Introduction to a special section: winter terrestrial ecology in Arctic and alpine tundra

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I am very pleased to present this special section of articles on winter terrestrial ecology in Arctic and alpine tundra. This is a new and developing field of research, and has been hitherto little studied. Much is unknown about the ecology of the dark, cold period of the year, as traditionally ecologists have travelled to their field sites in summer, when the snow has melted and the plants, soils and invertebrates are more readily available to be studied. Arctic research in the summer is often challenging; Arctic research in the *wintertime* presents even greater obstacles. However, in tundra areas the long winter is an important determinant of the physical framework for living organisms, both during the winter itself and during the short growing season. Winter ecosystem respiration is an important contributor to the annual CO_2 flux in the High Arctic, as shown in this issue in papers by Strebel et al. and Morgner et al., and values vary greatly between vegetation types. Carbon sink strength in the tundra is therefore overestimated if cold-season dynamics are not included, and estimates will be less biased at drier sites with little snow accumulation.

The global climate is warming, and it is warming faster at the polar areas, where the impact is also greatest. Many ecological-effect studies have been carried out in the tundra, but mostly during summertime. However, increases in winter temperatures and precipitation, predicted to have greater magnitude than those during summer, may have much stronger impacts than changes during summertime. To investigate this, the impacts of changes in snow depth and duration on plant physiological traits (electrolyte leakage, photosynthetic capacity and

Snow fence deployed to experimentally increase snow depth in Adventdalen, Svalbard. (Photo by E.J. Cooper.)

The windscoop beneath the kittiwake cliffs, Kongsfjorden, Svalbard, April 2009, illustrating the lack of snow cover on the ornithogenic soils where the dipteran *Heleomyza borealis* overwinters. With so little snow cover, soil temperatures track air temperatures closely. (Photo by S.J. Coulson.)

The aphid *Acyrthosiphon svalbardicum* is found feeding on *Dryas octopetala*, but has a more restricted local distribution than that of the food plant. Here snow depths are recorded close to Gåsebu cabin, Kongsfjorden, Svalbard, April 2009 using an avalanche probe and a differential global positioning system (DGPS). On top of the ridges the snow cover can be very thin. Close to the base of the DGPS pole a leaf of *D. octopetala* can be seen emerging from the snow. (Photo by S.J. Coulson.)

Labour-intensive snow removal experiment in alpine vegetation at Stillberg station, Davos, Switzerland. (Photo by S. Wipf.)

Investigations of winter ecology can involve snow pits, such as this one at Latnjajaure, 15 km from Abisko, Sweden. Shown here, an infrared gas analyser for carbon dioxide measurements is being lowered into the pit. The instruments are equipped to withstand low temperatures and harsh weather, and the gear is mounted on a backpack frame to facilitate hiking and skiing with it. (Photo by M. Björkman.)

Headspace bottles used for collecting air samples within the snow. The probe (at the back) is inserted into the snow and air is drawn into a gas-proof syringe. Air samples are then transferred into the bottles using needles.Air samples can be analysed for gases such as CO_2, CH_4, N_2O and SF_6. (Photo by M. Björkman.)

CO_2 flux is measured at the bottom of a snow pit in Svalbard using an infrared gas analyser. The case is insulated and heated so that measurements can be carried out at subzero temperatures. (Photo by A. Bailey.)

decrease of carbohydrate reserves) were studied using transplant experiments, as reported in this issue by Saarinen & Lundell. The effects of snow-depth manipulation using snow fences on CO_2 flux in the High Arctic are presented here by Morgner et al., and comparisons are made by Björkman et al. to the responses in the sub-Arctic. The effects of snow removal and natural snow gradients on plant growth are reported by Rixen et al.

Wipf & Rixen provide a comprehensive overview of snow manipulation experiments in Arctic and alpine tundra ecosystems, and describe the generalized plant phenology, productivity and community composition responses to changes in snow cover. In addition to experiments, plant survival though the winter can be modelled under changing climatic conditions. In order to do this, Thorsen et al. produced a model to simulate the dynamics of soil conditions at low temperatures, specifically the effect of snow cover, soil frost and surface ice in Norwegian grasslands. The model was calibrated against data from four locations in Norway, including two in the Arctic.

Animals, especially herbivores, are important components of the ecological system, and in this issue Strebel et al. report on the influence of goose grazing on soil organic carbon. Avila-Jiménez et al. examine the strategies that Arctic terrestrial arthropods have developed for overwintering in the soil. The distribution of these arthropods is partly dependent on snow depth, which regulates winter temperature. Their susceptibility to changes in winter climate is discussed: specifically, the effects of milder winters with an increased frequency of freeze–thaw cycles and surface icing, and changes in snow depth and duration.

The papers published in this special section of *Polar Research* were presented at the meeting Winter Processes in Arctic Tundra Ecosystems that was held in Longyearbyen, Svalbard, 9–11 June 2008, funded by NordForsk (grant number 080054). They enhance our understanding of the importance of winter in tundra ecosystems, and the ongoing physiological and biogeochemical processes. They indicate that changes in the winter climate in Arctic areas can have dramatic impacts for plants, microbes and soil invertebrates, as well as feedbacks to global carbon cycling. They also underline the need for further ecological and biogeochemical research to be carried out during winter in the Arctic, despite the physical and logistical challenges such work can pose.

Elisabeth J. Cooper
Department of Arctic and Marine Biology, University of Tromsø, NO-9037 Tromsø, Norway. E-mail: elisabeth.cooper@uit.no