Cree community of Whapmagoostui. **Kernaghan** has conducted soil microbial research on the alpine treeline and joins us for research on the arctic treeline. **Savidge** is taking advantage of the IPY opportunity to rekindle research on tree regeneration at one of his northern research sites. **Boudreau** will resume his research activities on northern ecosystems on tree line movement and caribou activity after a 2-year post-doctoral fellowship in forest ecology in South Africa.

Several of the other co-applicants have continuous histories of research experience in the North: **Doubleday** (northern communities), **Henry** (Northwest Territories), **Hik** (Yukon), **Johnstone** (Yukon and Alaska), **Kershaw** (Northwest Territories, Churchill), **Payette** (northern Quebec), **Van Oostdam** (Northern Contaminants Program, Arctic Monitoring and Assessment Program). Some co-applicants hold important positions in northern research: **Harper** is a member of the PPS Arctic steering committee, **Payette** is the director of the NSERC Northern Research Chair which also includes **Harper** and **Boudreau**, **Hik** is the Canadian IPY Secretariat and **Henry** is the leader of CANTEX (Canadian Tundra Experiment). In addition, **Harper, Doubleday, Bell, Hermanutz, Jacobs, Johnstone** and **Van Oostdam** have extensive experience interacting with northern communities. Our team currently represents all major regions within the Canadian circumpolar forest-tundra ecotone including Labrador (**Bell, Hermanutz, Jacobs, Laroque, Marino, Simms**), Quebec (**Harper, Berninger, Boudreau, Kernaghan, Payette**), Churchill in central Canada (**Kershaw**), Northwest Territories (**Henry**) and Yukon (**Danby**, **Green, Hik**, **Johnstone, Savidge**); **Doubleday, Van Oostdam** and **Donaldson** are working in several communities.

Research expertise provided by the PPS Arctic Canada team covers many disciplines resulting in complementary knowledge and experience that is required for our interdisciplinary research program. In each case, members of the team bring the depth of knowledge and experience necessary to accomplish our proposed research objectives. **Harper** will apply her research experience in forest structure and composition at boreal forest edges, edge theory and spatial pattern analysis to investigate the spatial pattern of the forest-tundra ecotone. **Bell, Green, Payette, Laroque** and **Savidge** have the expertise and equipment to conduct dendrochonological analyses. **Laroque** has established a dendrochronology research centre at Mt. Allison (Director, Mount Allison Dendrochronology Laboratory). **Kershaw** has conducted research on treeline and timberline including disturbance ecology and recently dendroclimatic studies. He also conducts long-term environmental monitoring including winter snowpack measurements. **Hik** has conducted ecological research in Arctic and alpine environments including long-term studies in the Kluane area of Yukon. Impacts of climate change on alpine and arctic tundra ecosystem processes and function continues to be a major theme of his research. **Johnstone** has ongoing interest and experience in disturbance effects on tundra and boreal ecosystems. **Hermanutz** has research experience in plant-animal interactions, disturbance, community and population ecology of arctic and boreal systems and processes that mediate change in those systems. **Marino** has been working on cryptogam ecology for over 15 years and his expertise is in community ecology of boreal and subarctic systems. **Savidge** will apply his 30 years of physiology expertise into conifer growth and development and, in collaboration with the National Tree Seed Centre and others team members, will focus on aspects of conifer seed ecophysiology in relation to treeline dynamics. **Berninger** has been using ecophysiological research to understand and model the growth of boreal and subarctic forests. He has been applying these approaches to dendroecological data and is co-author of a recent review of climate change effects on treelines. **Danby** has expertise in GIS and remote sensing. **Simms** has extensive experience as a GIS specialist applying spatial theory to ecological problems with specific interests in climate change impacts on human health and well being. **Payette** and **Boudreau** will apply their knowledge of ecological processes driving northern ecosystems to investigate altitudinal tree line movement and its potential impact on regional biodiversity. They will also use their dendro-ecological expertise to evaluate interactions between anthropogenic activity, caribou, and treeline dynamics. **Jacobs**, the project manager of the Labrador Highlands Research Group, has been working in the arctic for over 30 years with extensive expertise in climatology, climate modelling and investigations into the impact of climate change on aboriginal country foods. **Doubleday** has experience in paleoclimatological reconstruction using vegetation and fire, as well as in recent paleolimnological work on anthropogenic combustion records in the Arctic. In addition, she has extensive northern community experience, including development of legal regimes related to resources and environment. **Donaldson** has a research background in a range of public health topics, including environmental contaminants, environmental change and food choice research. **Van Oostdam** has extensive experience in human health effects, environmental contaminants and risk management discussions of traditional foods in the Arctic.

Co-supervision of graduate student projects among the co-applicants illustrates the complementary nature of our expertise. We will also promote further interaction among the co-applicants by encouraging other team participants to become committee members of our graduate students. In addition to our complementary individual research expertise, several of us have interdisciplinary expertise involving both the natural and social science. For example, **Harper** is currently supervising a graduate student who will involve the Cree high school into his research on restoration in their community. **Johnstone** has been extensively involved in developing community-based monitoring programs in northern communities. **Jacobs** and others (including **Hermanutz, Bell, Simms**) are actively involved in working with Innu Nation of Labrador to integrate traditional knowledge of climate change into their ongoing research and to ensure the group's research outcomes are communicated to the Innu.

<u>Collaborators and linkages</u>

Our collaborators include international researchers with the international PPS Arctic cluster, national collaborators whose independent research contributes to our Long-term objectives and who are part of the international PPS Arctic cluster, and national collaborators who are linked to individual co-applicants in PPS Arctic Canada. We also acknowledge the support and encouragement from our supporting organizations including First Nations, government organizations and academic institutions (Section 8, letters of support).

We have several representatives of international PPS Arctic listed as collaborators on our proposal (**Hofgaard, Cairns, Lloyd, Rees, Skre, Sveinbjörnsson, Trombotto, Vlassova**), but we expect to collaborate with all members of our international cluster. In particular, **Hofgaard** is the leader of the international PPS Arctic cluster. She has also included a few of our Canadian team members (**Harper, Berninger, Danby, Henry**) and our collaborators (**Cairns, Rees, Sveinbjörnsson**) as collaborators on her PPS Arctic Norway grant proposal which has similar objectives to our proposal, notably to characterise the roles of environmental conditions and disturbances in shaping the structure and position of the arctic-boreal transition (similar to our Long-term objective I) and to assess the climate impact of changes in forest area from 2000 to 2100, taking into account the changes in both surface albedo and fluxes of CO_2 and other greenhouse gases (which will contribute to our Long-term objective II). **Cairns** studies the effects of plant-animal interactions on treeline dynamics in Sweden (contribution to Long-term objective I). **Lloyd** is documenting patterns of treeline advance in Alaska and the interaction of climate warming with fire disturbance on treeline and has proposed research on climate sensitivity and tree growth in boreal forest trees near treeline (similar to Long-term objectives I and II). **Rees** will provide additional expertise in remote sensing and will work closely with **Harper, Danby** and **Hik** on our Short-term objective 4. **Skre** is participating in a research project proposal on transitional ecosystems as indicators of climate change including topics such as socio-economic impacts and spatial and temporal analysis, similar to the PPS Arctic but on a European scale. **Sveinbjörnsson**'s research on the performance of white spruce at treeline in Alaska matches our Long-term objectives I and II. **Trombotto** is an expert in landscape change, and will work with **Doubleday, Harper, Berninger** and others interested in the re-photography of sites and the development of visual assessment tools for documenting change. **Vlassova** is an expert on issues of northern land use, environmental impact assessment and sustainable development, and conducts research on climate change, land-use planning and regulation, public participation and partnership, social sustainability, and uses methods of social inquiry in indigenous communities. Collaborations with these international researchers allows us to extend our Long-term objectives to the circumpolar forest-tundra ecotone within the framework of PPS Arctic. We will integrate closely with our international collaborators during the PPS Arctic annual meetings during which time we will work together towards the objectives of the international cluster and the development of a long-term forest-tundra ecotone network (Sections 16, 17).

Within Canada, **Alstrom-Rappaport, Egger, Levesque** and **Sirois** are collaborators for our general project because they have individual projects with their own funding that contribute to our Long-term objectives. They are or will be invited to be part of the international PPS Arctic and therefore we will collaborate with them in a similar way as our international collaborators. **Levesque**, who is part of the CiCAT project with which we have close linkages (see below), studies processes at shrubline which could provide insight into the dominant factors controlling change in vegetation structure (Long-term objectives I and II) and changes in berry abundance (Long-term objective III). **Sirois** has proposed research to anticipate the responses of Canadian tree species and forested ecosystems to the projected global climate change (contribution to Long-term objectives I and II). **Alstrom-Rappaport** will use molecular techniques to characterize genetic differences among study tree populations (Long-term objective II). **Egger** (co-applicant on separate IPY proposal) will utilize some of the same research sites as **Green** for collaborative examinations of links between above-ground and below-ground responses to climate change (Long-term objective II).

Simpson will collaborate most with **Savidge** and **Hermanutz** in the capacity of co-supervisor of their graduate student. As manager of the National Tree Seed Centre of Canada (Canadian Forestry Service, Fredericton, New Brunswick), he will also be a collaborator for the general project to establish a northern trans-Canada tree seed legacy with our assistance. In Labrador, collaborator **Jeffery** (and colleagues at the Wildlife Division) will assist in site selection and research inputs for the use by key wildlife species of vegetation, such as the endangered Mealy Mt. and Red Wine caribou herds. Travel support by our collaborator is a key input to our travel budget. In northern Quebec, **Barrett** and **Larrivée** will assist with community participation in our research, particularly with the photography project and projects concerning the health and well-being of northern residents. **O'Donohue** and **Janowicz** will assist with site selection in the Yukon since both have extensive knowledge of the ecology and climates at the locations where research activities will take place. **Alstrom-Rappaport, Egger** and **Marion** will conduct research activities at sites identified by **Green**, and the research teams will share resources for travel, accommodation and sampling activities for leveraging of research resources. **Marion** has expertise in dendroecological studies in Yukon, and will provide direct support for project activities including procurement and processing of increment samples. **Peter, Ogden** and **Gilbert** have unique connections with communities in the Yukon where project activities will occur. **Peter's** role will be to guide the proposal through the First Nations review process, to assist in making outreach links to the First Nations communities and to recruit Northern students. Additionally, he has indicated that they may be able to provide resources for study activities (e.g, use of vehicle for field sampling, GIS support). **Ogden** and **Gilbert** will be key contacts for the recruitment of Northern students/participants and facilitation of education and outreach activities to local communities, land managers and students at Yukon College in Whitehorse.

Our list of collaborators is not exhaustive. Once our project is underway, we will pursue additional collaborations, for example **Savidge** with the Yukon Forest Management Branch, Environment and Natural Resources NWT, Nunavut Department of Environment, and **Haper** and **Berninger** with Ressources naturelles et Faune Québec.

PPS Arctic Canada is well situated, both geographically and thematically, to complement and link with other IPY research projects. We are closely related to CANTTEX (part of ITEX). **Henry** is the leader of ITEX and CANTTEX, and is leading CiCAT, a separate IPY application linked to the ITEX IPY core project. **Hermanutz, Jacobs, Bell, Marino, Simms** and **Laroque** are part of a CANTTEX project in Labrador, and **Harper, Hermanutz, Jacobs, Laroque, Marino, Payette, Simms** and **Levesque** are co-applicants for CiCAT. Geographically, CANTTEX covers the high and low arctic, and overlaps with PPS Arctic Canada at treeline. We consider this overlap beneficial and it will allow considerable synergies between the projects. Results from CANTTEX studies conducted in the forest-tundra ecotone can contribute to our Long-term objectives; however, CANTTEX has its own objectives and by itself address very few of our objectives. We will also benefit from the common protocols developed for ITEX and CANTTEX. We will use these wherever possible and they will form the basis for developing our own protocols for the international PPS Arctic. We will strengthen our linkage with CANTTEX by inviting them to join our community workshops and our co-applicants that are involved in both projects can present results from CiCAT at our annual PPS Arctic meetings.

We have also developed close relationships with the two other projects that are also endorsed by PPS Arctic: Yeendoo Nanh Nakhweenjit K'atr'ahanahtyaa - Environmental Change and Traditional Use of the Old Crow Flats in Northern Canada (YNNK) and The Impacts of Climate Change on the Well-being of Communities in Northern Ontario's Hudson Bay Lowlands. Under the endorsed international IPY project PPS Arctic, we are the representative Canadian component with a broad geographical focus. The YNNK project is a community-initiated case study that overlaps with one of our study areas (Old Crow). We will take advantage of this overlap by organizing a regional community workshop at Old Crow on native plants. We believe that both projects will benefit from the connection between a focused, detailed local investigation into environmental change and consequences for human subsistence within the treeline ecotone as a case study to our more extensive treeline network. The Hudson Bay Lowlands study will focus on a different region than our proposed research which focuses on climate change and its effects on communities. Results from both projects will be relevant to our Long-term objectives. In addition, we are developing linkages with Fraser Taylor and Peter Pulsifer at Carleton University who are proposing a Polar Atlas for out reach, long-term education and communication.

We have begun to pursue linkages with other IPY projects including: CALM, SEARCH, Greening of the Arctic, Back to the Future, CLIC, Arctic Wolves and CARMA. In particular, SEARCH involved remote sensing of the circumpolar region which would link very well with our Short-term objectives 1 and 4.

Collaboration in PPS Arctic Canada

The PPS Arctic Canada research team represents sites that cover the broad geographical region of the forest-tundra ecotone across Canada. The participation of our collaborators extends this coverage to the circumpolar forest-tundra ecotone and into the shrub tundra. Our team of co-applicants and collaborators provides both a depth and breadth of research experience that integrates social and natural science through our complementary expertise. The collaboration within our team leads to synergy as we take an interdisciplinary approach to integrate community participation into scientific research and then bring the results back to the community. Almost all members of our research team have both the knowledge and expertise in northern research, and have demonstrated their ability to interact with both other researchers and especially with Northerners in past research projects in the North.

Our collaboration within our team and with northern communities has begun in the writing of this proposal. At the introductory PPS Arctic meeting, which we exchanged ideas about common protocols and made suggestions for expanding individual research projects among multiple sites including co-supervision of students among researchers with complementary expertise at different institutions. We will continue to seek out new opportunities for collaboration as we invite other co-applicants and collaborators to act as committee members for student projects. Co-applicants, collaborators and their students are expected to contribute to our common objectives through participation at our annual PPS Arctic meetings, community workshops and international scientific conferences, as well as through dissemination of their research results through scientific publications, nontechnical reports, data management and other legacy items (Section 16). The annual PPS Arctic meetings and community workshops will encourage further integration of different research projects towards our common objectives as we plan a long-term network of forest-tundra ecotone sites.

References:

ACIA 2004. Impacts of a Warming Arctic: Arctic Climate Impact Assessment. Cambridge University Press, Cambridge. **Berninger F. et al. 2004.** Tree Physiology 24:193-204. **Bielawski E. 1992.** North Perspectives 20:5–8. **Chapin III, F.S. et al. 2000.** Global Change Biology 6:211-223. **Chapin III, F.S. et al. 2004.** Ambio 33:361-365. **Freeman M. and Carbyn, L. (eds). 1988.** Traditional knowledge and renewable resource management in northern regions. ACUNS. Occasional Publication No. 23. **Grace, J. et al. 2002.** Annals of Botany 90:537-544. **Green, D.S. 2005.** Canandian Journal of Forest Research 35:910-917. **Green, D.S. In Review.** Tree Physiology. **Hinzman, L.D. et al. 2005.** Climate Change 72:251-298. **Hobbie, S.E. and Chapin III, F.S. 1998.** Journal of Ecology 86: 49-461. **Hofgaard, A. et al. 2005.** PPS Arctic. Proposal for IPY. **Huntington, H. P. 2000.** Ecological Applications 10:1270-1274. **Kaplan, J.O. et al. 2003.** Journal of Geophysical Research 108:1-17. **Körner, C. 1998.** Oecologia 115:445-459. **Körner, C. and Paulsen, J. 2004.** Journal of Biogeography 31:713-732. **Lloyd, A.H. 2005.** Ecology 86:1687-1695. **Lloyd, A.H. and C.L. Fastie. 2003.** Écoscience 10:176-185. **Lloyd, A.H. et al. 2003.** Journal of Geophysical Research - Atmospheres 108: 2-1-2-15. **MacDonald, G.M. et al. 2000.** Quaternary Research 53:302-311. **McLeod, K. 2001.** PhD dissertation, University of British Columbia, Vancouver. **Morneau, C and Payette, S. 1999.** Canadian Journal of Zoology 78:1784-1790. **Ogurtsova, M. et al. 2005.** Quaternary Research 63: 182-188. **Palko, S. et al. 1996.** The Canada Vegetation and Land Cover. Natural Resources Canada, Ottawa, ON. **Payette, S. and Filion, L. 1985.** Canadian Journal of Forest Research 15:241-251. **Payette, S. and Morneau, C. 1993.** Quaternary Science 39:84-89. **Payette, S. et al. 2001.** BioScience 51:709-718. **Serreze, M.C. et al. 2000.** Climate Change 46:159-207. **Strauss, A.L. and J. Corbin 1990.** Basics of qualitative research: Grounded theory procedures and research. Newbury Park: Sage Publications. **Susiluoto S. and Berninger, F. In Review.** Environmental and Experimental Botany. **Sveinbjörnsson, B. 2000.** Ambio 29:388-395. **Timoney, K.et al. 1992.** Arctic 45:1-9. **Tranquillini, W. 1979.** Physiological ecology of the alpine timberline. Springer-Verlag, New York.