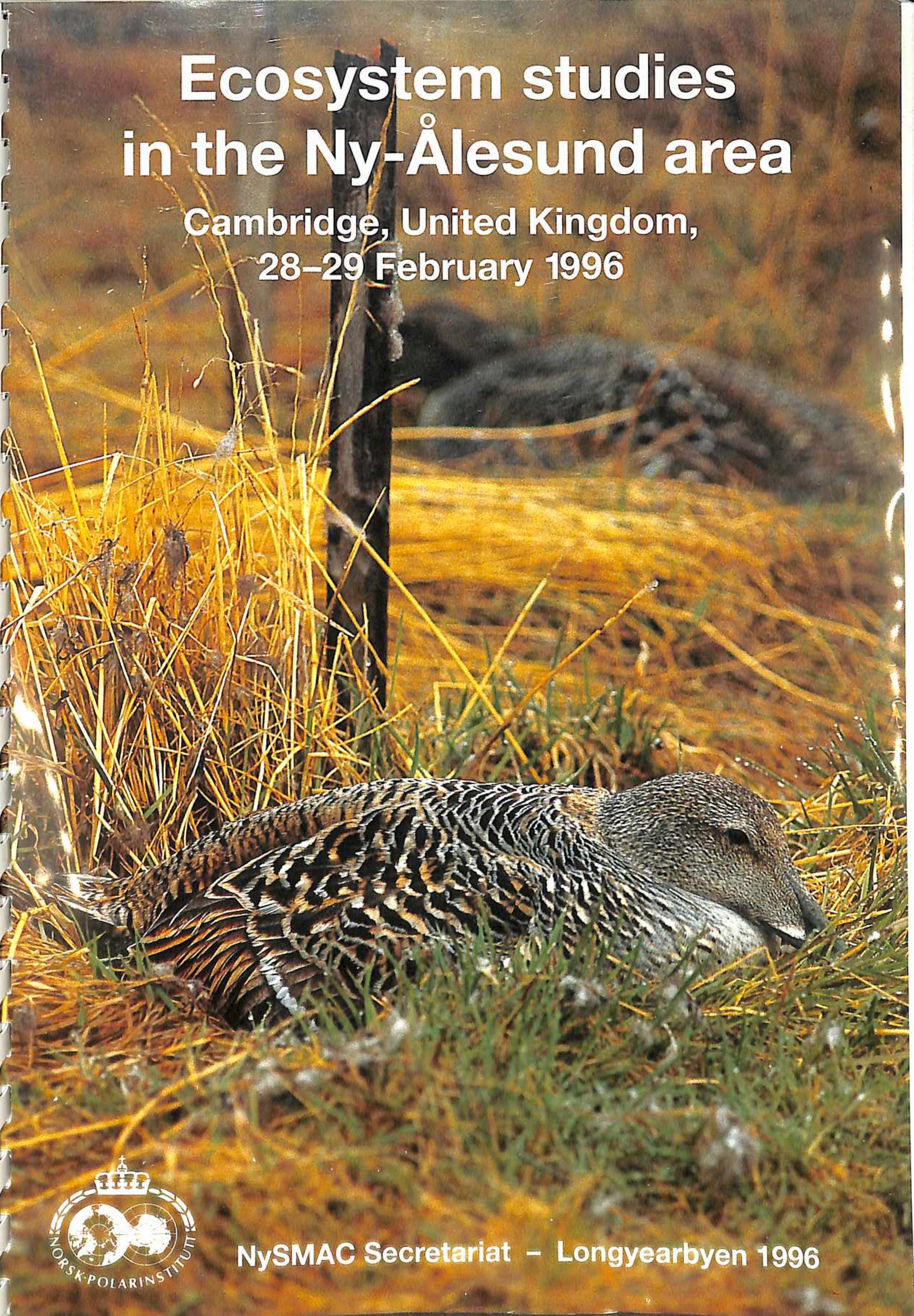
# Ecosystem studies in the Ny-Ålesund area

## Cambridge, United Kingdom, 28–29 February 1996



NySMAC Secretariat - Longyearbyen 1996

# EOSYSTEM STUDIES IN THE NY-ÅLESUND AREA

**Scientific Seminar**
**Cambridge, UK, 28 - 29 February 1996**

Agenda and abstracts

Norwegian Polar Institute
1996

# ECOSYSTEM STUDIES IN THE NY-ÅLESUND AREA

**Scientific Seminar**
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## Introduction

*by Dr. Nils Are Øritsland, Norwegian Polar Institute*

Besides the obviously sensible objective of bringing together the ecologists that are working at Ny-Ålesund, the seminar *Ecosystem Studies in the Ny-Ålesund Area* had a further object. We envisaged that these same ecologists could be motivated to take part in a process which would address, through a truly joint international effort, central problems in modern ecology. Although this vision was reflected in the agenda for the meeting, much remains to be done before we can see the outlines of a joint programme that will draw enthusiastic support by the nations involved. We are still in a situation where a number of ecologists have separate projects located at Ny-Ålesund, but there is little interaction between the scientists and actual co-operation is rare.

There are two paths that, perhaps, could improve the situation. One is to arrange regular international meetings for ecologists who work at Ny-Ålesund, and hope that spontaneously they will generate new ideas for co-operative research. Scientists may start co-operative work when they see each other working on closely related scientific problems. If, in addition, home institutions also encourage their scientists to work with colleagues from other nations, and even have money earmarked for that purpose, some truly original and good basic research projects might emerge from a system of regular meetings. The second way would be to start at the institutional management level. Using this approach, science directors would have to set up well-specified frameworks for international collaborative projects within themes which are politically attractive, and then go out on the market for scientific personal, quite possibly outside the polar circles. Experience has shown that a middle road may well be best. Experienced polar biologists are asked to formulate new projects under general and politically accepted themes, such as "climate change" or "pollution". This approach works well in terms of creating proposals, but the resulting programmes tend to become mixtures of research which extends that on which the scientist is already working, and may often not be easy to justify as relevant to national and political problems. Therefore, it is essential that the problems are specified in detail before research proposals are solicited.

So what kind of ecological research should be pursued at Ny-Ålesund? We have attempted to find an answer to this question by asking two further questions: "What are the most central problems in ecology today?", and "What kind of work at Ny-Ålesund would contribute significantly to solving these problems?". During the Seminar it became evident that there was no agreement between ecologists as to the most central problems in their own general field of research. The science of ecology remains still a collection of separate empirical rules and pieces of theory. It is not like in physics, where the general foundation of knowledge has been developed sufficiently to induce general agreement that, for example, the contradiction between quantum mechanics and general relativity is a central challenge.

At Ny-Ålesund we have an array of interesting ecological projects, including both basic research projects and politically endorsed work concerning pollution and climate. We hope the present collection of project presentations will be useful both for specialists interested in establishing new co-operative projects and as a general source of information about the activities at Ny-Ålesund. We suggest that the five nations already involved in ecological research at this site join forces and contribute both personal and funds toward the establishment of a Scientific Integration and Analysis Group. The mandate of this group would be the synthesis of knowledge gained through specialised field work into more comprehensive ecological theory. Such a group would be required to work with the project specialists and could be a catalyst for the establishment of new international research projects.

Attempting to look into the future it seems possible that the ecological work at Ny-Ålesund should focus mainly on population, community and systems studies and backed by ecophysiological examinations of adaptations of the organisms to the environment. Studies that require the maintenance of elaborate equipment may, perhaps, not be suitable at this location because of the costs for transport and accommodation. Nevertheless, the arctic organisms are very interesting with respect to their biochemical and metabolic adaptations to the seasonal variations in temperature and solar radiation. One could, for example, envisage that enzyme properties from arctic organisms could be utilised in production of single cell protein. This type of advanced studies require specialised laboratory facilities and should possibly be located at Longyearbyen.

We suggest that another ecologist's meeting should be arranged next year, this time focusing on the significance of the results from recent and current projects and their contribution to theoretical ecology.

The project presentations in the present report are provided as an information service and may not be used without the consent of the authors.





# ECOSYSTEM STUDIES IN THE NY-ÅLESUND AREA

## Scientific Seminar
## Cambridge, UK, 28 - 29 February 1996

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| Invitation from: | The Ny-Ålesund Science Managers Committee (NySMAC) |
| Host: | British Antarctic Survey, Cambridge, UK |
| Programme Committee: | Dr. Nigel Webb, ITE Furzebrook Research Station, UK<br>Dr. Nils Are Øritsland, Norwegian Polar Institute |
| Secretariat: | Nick Cox, British Antarctic Survey, UK<br>Elisabeth Stoltz Larsen, Norwegian Polar Institute |

## AGENDA

**Wednesday, February 28**

10:00 - 10:15 **Opening session**
Welcome from the Director of the British Antarctic Survey
*Dr. Barry Heywood*

Aims of the Seminar and Adoption of the Agenda
*Dr. Nigel Webb*

**Session 1:** **Research Reviews**
Chair: *Dr. Nigel Webb*

10:15 - 12:10 *The Arctic Terrestrial Ecology Special Topic Programme:*

10:15 - 10:35 Plant and soil processes in high Arctic Ecosystems: Past progress and themes for future research
*Dr. Philip Wookey and Dr. Clare Robinson*

10:35 - 10:55 Nitrogen-use by salix and dryas in the high Arctic: Impact of atmospheric nitrogen deposition
*Prof. Ian Alexander*

10:55 - 11:15 Photosynthetic and respiratory responses to temperature in some arctic plants of varying ranges of latitude
*Dr. Alistair Headley*

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| 11:15 - 11:30 | Coffee |
| 11:30 - 11:50 | Terrestrial invertebrate studies<br>*Prof. Ian Hodkinson and Dr. Nigel Webb* |
| 11:50 - 12:10 | Overview of the Special Topic<br>*Prof. John Lee* |
| 12:10 - 12:30 | UCL/ Bergen University Project on environmental change<br>*Prof. John Birks* |
| 12:30 - 12:50 | Reindeer host-parasite studies<br>*Dr. Steve Albon* |
| 12:50 - 13:10 | Tundra soil, vegetation, atmosphere climate interaction<br>*Dr. Colin Lloyd* |
| 13:15 - 14:15 | Lunch |
| 14:20 - 14:40 | Marine ecological research of NIPR in Kongsfjorden<br>*Dr. Hajime Ito* |
| 14:40 - 15:00 | Polish marine biological surveys in Kongsfjorden<br>*Dr. Jan Weslawski* |

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| **Session 2:** | **National and international contexts of ecological research at Ny-Ålesund**<br>Chair: *Dr. Pål Prestrud* |
| 15:15 - 15:45 | *Dr. David Drewry, Deputy Chief Executive, NERC* |
| 15:45 - 16:15 | *Dr. Pål Prestrud, Research Director, Norwegian Polar Institute* |
| 16:15 - 16:30 | Tea |
| 16:30 - 17:00 | *Prof. Sven-Axel Bengtson, Chairman, TERRØK* |
| 17:00 - 17:30 | *Prof. Bill Heal, University of Edinburgh* |
| 17:30 - 18:00 | Discussion |

**Thursday, February 29**

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| **Session 3:** | **Research reviews (cont.)**<br>Chair: *Dr. Fridtjof Mehlum* |
| 10:00 - 10:20 | Ornithological studies<br>*Dr. Fridtjof Mehlum* |
| 10:20 - 10:40 | Flyways of geese<br>*Dr. Jeff Black* |





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| 10:40 - 11:00 | Goose physiology<br>*Prof. Pat J. Butler* |
| 11:00 - 11:20 | Ecotoxicology in seabirds and marine mammals<br>*Dr. Geir Wing Gabrielsen* |
| 11:20 - 11:40 | Coffee |
| 11:40 - 12:00 | Seals<br>*Dr. Ian Gjertz* |
| 12:00 - 12:20 | Reindeer versus vegetation dynamics<br>*Dr. Nils Are Øritsland* |
| 12:20 - 12:40 | Marine ecological studies in Ny-Ålesund in 1994 – Experiences, results and perspectives<br>*Dr. Dieter Piepenburg* |
| 12:40 - 12:50 | Relationships between BIODAF at Ny-Ålesund and other marine biological projects conducted by the Norwegian Polar Institute<br>*Dr. Stig Falk-Petersen* |
| 12:50 - 13:10 | Planned and ongoing research of the Alfred Wegener Institut<br>*Dr. Christian Wiencke* |
| 13:15 - 14:15 | Lunch |

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| **Session 4:** | **Workshop: *New directions for Arctic Ecological Research***<br>Challenges and components of contemporary ecological research programmes for Ny-Ålesund<br>Chair: *Prof. Bill Heal* |
| 14:15 - 16:15 | Discussions/ Workshop |
| 16:15 - 16:45 | Tea |
| 16:45 - 17:45 | Discussions (cont.) and conclusions |
| 18:00 | **Reception** |

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## Aims of the Seminar

*by Dr. Nigel Webb, Furzebrook Research Station, UK*

The Ny-Ålesund Seminar Series was conceived by NySMAC as a means of bringing together research scientists involved in programmes running at Ny-Ålesund or having an interest in that area. The first Seminar was held in Potsdam in Germany in May 1995, and included talks which covered physical, atmospheric, earth and biological sciences.

This Second Seminar is devoted to biological science and particularly to ecology. Since the 1970s a wide range of projects have been carried out on Svalbard and particularly at Ny-Ålesund. Prominent in this research have been the recent programmes such as the British NERC Special Topic in Arctic Terrestrial Ecology and the Norwegian TERRØK (Terrestrial Ecological Research Programme on Svalbard) which followed the Norwegian PRO MARE (Research Programme for Marine Ecology) programme.

Although other nations are developing research programmes, both the Norwegian and British programmes are in their closing stages. This provides the context for this Seminar. First, it provides an opportunity for those who have been working at Ny-Ålesund and in other areas of Svalbard to summarise their research and findings and to identify their achievements. Secondly, I hope participants will identify what they consider the new challenges to be so that we can set out ideas from which new programmes can be developed.

Sessions 1 and 3 will enable us to describe the achievements and identify the challenges. However, if we are to propose new programmes these need to fit into both a national and international context, and in Session 2 the speakers will help us to define this wider context. In Britain, in recent years, we have seen significant changes in the criteria demanded for research grant applications. We have become familiar with phrases such as the "user community", "meeting the needs of the user community", "the creation of wealth" and "the quality of life". In this way the direction and relevance of research has been set, and to be successful applications have to meet these criteria. Similar trends in research funding are beginning to affect other countries.

Besides meeting national criteria, research programmes have to fit into the international context. Arctic science is by its nature international both in concept and in practice. Currently, there is a plethora of international of global programmes. Most of these are focused on global change, the monitoring of the responses of organisms and biological systems to these changes, and the need to predict the consequences of change. Some of these programmes are established while others are in the planning stage. What is important is that our plans for research at Ny-Ålesund are formulated in this context. We shall need to assess the requirements of these international programmes and identify within them those activities which are best, if not uniquely, carried out at Ny-Ålesund or on Svalbard, and build our plans accordingly.

In formulating our plans we shall also need to consider human impacts on arctic ecosystems. Those areas of the Arctic which have easy access for the researcher are also reached easily by others. Tourism is growing in these areas and we might consider how wider human access to the Arctic can co-exist with scientific research. Although we should be concerned about the general impact of humans in the Arctic we also need to consider the specific impact of research projects. Even in temperate ecosystems this is a recognisable issue and I am well aware that over forty years of research on heathland





ecology has left an interesting "archaeology" on the national nature reserve close to the research station where I work. Research in the Arctic requires an infra-structure. We may need to consider whether we have the infra-structure we require, but we should ensure that it operates with minimum impacts. Likewise, the use of field sites for both observations and experiment needs to be carefully planned and when we have finished we should leave the site as we found it.

Session 4 will enable us to have a free-ranging discussion and workshop during which I hope we can develop our ideas and perhaps generate an outline for what we see as the way forward. This outline for the Seminar is ambitious as in it we plan to travel from the naïve curiosity of the researcher to the well-formulated research programme. In the next two days I hope we shall generate the momentum to take us well along this path.

# *Abstracts*

Ecosystem Studies
in the Ny-Ålesund Area

Cambridge, 28 - 29 February 1996

# Arctic Ecosystems & Environmental Change

Philip Wookey (Royal Holloway, University of London)
&
Clare Robinson (Sheffield Centre for Arctic Ecology)

## Abstract/Working Paper

**Rationale:** Polar semi-desert ecosystems of the high Arctic cover nearly two million km$^2$ but they have been the subject of remarkably few experimental studies of whole-ecosystem structure and functioning in relation to environmental change. In part this may reflect logistic difficulties of working in the high Arctic, but we also suggest that terrestrial ecologists may have underestimated the potential significance of high arctic regions in the global carbon and energy budgets into the next millennium. One key feature of many high arctic ecosystems which may make them sensitive or responsive to environmental change is the high percentage (>50%) of unvegetated ground interspersed with an incomplete mosaic of largely clonal plants: this may afford opportunities for the rapid colonisation of currently unvegetated ground by clonal proliferation and/or seedling recruitment of existing species, together with immigration from further south. At present insufficient information is available on the relative environmental constraints on such processes, together with the implications of changes in community structure and function for trace gas fluxes, soil organic carbon reservoirs, and the surface energy budget. A further, more pragmatic justification for conducting terrestrial ecological research in the high Arctic is that the extremely short growing season, together with the low stature of the vegetation and the relatively simple community structure, provide excellent opportunities to test fundamental ecological principles in the field.

**Research Objective:** to evaluate the potential for environmental change to exert a long-term impact on ecosystem structure and function in the high Arctic via shorter-term ecophysiological and developmental responses. The studies involve above- and below-ground processes, including changes in decomposition and nutrient cycling, and our approach has been to conduct factorial environmental manipulations (of temperature, soil moisture and nutrient status) over five growing seasons at a polar semi-desert site (78°56'N, 11°50'E) near Ny-Ålesund. Specifically, (i) polythene tents were used as a passive warming system to produce a 3.5 and a 0.7°C increase in air and soil temperatures, respectively, over ambient values, (ii) a 58% increase in summer precipitation was simulated by six additions of water per season and (iii) soil nutrient status was ameliorated by the addition of 5, 5 and 6.3 g m$^{-2}$ yr$^{-1}$ N, P and K, respectively, as inorganic fertiliser.

**Major research findings from investigations of plant performance:**

- Vegetative development (above-ground biomass, leaf areas and changes in percentage ground cover) of the major vascular plant species, *Dryas octopetala,* together with *Polygonum viviparum*, was strongly responsive to amelioration of soil nutrient status (NPK additions: +F treatments) but was largely unaffected by polythene tent (+T) treatments. The same pattern was observed for below-ground biomass (corm weights) of *P. viviparum.*
- In *D. octopetala* leaf development patterns (e.g. specific leaf area and growth) are 'tailored' to support optimal photosynthesis given additional supplies of potentially limiting nutrients (+F).
- Investment in reproductive structures of both *D. octopetala* and *P. viviparum* was dramatically increased in the tented treatments. Indeed, for *D. octopetala* +T was associated with a 695% increase in seed viability at the close of the 1993 growing season, compared with -T (untented) control plots. As for vegetative development there were also significant effects of +F treatments (in terms of seed numbers and weights for *Dryas*, and

bulbil numbers and weights for *Polygonum*), but these did not translate into an improvement in seed viability for *D. octopetala*.

- *Dryas octopetala* maintains tight control of water use efficiency over a broad range of soil moisture regimes, as indicated by data for $\delta^{13}C$ in +W treatments (58% increase in precipitation), and in a glasshouse study in which water was withheld.
- At the start of the fourth season of manipulations there was evidence that +F treatments were associated with an increased incidence of winter injury: this is thought to be a result of impaired winter hardening in the +F plots during the antecedent unusually mild autumn period (1993).

The vegetation responses suggest that significant warming at this site could, as a result of accelerated reproductive phenology and increased investment in reproductive structures, substantially improve fecundity. Whether or not this could translate into increased seedling or plantlet recruitment into the community will depend, however, on favourable conditions for germination and establishment: suitable microsites may not become available unless soil moisture and nutrient status improve substantially as a result of environmental change. Vegetative development appears to be relatively insensitive to warming but severely constrained by poor soil nutrient status: we suggest, however, that long-lived clonal plants such as *D. octopetala* can overcome nutrient limitations by tight internal recycling of nutrients assimilated over many growing seasons. Indeed the +F treatments seemed to induce a luxury uptake response which may have contributed to greater winter injury: this may prove maladaptive if soil nutrient status improved substantially as a result of soil warming (but see conclusions below on soil processes).

**Major developments in research on soils and below-ground processes:**

- Results for N mineralisation indicated that in the short-term there will be relatively little stimulation in response to small (<1°C) rises in soil temperature beneath polythene tents (+T). However, a significant increase in total N mineralisation, mainly as nitrate, occurred in the +F and +W treatments.
- After 13.5 months, the decomposition (mass loss) of *Salix polaris* litter was retarded by the +T treatments, while, by contrast, the +F treatments accelerated decomposition. Water additions had no significant impact.
- On three sampling occasions there was no +T effect on soil respiration ($CO_2$ fluxes) but, by contrast, respiration was significantly increased by an interaction between fertiliser and water treatments (F x W).

The results of the below-ground processes measured suggest that low nutrient availability, plus low soil moisture contents, limit decomposition and N mineralisation at this site. Our results do not conflict, however, with those from previous work in low arctic soils (e.g. Billings et al. 1982; Nadelhoffer et al. 1991) where larger soil temperature increases were found to have profound effects on soil respiration, since the increase in soil temperatures (0.7°C) produced in the present study was relatively minor.

**Synthesis of current conclusions:** Work to date at the polar semi-desert site has indicted that some facets of ecosystem functioning are highly responsive to amelioration of environmental constraints: thus the frequency of years with successful seed set may be expected to increase if summers become significantly warmer (or snowmelt and flowering occur earlier). This could, in the longer term, result in increased seedling recruitment into the population (with implications for intraspecific genetic variability and environmental tolerance). The work on below-ground processes, however, together with the +F manipulations of soil nutrient status, illustrate the profound significance of nutrient availability at this site. Clonal spread of existing vegetation onto adjacent bare ground, together with seedling recruitment into the population , may be severely constrained by limited availability of microsites with suitable nutrient and water status to support rooting of lateral ramets, or the germination of seeds and bulbils. It remains unclear whether the temperature increases predicted by General Circulation Models (GCMs) will result, in the longer term, in significantly improved rates of decomposition and nutrient mineralisation. Summer water availability is also likely to be critical for decomposition processes (and seedling recruitment), yet firm predictions of soil moisture status during the growing season are currently impossible on the basis of GCM output.



**Themes for future research at Ny-Ålesund:**

- Our interpretation of the long-term significance of increases in seed viability (e.g. in *D. octopetala*) in response to +T treatments is limited by our restricted understanding of the environmental factors which influence germination and establishment. In general terms more work is needed in the high Arctic on seed banks, seedling recruitment, and the potential for immigration of species from further south. This work needs to be of sufficient duration to enable seedlings to be identified and for potential biodiversity (both inter- and intra-specific) to be evaluated.

- Work is needed on below-ground biodiversity (decomposer community) in order to relate community structure to function at the micro-scale. This would link with ecophysiological studies of soil invertebrates which have been undertaken by another group in the Arctic Terrestrial Ecology Special Topic Programme (Hodkinson, Webb, Bale, Coulson and Strathdee).

- Paradoxically there is little information available on the potential ecological impacts of winter warming, or changes in the depth and/or longevity of the snowpack, or the duration of the growing season, even though GCMs predict considerably greater winter than summer warming at high latitudes. Experimental manipulation of snowpack depth, or the possible increased incidence of liquid precipitation in winter (together with the formation of ice layers in the snowpack) could be simulated in the field without the need for expensive equipment or logistic support. It may be of particular interest to determine the importance of continued decomposition processes in the winter months (particularly in the early winter period when a substantial volume of the seasonally active layer may remain unfrozen even when air temperatures are below freezing).

- Currently there is no published information from polar semi-desert communities on the impacts of elevated atmospheric concentrations of $CO_2$: it is paradoxical, however, that this is one component of environmental change that is unequivocally linked with anthropogenic activities. It can be hypothesised that increases in water use efficiency (WUE) in such ecosystems, as a result of the $CO_2$ fertilisation effect, may have major implications for vegetation cover, whole-ecosystem water fluxes, and surface energy balance. We therefore propose that *in situ* manipulations of atmospheric $CO_2$ would be timely in the Ny-Ålesund region, although suitable infrastructure is necessary (gas and power supplies) well away from the direct disturbance of the community.

- Alongside in situ manipulations of $CO_2$ it would be appropriate to introduce manipulation of UVB, possibly in factorial combination. Of particular interest here are the potential impacts of increased surface fluxes of UVB on N-fixing cyanobacteria in cryptogamic crusts (important in the N economy of polar semi-deserts). The predominance of evergreen perennials (such as *D. octopetala*) may also predispose these systems to cumulative impacts due to the longevity of individual leaves. As with $CO_2$ manipulations there would be considerable demands for suitable infrastructure to conduct experiments of this kind.

**Publications from the project are listed separately**

**Co-workers on the project are as follows:** Professor Terry Callaghan and Dr Jac Potter (Sheffield Centre for Arctic Ecology), Dr Malcolm Press and Professor John Lee (University of Sheffield), Dr Andy Parsons and Dr Jeff Welker (Colorado State University).

## Arctic Ecosystems and Environmental Change

### Publications List


1. Callaghan TV, Cox NI, Wookey PA & Welker JM (1992) A new NERC programme of research on ecology in the Arctic. In ***Institute of Terrestrial Ecology 1991-1992 Report***. pp. 32-33. Natural Environment Research Council.

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12. Wookey PA & Robinson CH (submitted) Interpreting environmental manipulation experiments in arctic ecosystems: are 'disturbance' responses properly accounted for? In: Crawford RMM (ed) ***Disturbance and Recovery in Arctic Lands: an Ecological Perspective***. Kluwer Academic Publishers, Dordrecht, the Netherlands.

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## Effects of nitrogen fertilisation on three arctic dwarf shrubs


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Arctic vegetation is thought to be nutrient limited, particularly N-limited, and is therefore potentially sensitive to increased N inputs from atmospheric deposition or the enhanced N mineralisation associated with global warming. Since 1991 N has been applied to communities of three dwarf shrubs in polar heath near Ny-Ålesund, at rates equivalent to 10 and 50 kg N $ha^{-1}$ $a^{-1}$ . The test species, *Salix polaris, Dryas octopetala* and *Cassiope tetragona*, allow a comparison of the response of shrubs of contrasting life form (deciduous, winter-green and evergreen) and mycorrhizal infection (ectomycorrhizal and ericoid mycorrhizal).

The foliar N concentration in all three species rose in response to the higher N application (50 kg $ha^{-1}$ ), but annual variation in leaf phenology masked possible effects of the lower application. However, when $\delta^{15}$ N was determined this clearly showed uptake of applied N even at the lower application. Thus the shrubs are clearly sensitive to low levels of atmospheric N input.

*Salix polaris* leaf biomass increased in response to the higher N application in 1992 but by 1993 *Dryas* and *Cassiope* had still not responded. *Salix* appears to allocate a higher proportion of its resource below ground than *Dryas* and fine root numbers of *Salix*, but not *Dryas* were reduced by the higher N application in 1993. Hair root production by *Cassiope* was also reduced. The time scale over which a below-ground response occurs is longer than that above ground.

*Salix* and *Dryas* share a community of >30 ectomycorrhizal fungi but the relative proportions of mycorrhizas formed by different fungi differ on the two host species. Thus *Lactarius lanceolatus* forms 75% of the mycorrhizas on *Dryas* but only 18% on *Salix*. Overall *Salix* had lower mycorrhizal infection (72%) than *Dryas* (90%) and infection in *Salix* was reduced (to 33%) by N-fertilisation while *Dryas* was unaffected. Fertilisation also altered the proportions, and reduced the diversity, of fungi on *Salix* root systems and reduced fruitbody production. Ericoid infection of *Cassiope* was reduced by fertilisation.

In 1993 heavy rainfall in November froze and encased the vegetation in ice until June 1994. this lead to death of *Dryas* and *Cassiope* particularly on those plots receiving high additions of nitrogen, probably because of delayed hardening.

This study has demonstrated that dwarf shrubs are affected by levels of N fertilisation equivalent to those in atmospheric deposition over much of N. Europe. Higher inputs lead to reductions in mycorrhizal infection and loss of fungal diversity. Tolerance of winter injury is reduced. There were marked differences in response between the shrubs which might be expected to influence the outcome of competitive interactions. Long periods of monitoring are required in experiments such as this to allow responses to be manifest, to cater for annual variation, and to increase the probability of encountering extreme events.

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# THE ICEBERG ANALOGY AS APPLIED TO ARCTIC PLANTS

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## Abstract

Many Arctic plants have similar temperature optima for photosynthesis to that of temperate plants, but they are often found to have much lower temperature optima for growth. The aim of the investigation was to examine whether the higher allocation of biomass below-ground in arctic plants accounted for their lower temperature optimum for growth. The objectives of the investigation were firstly to establish the absolute and relative quantity of carbon lost through growth and respiration by roots and below-ground structures in a range of species of arctic, arctic-alpine and temperate plants with different latitudinal ranges, and secondly to establish the phenotypic flexibility to temperature in terms of dry weight allocation and carbon uptake and loss on a whole plant basis. In order to achieve these aims the seasonal course of biomass partitioning ànd above- and below-ground gas exchange in different species of buttercup (*Ranunculus*) was examined at Ny Ålesund, Svalbard and Abisko, N.Sweden. The effects of growth temperature were examined in the field at Abisko and in the phytotron at Tromsø.

There are strong seasonal trends in both photosynthesis and root or below-ground respiration, with a peak in mid-season. The rates of root respiration between 5 and 15°C were 1.5 and 7 times faster in the arctic species compared to the temperate species. The calculation of net carbon yield for a single season based on field measurements of gas-exchange characteristics through the season corresponded very closely to those based on changes in biomass. The larger biomass allocation below-ground (40-80%) and the higher rates of root respiration accounted for a larger proportion of the carbon loss in the more northerly species.

Species of arctic plant differ in their ability to acclimate their root respiration to increasing growth temperature, with *R.pygmaeus* showing complete homeostasis of root respiration to a 10°C increase in growth temperature. Different species have different susceptibilities to increasing temperatures due to their phenotypic plasticity which in some cases is due to genotypic variation. Considering these observations *R.glacialis* and *R.sulphureus* show the lowest flexibility of biomass allocation and ability to acclimate root respiration. *R.pygmaeus* showed the greatest flexibility of biomass allocation and ability to acclimate root respiration. The growth of *R.glacialis, R.sulphureus, R.nivalis* and *R.pygmaeus* at 6, 12, 15 and 18°C confirmed the predicted relative sensitivities of these species to increase temperature.

There are at least four areas that need further investigation as a consequence of the results of the present investigation and they include: (i) the relative importance of warming of the air and soil on the carbon budget of arctic plants when grown under natural light conditions, (ii) the effect of extended growth period on the carbon balance of high and mid-arctic species, (iii) the stimulus (daylength, light-quality and innate phenological cycle) for senescence in high and mid-arctic plants and (iv) the contribution of respiration to carbon loss from rhizomes and roots during the 'dormant winter period' in arctic and alpine plants.

**Temperature, climate change and the environmental constraints on the life history strategies of arctic terrestrial invertebrates.**

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*The sites, the animals and the experiments*

The two main sites at Ny Ålesund, represented typical outer and inner fjord vegetation types, corresponding to the *Dryas octopetala* (=polar semi-desert) and the *Cassiope tetragona* (=moss tundra\tundra heath) zones respectively (Coulson *et al.* (1993). Intensive work has also been carried out at the Krykkjer and Stuphallet bird cliffs and a *Dryas*-rich site adjacent to the 'French Camp'. Tent/cloche experiments were conducted over 3 years to investigate the effect of raised summer temperatures on the dominant soil-dwelling mites and Collembola and on the main herbivore of *Dryas*, the aphid *Acyrthosiphon svalbardicum*. Detailed work, characterizing thermal physiology, was conducted on the dominant species of mite and Collembola and on the aphid. Limited studies were also made on the effects of temperature on the abundance of flying Chironomidae (Diptera) and on cold-hardiness in the freeze tolerant tolerant dipteran larva *Heleomyza borealis*.

*Results of the field temperature manipulation experiments*

<u>**The below-ground fauna**</u>

- No significant effect of enhanced temperature on total mite population emerged at either site, even after three years.
- Collembola numbers in year three were significantly lower in the tented compared with the untented plots at the polar semi-desert but not at the tundra heath site.
- The decline in Collembola numbers corresponded with a particularly warm and dry spell in July 1993. The polar semi-desert site dried out more quickly than the tundra heath.
- Collembola species appeared more susceptible to elevated temperatures than the mites. The effect appeared linked to soil moisture status.
- Year to year variation in climate, interacting with physical differences between sites, produced an equal or greater effect on microarthropod numbers on any one site than the 8-10% increase in 'heat availability' (day degrees) resulting from the tent treatment.

<u>**The above ground herbivore *Acyrthosiphon svalbardicum***</u>

- The full range of morph types, fundatrix, vivipara, ovipara and male were described and the life cycle was shown to be genetically controlled.
- Field temperature manipulation raised average summer temperature by 2.8°C. This advanced the phenology of both the aphid and its host, leading to higher aphid densities.
- Ameliorated cloche temperatures provided the aphid with sufficient advantage to complete three generations whereas in controls the third generation failed to mature. This led to an eleven-fold increase in numbers of overwintering eggs in cloche treatments within one year.
- *Acyrthosiphon* is well-adapted to respond rapidly to enhanced temperature regimes. Guaranteed egg production by mid-summer, combined with an in-built flexibility to produce an extra generation in favourable seasons, is particularly advantageous.
- Analysis of climatic data for the past 23 years showed that thermal budgets during 1992, the year of the experiment, were typical and that a similar increase in egg density would have been produced by a 2.8°C temperature amelioration in most years.

*The physiological responses to temperature*

**The below-ground species**

♦ For a range of mite and Collembola species locomotor activity ceased at between -3 and -6°C.
♦ Summer supercooling points were highly variable both within and between species e.g. in adults of the mite *Camisia* SCP ranged from -3 to -28°C. For most species mean SCP was raised during the summer. The SCP of the collembolan *Hypogastrura tullbergi* fell from -21 to -9 over a 6h period as the animal became active at snow melt. Unusually, the SCP of *Onychiurus arcticus* remained consistently above -10°C even when the animal was starved and dehydrated. For several species, including *Hypogastrura tullbergi* and *Onychiurus groenlandicus* SCP was a poor indicator of cold tolerance: animals, when cooled slowly, died at temperatures above the SCP.
♦ The most cold susceptible species, *O. arcticus*, showed 30% survival after 84 days at -5°C.
♦ Summer polyol (antifreeze) concentrations varied seasonally but were low. The important polyol differed between closely related species e.g. glucose in *O. arcticus*, sorbitol in *O. groenlandicus*.
♦ Under non-limiting conditions of moisture and 1h exposure the Thermal Death Points of the mite and Collembola species were 40-45 and 35-40°C respectively, values little different from those for temperate species. Three hour exposures reduced TDP by around 2.5°C. Moisture stress had little effect on the TDP of mites but a highly significant effect on the Collembola. When kept in moist conditions, *O. arcticus* survived more than 68 and 196 days at 25 and 5°C respectively.
♦ Water loss by *O. arcticus* was highly correlated with the SVPD of the surrounding air. Animals survived water loss of 60% of body weight. Uptake of free water was much more rapid than absorbtion of water from a saturated atmosphere. Water uptake rates were generally slower than maximum rates of water loss under desiccating conditions.
♦ Limited analyses of the feeding biologies of the common species showed that food prefences could determine the position of preferred feeding sites within the soil temperature profile.
♦ The respiratory response to temperature for some Collembola and other taxa was compared with existing data for polar and alpine species. The surface-dwelling *O. arcticus*, has an unusually high $Q_{10}$ of 7.0 over the range 0-10°C, emphasising its ability to respond to temperature enhancement within the lower end of the range.
♦ The high and low temperature mortality response profiles for each species, viewed in conjunction with three years' microclimatic data and 30 years macroclimatic data for Ny Ålesund, were used to model the effects of different climate change scenarios on the arctic soil microarthropod communities.

**Above-ground species-*Acyrthosiphon svalbardicum***

♦ Overwintering eggs passed through a period of diapause. This was completed before mid-January and it was higher spring temperatures that control the timing of hatch.
♦ Overwintered eggs survived -27°C for at least one month.
♦ Active stages showed cold hardiness characteristics typical of aphids but with evidence that survival in adult fundatrices was enhanced over temperate counterparts.
♦ The distribution and phenology of were closely linked to summer temperatures and date of snow clearance. Thus, within Kongsfjord, despite the ubiquitous distribution of its host plant, the probability of aphid occurence decreased as one moved towards the colder mouth of the fjord or away from the warmer shoreline.

**A full list of publications is available on request**



**Publications from Arctic Special Topic Programme, Svalbard invertebrate project 1991-.**


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# STUDIES ON ENVIRONMENTAL CHANGE ON SVALBARD

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Arctic ecosystems are traditionally assumed to be stable in their structure and composition and to have remained unchanged for hundreds or even thousands of years because the arctic environment is assumed to be relatively stable. Assessment of Arctic ecosystem change over the time spans of $10^2$-$10^4$ years can only be made by detailed palaeoecological studies of fossils (e.g. seeds, fruits, leaves, diatoms, chironomids) preserved in lake sediments.

Recent palaeoecological investigations on Svalbard by our laboratories involving plant macrofossils, diatoms, and sediment chemistry and composition show that considerable biotic changes and hence environmental shifts have occurred on Svalbard over the last 9000 years. Arctic ecosystems appear to be very susceptible and responsive to environmental change. Earlier palaeoecological studies on Svalbard have been based entirely on fossil pollen assemblages, the interpretation of which in arctic areas is notoriously problematical because of the preponderance of long-distance extra-regional pollen and spores from areas further south. By studying locally derived fossils such as leaves, fruits, diatoms, etc., we avoid the problems inherent in arctic pollen analysis.

Plant macrofossils in lake sediments at Skardtjørna (78°00'N, 13° 40'E) west of Linnédalen and south of Isfjorden provide a unique record of vegetational change in an outer-fjord area. Today the site is surrounded by very open *Dryas octopetata - Salix polaris - Saxifraga oppositifolia* vegetation. Plant macrofossils show that between about 4000 and 8000 years ago the vegetational cover was considerably greater than today and the vegetation was comparable to the *Cassiope tetragona* vegetation of inner-fjords today. Fossils of *C. hypnoides* and *Salix glauca*, both confined to mild inner-fjord areas today, suggest that climate was about 2°C warmer than today at Skardtjørna 4000-8000 years ago.

Palaeolimnological investigations at Arresjoen (79°40'N, 10°45'E), situated on acidic bed-rock on Danskøya, show that considerable changes in the diatom flora have taken place in the lake during the last 2500 years with the apparent extinction of some taxa and the appearance and expansion of other taxa. The fossil diatom assemblages can be used to reconstruct past lake-water pH. This appears to have decreased from pH 6.5 to about pH 5.8 over the last 2500 years. The causes for these changes are, as yet, unclear. The recent (last 100 years) sediments at Arresjoen show contamination by atmospheric pollutants, with increased concentrations of cadmium, lead, nickel, and copper, the appearance of organic pollutants (PAH, PCB, HCB, DDE), and the occurrence of carbonaceous particles formed by the combustion of fossil fuels. Analysis of the heavy metal concentrations of fish livers from 15 remote arctic and alpine lakes in Europe shows that arctic char at Arresjoen has the highest concentrations of mercury of anywhere in Europe, even when the effects of age, growth stage, sex and species are allowed for statistically. These results clearly indicate the recent deposition and incorporation of long-distance pollutants in arctic ecosystems at 79°N.

Recent climatic change, as reflected by glacial retreat, increased vegetational cover, and decreased inwashing of minerogenic matter, is recorded by changes in the organic/inorganic content of lake sediments. A consistent picture is emerging of decreasing inorganic content and increasing organic content in the last 50-100 years from lakes in north-west Svalbard and from Ossian Sarsfjellet (78°57'N, 12°28'E) at the head of Kongsfjorden near Ny Ålesund, suggestive of recent climatic amelioration.

Current investigations on Svalbard include the building-up of a modern diatom - water chemistry calibration data-set over the pH range 5.6 - 8.4, the study of inorganic and organic atmospheric pollutants in a series of lakes along the west coast from 77°33'N to 79°48'N, and the reconstruction of recent environmental change using diatoms and other algal remains, chironomids, sediment composition, and terrestrial plant fossils from five lakes on a north - south transect along the west coast in relation to modern climatic gradients and local pollution sources.

Priority future research directions on arctic environmental change are (1) further, more detailed studies on lake sediments covering the entire post-glacial (9000-10000 years), (2) fine-resolution studies on the response of arctic terrestrial and freshwater ecosystems to recent climatic change associated with the onset and the end of the 'Little Ice Age', the dating of which on Svalbard is poorly known, (3) studies on the existing biodiversity of diatoms in Svalbard lakes, (4) the effects of recent atmospheric pollutants on arctic freshwater biota and ecosystems, and (5) the linking of records of recent organic and inorganic pollution in lake sediments with records in fjord sediments.

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## PARASITES, BODY CONDITION AND REPRODUCTION IN SVALBARD REINDEER

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Abstract

High Arctic island populations of reindeer and caribou are characterised by unusually high annual variation in fecundity (from as little as 20% of females pregnant/calving to as many as 80%). Although over-winter mortality may also be very variable, previous work on Svalbard reindeer has suggested that fecundity is the key factor responsible for the marked fluctuations in population size. Theoretical models show that parasite-induced changes in fecundity of hosts may generate population cycles or chaos. Here we provide evidence that gastro-intestinal nematodes are a candidate mechanism regulating Svalbard reindeer.

In mammals, including the cervidae, fat reserves are an important factor influencing both puberty and the probability of subsequent reproduction. Cross-sectional data gathered from females culled in October, after the rut, shows that the probability of ovulation rose significantly as back-fat depth increased in yearlings. More than 90% of adults had ovulated but those that had not ovulated tended to have low fat reserves.

Fat reserves (back-fat depth) in cull females were negatively related to the intensity of infection (number of adult nematodes in the abomasum, mainly *Ostertagia grühneri*). Presumably this was because high parasite burdens reduce digestive efficiency and, in the short summer growing season, retard the accumulation of fat deposits. Yearling females had less fat than adults which explains their lower ovulation rate. However, after controlling for fat and age, the probability of ovulation increased, rather than decreased, with parasite burden.

In spring, pregnancy rates in live animals were assessed by both ultrasound and progesterone assays. Pregnancy was lower than the ovulation rate in the previous autumn but nonetheless was related, positively to body weight and negatively to counts of nematode eggs in the faeces (an index of parasite burden). The implication is that smaller, probably less fat, individuals with comparatively high parasite burdens ovulate but either fail to conceive or maintain a pregnancy.

Future work will include experimental manipulation of parasites by anthelmintic treatment to measure subsequent condition and pregnancy rates compared to normal controls. In addition investigations of spatial heterogeneity in the intensity of infection within and between populations may elucidate the importance of variation in the nutritional plane and local host density.

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**Tundra Soil-Vegetation-Atmosphere Climate Interaction**

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The effect of predicted global climate change due to increased greenhouse gases will be most pronounced in high latitudes (Houghton *et al.*, 1990). Such warming will initially affect the hydrology of these regions. Not only will the change in the extent and timing of the snow cover affect radiation feedback but the expected warming will almost certainly change the extent in time, space and depth of the unfrozen soil layer above the permafrost. These soil layers are potential sources of both carbon dioxide and methane. This project, which began in 1994, had the overall objective of determining the relationship between the energy balance, the release of greenhouse gases and the depths of the saturated and unsaturated soil zones above the permafrost using micrometeorological, soil physical and hydrological techniques at a field scale, *ca* 500m x 300m. The measurement techniques employed include eddy correlation measurements of sensible heat, evaporation and carbon dioxide surface fluxes; temperature and soil resistivity profiling and Time Domain Reflectometry (TDR) measurements for identifying and quantifying the soil thermal and moisture regime above the permafrost; runoff plots and pressure transducers for quantifying hillslope runoff; snow depth surveys and digital camera techniques for quantifying the rate and amount of snowmelt. These measurements are largely automatic and continuous. The project has two field sites. The major field site, in the Bayelva river valley is a relatively wet site, described as 100-50% *Luzula* lichen heath on a clay silt soil with a 20mm organic surface layer. The other field site is a dry plateau, described as a 50-10% *Saxifraga oppositifolia* lichen heath on a surface composed largely of carboniferous limestone gravel and boulders.

A short one-month field programme was conducted in August 1994 followed by a season long programme in 1995 extending from before the snow-melt at the end of May through to near the end of the active season in early September. At the start of the project, an Automatic Weather Station was installed which has been collecting data throughout the project including unattended operation through the winter.

A pertinent subset of the measurements taken were presented. All these results are from the "wet" Bayelva river valley site. Other workers in Tundra soils have found that soil water can remain unfrozen at temperatures below $0^0$C - even as low as -$50^0$C (Anderson and Tice , 1970). Combined analysis of the soil temperature and soil resistivity measurements showed that the soil at our field site at Ny-Ålesundexhibits no depression of soil water freezing point temperature probably reflecting the low organic content of the soil. Diurnal fluxes of sensible heat, latent heat and carbon dioxide for snow cover (2 June) and mid-summer (26 July)were shown. During snow cover, and despite 24 hour daylight, there is a pronounced diurnal cycle to the measurements. Overall energy exchange is low due to the high albedo of the snow pack, with evaporation from the melting snow peaking at 20Wm$^{-2}$ , sensible heat flux was negative throughmost of the day, again peaking at -20Wm$^{-2}$, indicating that the surface air layer over the snowpack was contributing its heat content to evaporation and snowmelt. The midsummer diurnal fluxes showed near equality between sensible and latent heat, with both peaking near 150Wm$^{-2}$. Carbon dioxide during this day showed a net accumulation at the surface, with maxima near 1.1μmol.mol$^{-1}$. Cumulative fluxes over the period late May to early September. showed that evaporation from the surface, which exceeded sensible heat by 15 per cent, was nearly double the rainfall during that period and that the surface was a net accumulator of carbon of 7gCm$^{-2}$, although because of gaps in the carbon dioxide data, this figure is speculative. One of the priorities for the 1996 field season is to gather a complete carbon dioxide dataset from late May to early September. The carbon dioxide data did appear to show a nearly constant uptake of carbon from just after the snow disappeared to the middle of August. A short carbon dioxide dataset during the last days of August showed the surface to be a net, but small, source of carbon dioxide. A near surface soil moisture survey over an area of 100m x 100m at 5m intervals, six days after rainfall showed a patchwork of volumetric soil moisture values between 17% to 35%. Such persistent heterogeneity in soil moisture will certainly produce heterogeneity in evaporation but will also probably be reflected in similar heterogeneity in carbon dioxide sources.

While 1996 is the final year of this project, it will also be the first year of a three year EU framework IV funded multinational programme. This programme, the Land Arctic Physical Processes (LAPP) project, coordinated by the Institute of Hydrology and including teams from SINTEF-NHL, Trondheim, the Institute of Terrestrial Ecology, Edinburgh, the University of Copenhagen and the Finnish Meteorological Institute and Finnish Environment Agency, both at Helsinki, will extend the current work being undertaken at Ny-Ålesund to other field sites and will include a methane flux measurement programme. The LAPP field sites cover the north-south extent of the Tundra biome (Ny-Ålesund to Kevo and Kaamanen in northern Finland) and the east-west extremes of the biome in western Europe (Kevo to Zackenberg/Disko Island in Greenland). Contiguous measurements will begin at these field sites this summer (1996) with repeat field seasons in 1997 and 1998. The process knowledge gained will be used to prove or improve one-dimensional Soil-Vegetation-Atmosphere Transfer (SVAT) schemes which are used in General Circulation Models (GCM's) and Hydrological models. This will be done in the lifetime of the project and will help to improve the estimation of the exchanges of water and carbon in the Arctic.

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# Marine ecological research of NIPR in Kongsfjorden

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Since 1991, National Institute of Polar Research (NIPR) Japan have started oceanographic surveys (physical and biological aspects) in Kongsfjorden, Svalbard. Several observations of water temperature and salinity during sea ice free period (June - September) revealed the development of strong vertical stratification of the euphotic surface water (Ushio et al., 1995). It was thought that such stratification might be created by in-flow of freshwater from glaciers surrounding the fjord and continuous solar radiation during summer. Microorganisms living in the fjord may be affected their activities by such physical conditions. In this paper temporal changes in phytoplankton biomass and primary production, as well as some environmental conditions in the fjord during early summer (May - June, 1993) were summarized, and some effects of vertical stratification of surface water on the phytoplankton production were discussed.

## OCEANOGRAPHIC CONDITIONS

Fjord surface was covered by thin sea ice by the beginning of May, 1993. Obvious ice melting and breakage started on 8 May, and almost all sea ice was melted/flushed away by the middle of May. Surface temperature gradually warmed and the salinity decreased after that. The warmer and less saline water appeared on the top 20 m depth in June. It seemed that vertical mixing between epi- and hypolimnion didn't occur. Due to silty water, transparency of the fjord water was poor. Photosynthetically active radiation (PAR) was absorbed/scattered and only 0.1% of the surface PAR reached to the lower part of the epilimnion.

## PHYTOPLANKTON

Phytoplankton blooming occurred just after the sea ice disappearance in May. Chlorophyll *a* in the surface water reached more than 5 µg/l in early May, but gradually decreased to less than 0.5 µg/l showing some fluctuation in mid-May. Nutrients depression such as nitrate and silicate occurred in the surface water, and then these might terminate the phyoplankton bloom. The Chlorophyll *a* never showed any clear increase in the surface water after that. With these changes majority of phytoplankton community sifted from large-sized diatom to small flagellates.

Phytoplankton production was estimated by means of *in situ* incubation method in mid-May and early June. Large differences in the maximum photosynthetic rate and production were detected, which were nearly 3 and 10 times higher in the blooming condition (mid-May) than the post blooming June, respectively (Table 1, Yamaguch et al., 1994; Miyahara 1993).

TABLE 1 Photosynthetic production in the euphotic surface water columns in Kongsfjolden, 1993. The productions were estimated by in situ incubation with adding $^{13}C$ tracer method.

| Date | Maximum Photosynthesis (mgC/mgChl/hour) | Chlorophyll *a* concentration (μgChl/litter) | Production ($mgC/m^2/day$) |
|---|---|---|---|
| 15 May | 1.26 | 5.6 - 6.8 | 1,100** |
| 7 June | 0.45 | 0.06 -0.33 | 87* -119** |

* Estimation was made under cloudy day condition

** Sunny and clear day condition

Inhibition of photosynthesis by strong light (PAR) and UV exposure was observed, but the inhibition was limited only surface a few meters. Phytoplankton in the separated surface epilimnion in this fjord in summer, may be suffering from nutrient depression and possibly strong and harmful light exposure, and then the chance of blooming was thought to occur just the starting period of summer water stratification period.

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## Polish marine ecological studies in Kongsfjorden

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Polish research vessel "Oceania" first sailed to Kongsfjorden in early August 1988 to collect benthic and pelagic samples in the framework of joint, Norwegian-Polish project on Ringed seals diet (Norsk Polarinstitutt and IO PAS). Besides marine biological sampling, the hydrology have been surveyed as well on 13 stations. Data from this cruise, both on the fjordic environment and on ringed seal diet have been published (Węsławski et al 1991, Węsławski et al 1994). Next visit have been payed in 1993 in the framework of Polish National Programme "Fresh Water Cap", aiming to access the impact of freshwater on Svalbard marine ecosystem. Three benthic and plankton stations were completed on this occasion. Results are partly published in Węsławski et al (1995). Third visitof "Oceania" was organised in the framework of multinational, interdisciplinary project BIODAF (Biodiversity of Arctic Fjords) in July 1995. The aim was to collect the reconaissance set of data for future comprehensive project. STD, phyto and zooplankton sampling, primary production measurments, light attenuation profiling, suspensions and sedimentation measurmens were collected in water column on 18 stations. Benthic fauna was sampled with the use of Van Venn grab, triplicate samples from 16 stations, subsamples for granulometric analyses, and meiofauna were taken as well. The artificial substrata provided by Plymouth Marine Laboratory were deployed by SCUBA diver at Ny Alesund for the biodiversity studies. The results are in processing now and going to be ready for the common use in late spring 1996. The team of seven scientists works on species identifications (Malacostraca, Polychaeta, Echinodermata, Mollusca, Pisces). Other benthic groups and meiofauna are going to be presented in higher taxonomic levels. Data are currently stored in ARK-INFO GIS system. Based on our observations Kongsfjord in the northernmost of the subarctic fjords. Its hydrology is dominated by Atlantic waters, and it has not any cold resiudual near bottom water as in the case of some other Spitsbergen fjords (Hornsund, Van Mijen). Glaciers influence is immense both on the pelagic and benthic fauna. The biomass of plankton and benthos is relatively high with clear indication for intensive pelago-benthic coupling. Kongsfjorden fauna is poor in truely Arctic species, the dominants are subarctic forms. We plan to send "Oceania" to Kongsfjorden again in July 1996. We plan intensive sampling programme focused on near glacier bays, rates of plankton mortality and assesment of the amount of dead plankton sedimenting to the fjord bottom. Both the cruise and sampling programme is open for the suggestions from BIODAF members. Besides ship based activity, the field team will work in April-May 1996 on the fast ice ecological role in Kongsfjorden.

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## IO PAS team presently engaged in Kongsfjorden BIODAF study:

hydrology - W. Walczowski, P.Wieczorek. A. Lech

underwater light measurments - S.Sagan

phytoplankton and primary production - J.Wiktor, R.Hapter, B. Witek

suspensions and sedimentation - M.Zajączkowski

satelite imagery - A. Krężel

zooplankton - J. Koszteyn, S. Kwaśniewski, K. Dmoch

meiofauna - M. Szymelfenig

benthos - JM Węsławski, S. Gromisz, M. Włodarska

seabirds and sea mammals - M.Malinga, L.Stempniewicz



# Ornithological studies in the Ny-Ålesund area.

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**Historical background**

The Ny-Ålesund and the Kongsfjorden region have been known since the 19th century to be an important area for arctic birds. The bird fauna in this region is characterized by the predominance of species depending on the marine food chain. It is estimated that marine birds contribute more than 95 % of the energy requirement of the total bird community in the region. Presently, the common eider is the main marine bird consumer, whereas the barnacle goose is the main consumer in the terrestrial ecosystem. The barnacle goose is a relatively newly established species in the area. The first breeding pairs were encountered in the early 1980-ies. Although marine birds predominates over terrestrial birds in abundance and biomass, the Kongsfjorden region has low abundance of seabird colonies compared to other regions of Svalbard, such as in the southern and southeastern parts of the archipelago. Also, most of the prey consumed by marine birds breeding in the Kongsfjorden region is taken in waters outside Kongsfjorden.

Ornithological research in the Ny-Ålesund area started in the late 1960-ies, and expanded through the 1970-ies and the 1980-ies. Researchers from several nations have participated in various types of studies, mainly within ecology and physiology. Among nations involved were Norway, Sweden, Denmark, Finland, the Netherlands, U.K., Poland, and USA. The Norwegian Polar Institute initiated in the early 1980-ies comprehensive long-term studies of different aspects of the ecology and eco-physiology of birds. Another institution involved in several physiological projects is the Department of Arctic Biology at the University of Tromsø, Norway.

Bird species/groups studied in the Kongsfjorden region have been colony nesting seabirds, eiders, geese, waders and ptarmigan. In recent years the barnacle goose have been a major study object involving research groups from Norway, the Netherlands and U.K.

The lush vegetation and the wetlands in the immediate surroundings of the Ny-Ålesund settlement have attracted a variety of bird species to breed or to forage. The proximity of these birds to laboratories and experimental facilities have proved ideal for detailed ornithological studies, as well as for educational purposes. Recent developments with increased human activity in the area combined with heavy grazing of the vegetation by introduced reindeer have made the area less attractive to birds.

**Future studies**

Relevant topics of interest to ecological studies of birds in multi-disiplinary ecological programs in the Ny-Ålesund/Kongsfjorden region:

Stability of arctic ecosystems
- natural variance - amplitudes and frequencies
- resistance to external impact

Transport of energy and nutrients between marine and terrestrial ecosystems
- transport by marine birds
- run-off from terrestrial systems
- effects of absence of enrichments from the marine systems

Predator - prey interactions
- effects on predators to variance in prey abundance
- effects on avian prey populations (eiders, geese) by predators

Herbivore - plant interactions
- relationship between primary production and herbivore community structure and biomass
- relationship between primary production and herbivore population recruitment



# Arctic goose research in Svalbard: where do we go from here?

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Because arctic geese from Svalbard spend about half of their year in Norway and the other half in Britain [or other Europe countries] natural and/or human induced changes in one country may have serious implications at the other end of their range. For example, the agricultural policy in temporate regions, which now produces ample goose food, has lead to an unprecedented increase in goose numbers throughout Europe and North America (Owen & Black 1991). These large populations are beginning to have a substantial impact on the vegetation communities in arctic areas, thus potentially affecting a range of plant and animals.

The Svalbard Barnacle Goose is unique and perhaps doubly useful as a study species because researchers have been able to track individuals throughout their range, from the colonies in Svalbard, during migration to Bear Island, to the Solway Firth in northern Britain, turning north again to the archipelagoes of Helgeland and finally returning to Svalbard. With some effort WWT has been able to track about 25% of the population (currently 3500 individuals), recording the survival and reproductive performance of 95% of the sample each year. This track record boasts greater success than any other waterfowl study in the world. Conclusions from this study are therefore well used to steer the conservation and management of goose and other waterfowl populations throughout the Northern Hemisphere if not globally.

The Norwegian and British governments have realised the potential of the study and have come together to design a Flyway Plan which outlines the background and future directions. This paper summarises the findings of WWT's arctic goose research and outlines the need and direction for further ecological research in the field.

### WWT's Barnacle Goose project: a study in individual and population behaviour

The aim of this project is to identify the proximate and ultimate factors that influence reproductive performance and survival of the Svalbard Barnacle Goose and to determine how various individual strategies affect population size, distribution and productivity over time. The study is grounded in ecological and evolutionary principles and ranges from individuals to flocks, cohorts, breeding colonies and sub-populations. Since the geese are vegetarians we spend much of our time studying their food and feeding ecology, so WWT are able to contribute to the conservation and management of the wetlands [including the arctic ecosystem] and inland habitats which the birds exploit. Since 1970, when the study of individuals was initiated, 61 scientific papers and three major books have arisen which have been largely dependent on this project: *Wild Geese of the World* (Owen 1980), *Waterfowl Ecology* (Owen & Black 1989), and *Partnerships in Birds - the study of monogamy* (Black 1996).

WWT recognises the importance of long-term studies in order to answer increasingly complex questions. Many of these questions are of an applied nature and will probably continue to be relevant to management planning. In addition, the project contributes to a wide range of fields and disciplines including foraging ecology and competition, habitat use, energetics, demography, population dynamics, biparental care, social evolution, life history strategies, mating systems, goose plant interactions and reserve management. The project supplied the first plenary presentations of the 7th and 8th Arctic Goose Conferences, in San Francisco in 1990 (Owen) and Albuquerque in 1995 (Black).

The study is sustained by WWT staff and major contributions from the Universities of Birmingham, Bristol, Cardiff, Groningen (The Netherlands), Queens (Kingston, Canada), Oslo (Norway), Oxford, Rennes (France) and Tromsø (Norway). Among government organisations, the Directorate for Nature Conservation, Fylkesmannen i Nordland, Norsk Polarinstittut and Syssyelmann på Svalbard, have played important roles in Norway and SNH, EN and JNCC in the UK.

**Research needs and future studies**
This section is drawn from a review of the **Flyway conservation and management plan for Svalbard Barnacle Geese** (Black 1996). Whilst previous research points to areas where density dependent effects are occurring, we have a long way to go in quantifying the causal, functional and behavioural responses that influence the distribution and dynamics of this population. In particular, there are three developments in the recent history of the Svalbard Barnacle Goose that need our attention. We need to assess what impact the following human and natural events may have on the population.

a) The effect of increased density of birds in Svalbard in the form of the fluctuating reproductive performance of established colonies, the appearance of satellite colonies and the response of and potential deleterious effect on arctic vegetation to persistent goose grazing.

b) The 'managed' distribution of foraging flocks during winter in Scotland and England, in the shape of the SNH Goose and Merse Management Schemes, and any further initiatives to change the grazing opportunities in winter.

c) The discovery of an agricultural food source during spring in Norway (i.e. currently used by 23% of the population) and the 'managed' redistribution of the geese that will be implemented by Norwegian managers.

Further studies are required that may affect Svalbard; these are not listed in order of priority.

a) Further quantify which individuals are responsible for continued growth in the population, their qualities, strategies and habitats.

b) At the Ny Ålesund colonies, investigate the proximate factors that are responsible for the density dependent decline in reproductive and survival parameters, namely the interaction between the geese themselves (social regulation and kin selection) and their food plants (foraging ecology and long-term plant phenology).

c) Through a series of annual surveys identify the status of vegetation communities at each of the main goose areas in Svalbard to assess where the vegetation community is in the continuum towards degradation due to overgrazing.

d) Detect and assess the implications of any further discovery of additional feeding areas, staging areas and/or nesting sites, i.e. inland expansion or short-stopping.

e) Determine the occurrence and significance of the gene flow that occurs between and within Barnacle Goose populations.

f) Besides identifying the precise degree and nature of site fidelity and movements on an individual level, determine how great the variation in habitat quality must be before geese abandon traditional haunts.

g) Further identify the interaction between Barnacle Geese and other species that compete for the vegetation and/or nest space; i.e. Light-bellied Brent, Pink-footed Geese, Eider Ducks and the Svalbard Reindeer.

h) Establish the significance of Bear Island as an autumn staging area to the geese.

**The relevance of the Ny Ålesund flock**
The Ny Ålesund flock (n=650 individuals), of which 70% are individually marked, and where the flock has become tame, enabling detailed observations to be collected at close quarters, provides an unprecedented opportunity to investigate the proximate factors that are responsible for the density dependent decline in reproductive and survival parameters, namely the interaction between the geese themselves (social regulation and kin selection) and their food plants (foraging ecology and long-term plant phenology). It would be advisable for funding bodies to support a long period of research on this flock.





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Black JM, Cooch EG, Loonen M & Owen M - Body size variation in a barnacle goose metapopulation: the effect of temporal and spacial scale.

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Rowcliffe M, Pettifor RA, Black JM & Owen M - Population viability of a small but increasing population of barnacle geese.

updated Feb 1996

# Behaviour and physiology of geese and other animals

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We have (had) two projects on Svalbard on the barnacle goose. **The first** was concerned with the development of the musculo-skeletal system and of the aerobic capacity of the locomotor muscles of the goslings in preparation for their first migration to southern Scotland. Basically, samples were taken from goslings in Ny-Ålesund of progressively increasing age, up to 7 weeks, when they become flighted and then from goslings at Hornsund between 8-12 weeks of age, up until they migrate. Samples were also taken at a similar times from a captive population in Birmingham. Basically, we found that, at least up to fledging, the captive population are similar in their developmental and physiological responses to those of the wild geese. Body mass increases rapidly and linearly with age (up to 7 weeks) and body composition is relatively lean (6 mg fat per g body mass) and skeletal size reaches adult dimensions. However, body mass continues to increase beyond 7 weeks, but consists primarily of lipid deposition (up to approximately 150 mg fat per g body mass), which is correlated with hypertrophy of the flight muscles. At 3 weeks of age, the muscles of the legs comprise approximately 13% of total body mass, whereas the pectoral muscles (major flight muscles) are a mere 1.5% of body mass. By the time they are ready to migrate, the leg muscles constitute just under 7% of body mass while the pectorals are approximately 17% of body mass. Beyond 7 weeks, there is a direct relationship between body mass and masses of the cardiac and pectoral muscles (Bishop *et al*, 1996. J. Zool - in press).

Citrate synthase (CS) is a mitochondrial enzyme and is a good indicator of the relative oxidative capacity of locomotory muscles in this species (Bishop *et al,* 1995 Am. J. Physiol. **26**, R64-R72). The mass-specific activity of CS in the pectoralis muscle increases in a similar manner to that of its mass, with a relatively large increase between weeks 5 and 7. In contrast, the activity of CS in a leg muscle declines after fledging. The concentration of plasma thyroxine ($T_4$) also increased with age, in parallel with the mass and CS activity of the pectoral muscles. Current work, on the captive population, is investigating the role of $T_4$ in the development of mass and oxidative capacity in the flight muscles.

**The second** project is concerned with the behaviour and energetics of the geese, with particular interest in incubation and migration. We are using satellite transmitters (or platform transmitter terminals - PTTs) attached to the outside of the geese to monitor their behaviour after they leave Ny-Ålesund and during migration. Over two years now (1994, 1995) we have found that after leaving Ny-Ålesund, the geese spent about 3 weeks in the Dalen of Nordenskiold (and they then travelled to Bear Island, where they stayed for 4-11 days. From there, they travelled to Scotland, via the coast of Norway. There may have been occasional short stops on off-shore islands.

We have been less successful on the energetics side, where we implant purpose-built heart rate data loggers (HRDL - Woakes *et al* 1995 Med. Biol. Eng. Comp. **33**, 145-151) into females that are known breeders before nesting and into adult birds during the moulting period. The former group are captured during the moulting period of the same year and the latter during the moulting of the following year. A combination of bad weather at the beginning of the season and failed loggers has meant that we have only acquired data from one incubating and one non-incubating female during the nesting period. There are clear differences in the heart rate ($f_H$) data between the two, indicating that incubation is energetically more costly. When we have acquired sufficient data, it will be possible to convert $f_H$ into oxygen uptake ($\dot{V}O_2$) using the relationship obtained by Nolet *et al* (1992 Physiol Zool **65**, 1188-1216). The HRDLs have been modified so that they should now store data for a whole year. This year we hope to obtain $f_H$ data relating to last year's migration. In order to determine the energy cost of the migration, we shall calibrate $f_H$ against $\dot{V}O_2$ for geese trained to fly at different speeds in a large wind tunnel.

Future work will involve year round recordings from HRDLs with much larger memories than the current models and, perhaps, application of the $f_H$ technique to other marine birds and to marine and terrestrial mammals (*cf* our work with British Antarctic Survey on marine birds and mammals:- Butler *et al,* 1992, J. exp. Biol. **170**, 35-42; Bevan *et al*, 1994, J. exp. Biol. **193**, 119-137; Bevan *et al*, 1995a, Phil. Trans. Roy. Soc. Lond. B **350**, 119-131; Bevan *et al*, 1995b, Physiol. Zool. **68**, 855-877; Butler *et al*, 1995, Braz. J. Med. Biol. Res. **28**, 1307-1317). It might also be possible to use, with captive seals, an instantaneous air flow and gas exchange system that has already been used with grey seals (Reed *et al*, 1994, J. exp. Biol. **191**, 1-18).





**Scientific Seminar in Cambridge, UK, February 28-29.**

**Ecotoxicology in seabirds and marine mammals**

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As part of the international Arctic Monitoring and Assessment Programme (AMAP) the Norwegian Polar Institute (NP) has carried out a survey of contaminants of seabirds and marine mammals in the Barents Sea and Svalbard area. The aim of this study has been to obtain baseline information on the environmental status of Arctic animals as part of an ongoing international effort to fill knowledge gaps. The monitoring data has also been used as a base for studies within ecotoxicology of Arctic animals.

The Barents Sea is highly productive and is inhabited by one of the largest concentrations of seabirds and marine mammals in the world (Sakshaug 1994). Until some years ago the Barents Sea and the Svalbard area were considered to be unpolluted and remote areas far from industrial activities or other sources of anthropogenic pollutants. In recent years, however, several investigations have been carried out suggesting the existence of long-range transport of various pollutants, such as radionuclides, trace metals and organo-chlorines, from industrialized to Arctic areas (Muir et al. 1992). This transport may lead to the accumulation of pollutants in marine ecosystems of polar regions (Waldichuk 1989). Top predators of these food chains, such as mammals and seabird species, are particular target organisms of this accumulation.

Monitoring studies of radionuclides found in seabirds and marine mammals from Svalbard and the Barents Sea areas have revealed values at background levels, even in seabird tissue samples collected on Novaja Zemlja. Several investigations of trace metals in seabirds and marine mammals from Svalbard and the Barents Sea areas have also indicated low levels, when compared to the Baltic and the North Seas (Savinova et al. 1995). Interspecific differences between the accumulation patterns of these pollutants have been found in seabirds and marine mammals. However, these differences are mainly explained as a result of feeding at different trophic levels.

With regard to environmental pollutants in Arctic animals the greatest concern has been towards persistent organic pollutants (POPs), and especially polychlorinated biphenyls (PCBs), which have been detected in considerable concentrations in Arctic marine top predators, such as the glaucous gull and polar bears collected at the south eastern part of Svalbard (Skåre et al. 1994, Gabrielsen et al. 1995). Our studies suggest that PCBs are the greatest threats to Arctic species today. Because PCBs have a low water, and a high lipid, solubility it concentrates in fat tissues and biomagnifies in food chains. Since fat is an important body resource for Arctic animals the PCBs may have a dangerous effect on polar bears and glaucous gulls.

In 1972 the first two papers were published about the presence of PCBs in seabirds from the Barents Sea area (Bourne and Bogan, 1972) and in ringed seal from the Canadian Arctic (Holden, 1972). During the past decade numerous studies of seal blubber collected both in the Canadian and from the Norwegian Arctic confirm levels around 1-6 ppm (lipid weight) (Carlberg and Bøler 1985, Muir et al. 1992, Daelemans et al. 1993, Espeland 1993). In polar bear blubber large individual and geographical differences have been found in samples collected in Alaska, Canada and Svalbard. The levels of PCBs in polar bear blubber samples was lowest (1-6 ppm) in Alaska and Canada and highest (4-55 ppm) in samples collected at the south eastern part of Svalbard (Norstrøm et al. 1995, Bernhoft et al. 1995). In seabirds there are also large interspecific and geographical differences in PCB levels. Birds foraging at lower trophic levels (i.e. common eiders and little auks) have low PCB levels in fat tissue while the glaucous gull, the most important avian predator in the Arctic, has the high levels (Savinova et al. 1995). In glaucous gulls the highest PCB levels were found in birds collected on Bear Island. In liver from glaucous gulls collected on Svalbard a PCB level of 1 ppm was found (Savinova et al. 1995) while in the liver of dying birds on Bear Island the concentrations ranged from 1-32 ppm (Gabrielsen et al. 1995).

The precence of high PCB levels in polar bears and glaucous gulls has been a cause of concern since the tolerance of Arctic animals to xenobiotics such as PCBs remains largely unknown. Since PCBs are very lipophilic they can easily cross cell membranes and cause damage to cell structures and influence central biological processes. PCBs may affect immune functions, enzyme systems, vitamins and hormone status and may cause reproductive failure in some species.

In polar bears preliminary data suggests that vitamin A (retinol) and thyroid hormones can be used as biomarkers for the exposure of polar bears to PCBs (Skåre et al. 1994). The PCB levels found in polar bears in this area are higher than the value assumed to have a negative effect on the reproduction of seals from the Baltic Sea (Bergmann and Olsson 1985).

The Norwegian Polar Institute will in the future continue monitoring studies of Arctic seabirds and marine mammals in order to observe levels and trends of different pollutants. The institute will also continue ecotoxicological investigations of POPs and their effects on seabirds, seals and polar bears at Svalbard and in the northern part of the Barents Sea. These investigations will include both field and laboratory studies in order to monitor the effects of PCB pollutants on these animal's biochemistry, physiology and immunology. In order to reveal potential effects on reproduction of polar bears and glaucous gulls these biological effect studies will be combined with ecological effect studies (on individuals and populations).

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# Marine Mammals

Ian Gjertz

**Background**
The three categories of marine mammals found in Svalbard are: Seals, Whales and Polar Bears.

Seals:
6 species of seal are encountered in Svalbard waters: Ringed seal (*Phoca hispida*), Bearded seal (*Erignathus barbatus*), Harbor seal (*Phoca vitulina*), Walrus (*Odobenus rosmarus*), Harp seal (*Phoca groenlandica*) and Hooded seal (*Cystophora cristata*).

Ringed seals are by far the most common seal in the Kongsfjorden area. They are found here year-round. Bearded seals are not equally abundant, but are the second most common seal and are also found year round. Harbor seals are the least common seal in Svalbard and are predominantly found along the coast of Prins Karls Forland, but this species can occasionally be encountered in Kongsfjorden. Walruses are also not common here, but they are increasing in numbers and can be occasionally be encountered in the outer parts of Kongsfjorden. Hooded seals are rare in this area, and small groups of Harp seals are occasionally encountered passing through the area on feeding migration.

Whales:
The most common species, at least in the summer season is the White whale (*Delphinapterus leucas*). Apart from this Fin whales (*Balaenoptera physalus*)and Minke whales (*Balaenoptera acutorostrata*) are regularly observed in Kongsfjorden. Other whales that can be encountered are Killer whales (*Orcinus orca*), White-beaked dolphins (*Lagenorhynchus albirostris*) and Humpback whales (*Megaptera novaeangeliae*), but they are uncommon.

Polar bears:
Kongsfjorden is not regarded as important polar bear habitat. However bears are more often than before being observed there in spring.

**Status on marine mammal research in Svalbard.**

The interest for marine mammals in Svalbard dates back to 1603, but science was not part of the issue then. Apart from scientific work on polar bears, which started in Svalbard in the 1960s, little scientific effort was put into research on other marine mammals before the 1970s.

Seals:
From the late 1970s and up to today there has been continuos research on seals in Svalbard. The core area for this research has been Kongsfjorden, where annual studies have been conducted on ringed seals since 1979. Annual research on bearded seals in Kongsfjorden started in 1993.

Ringed seals:
The scientific work on ringed seals in Svalbard has covered a wide range of topics. A review of all work that has been done was presented by Christian Lydersen, Norsk Polarinstitutt.[1]. This covers: *Abundance and distribution, Population parameters, Growth, Feeding, Predation, Breeding, Breeding energetics, Diving, Thermoregulation, Seasonal changes in body mass and composition, Seasonal changes in sex organs, Annual energy budgets, Diseases and parasites, Pollution, and Management.* A large portion of this work has been conducted in the Kongsfjorden area.

Bearded seals:
The first work on bearded seals from the Svalbard area was published in 1973, and dealt with population dynamics and aging techniques. Little or no work was thereafter done on this species until 1993. Since then several studies of bearded seals have been, or are being, conducted primarily based in the Kongsfjorden area. These cover: *Population parameters, Growth, Feeding, Breeding, Breeding energetics, Diving, Satellite telemetry, Pollution, Behavior, Acoustics,*

Whales:
There has been very little research done on whales in Svalbard. Some surveys have been flown, and whales sampled off the coasts, but apart from this the first study on whales in Svalbard was a satellite tagging project on White whales in 1995.

Polar bears:
Scientific research on polar bears has been undertaken more or less continuously since the 1960s. This research has covered topics such as: *Abundance, Distribution, Migrations, Breeding, Breeding behavior, Population parameters, Feeding, Pollution, Interactions with humans, Energetics, Genetics, and Parasitology.*

## Future scientific research in Svalbard/ Ny-Ålesund

Future work in Ny-Ålesund should focus on the ringed seal and bearded seal. This because these seals are present all year and are common. There is furthermore a large amount of scientific data available on ringed seals both from the Arctic in general and Kongsfjorden in particular. Ny-Ålesund's location and excellent logistics offer unique opportunities to conduct year round studies on different aspects of seal biology. Adult ringed seals, and possibly also bearded seals, are territorial and return to the same sites each year. This suggests that it would be possible to conduct long term ecotoxicological studies on these seals, studies that might be difficult in other areas of the Arctic. The planned marine biological buildup in Ny-Ålesund offers the opportunity to conduct detailed studies of the food web in the fjord and to study the seals feeding habits and energetic requirements throughout the year, and especially in the winter season. The area should be well suited for behavioral and physiological studies, especially using telemetry and/or acoustical methods during winter.

[1] Lydersen, C. 1996. Status and biology of ringed seals (Phoca hispida) from Svalbard. NAMMCO Scientific Committee Meeting, Torshavn, Faroes, February 1996. SC/4/RS/4: 26 pp



Presentation to: 'Ecosystem studies in the Ny-Ålesund area' BAS' scientific seminar Cambridge, UK, Feb. 28 - March 1, 1996.

**Vegetation reindeer dynamics.**
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*Present activity.*

In 1978 I transferred twelve reindeer from a densly populated to an ungrazed area on Svalbard and have subsequently monitored the population. Some vegetation area estimates and detailed mapping had been carried out ~~by use of different methods~~ before the reindeer were introduced .The population increased exponentially with an average annual growth rate of 25 % during 15 years and declined sharply from about 400 to about 100 animals in 1993. Concurrent changes in the vegetation cover have be observed, but is has not been possible to establish projects undertaking quantiative studies of the vegetation's responses to grazing and with a resolution that fits our possibillities for observations of reindeer.

A simple nonlinear deterministic model, named REIKA, for reindeer vegetation interactions have been constructed (manus in prep.). Besides employing a conventional expression for reindeer population growth, the model assumes that the available grazing area is regulated downwards by the number of reindeer present in the area, i.e. by the reindeer density. It also assumes that the available grazing area is incremented by a vegetation growth factor if the reindeer density is low. This means that the grazing is considered as a rapid process that might override vegetation growth.

The model parameters might easily be fitted to make the model replicate the reindeer population development at NyÅlesund, and with a different set of parameter values it also simulate the observed fluctuations in populations size in Adventdalen in an interesting manner, also when perturbations due to 'bad winters' are excluded (Fig 1).

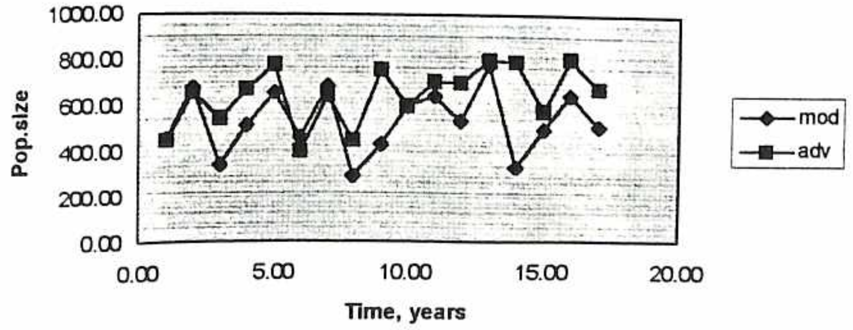


Fig.1. Comparison of observed (rectangles) and REIKA simulated (tilted rectangles) fluctuations in the population size of Svalbard reindeer in Adventdalen. The vegetation responses (not shown in the figure) regulating the the population size are speculative and construed from litterature.

Considering that the reindeer presumably strongly affects both plant species' abundance and ecosystem structure and function, both above and below ground a project on herbivore vegetation interactions on Svalbard seems warranted.

*Directions for further research.*

A project on reindeer vegetation interactions should pay critical attention to that the scale or resolution of the data collected from the vegetation agree with the grazing habits of the reindeer. This means that grazing effects on a high number of small and scattered vegetation patches on poorly vegetated areas must be recorded, and that we can not expect that satellite data have the necessary resolution. Even false colour aerial photographs with scale 1:10000 may be insufficient- partly due to resolution problems and partly due to the difficulties with distinguishing between the spectral signatures of soil and rocks and lichens and other dark coloured plants.

Besides the unresolved problems regarding compensatory growth and how grazing may have special effects on reproduction, or elicit defence responses in the plants (see refs.) it is important to keep the effects of both microtopography and snow characteristics in mind for a Svalbard project. Both snow cover and stones, small rocks and crevasses may shelter the plants from grazing and thus affect the potential for regrowth. It should be realised that also the position of ice layers in snow will influence the availability of the plants to grazing reindeer.

Finally, a project on reindeer vegetation interactions should also include areas where the grazing has been going on for a longer time than at NyÅlesund in order to elucidate the change from domination by lichens to vascular plants that might be expected as one of the a long term effects of grazing.

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## Marine Ecological Studies in Ny Ålesund in 1994 - Experiences, Results and Perspectives


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### Background

Scientists of the Institute for Polar Ecology (IPÖ) at Kiel University are engaged in both marine and terrestrial research in Arctic and Antarctic regions. One ongoing research project in Arctic waters is GRIEMSEA ("German-Russian Investigations on the Ecology of the Marginal Shelves of the Eurasian Arctic") which primarily consists of a series of shipboard field studies in the Laptev Sea. In addition, however, station-based investigations on selected species are included as well. The rationale of this approach is that ecophysiological as well as seasonal studies should be performed at a permanent coastal Arctic research station rather than during shipboard expeditions because the former generally provides better lab facilities and easier access to live organisms over a longer period.

The land-based research campaign was carried out in the "Nansen Lab" of the Norsk Polar Institutt in Ny-Ålesund (Spitsbergen). Consecutive sojourns of five IPÖ staff members (Hinrich Hanssen, Katja Hinz, Michaela Mayer, Michael Schmid, Christopher Zimmermann) and a Polish guest scientist from the Institute of Oceanology in Gdansk (Slawomir Kwasniewski) allowed continuous investigations on zooplankton, benthos and fish over nearly 5 months, thus covering a period from the beginning of May ("late spring", with the Kongsfjord being still ice-covered) until the end of September ("early fall").

### Selected Results

#### *Zooplankton*

Seasonal variation of the Kongsfjord zooplankton fauna was investigated by weekly samples taken with a hand net (40 cm diameter, 100 µm mesh) between May 13 and September 22 on a "routine" station near Ny Ålesund. In addition, water temperature, salinity and Chl a concentration in the water column were measured in five depths between 0-20 m. During the study period, four consecutive phases, differing in zooplankton composition and abundance, were identified (Kwasniewski et al., in prep.). In the summerly zooplankton distribution in Kongsfjord, examined at four stations in three depth strata during a cruise of the Polish vessel "Oceania" in June 1994, six distinct species assemblages were delineated (Kwasniewski et al., in prep.). For three dominant coastal copepod genera (*Pseudocalanus*, *Microcalanus*, *Oithona*), functional relationships between body mass and size were established over size ranges from eggs to adults (Hanssen, in prep). For *Pseudocalanus*, grazing rates were experimentally investigated in relation to food supply. The rates measured fell into the range reported for boreal copepods of similar size (Hanssen, in prep.).

#### *Fish*

The reaction of selected fish species (*Boreogadus saida*, *Myoxocephalus scorpius*, *Anarhichas minor*) to chemical and optical stimuli was investigated by assessing respiration and activity patterns. The experimental setup basically consisted of a continuous measurement of the oxygen uptake of a single individual in an intermittent-flow respirometer while monitoring concomitantly locomotory movements with a infra-red video camera over a period of several days. The fish specimens used for these ecophysiological studies were caught in the Kongsfjord using a fyke net or dredge. For several days before the measurements, they were maintained in cooled aquaria for acclimation. During the trials, different conditions of the test animals (acclimation, routine metabolism, spontaneous activity) as well as different responses to varying stimulations were detectable. The experiments were performed in the framework of a broader comparative study contrasting the response of fish from different regions and of different ecotypes (Zimmermann, in prep.).

***Note on terrestrial investigations in Ny Ålesund***

Prior to 1994, the lichen *Certraria nivalis* was investigated in Ny Ålesund in the framework of a comparative study along a latitudinal gradient from the Austrian Alps to Svalbard. The pattern in the intraspecific variation in morphology and physiology indicated that the population in Svalbard represents an extreme ecotype within the 'northern' geographical group of this species (Schipperges et al. 1995).

**Experiences**

The research campaign in Ny Ålesund in 1994 was primarily a pilot study. A principal objective of this sojourn was to assess the feasibility of various marine ecological investigations. The experiences will help to develop well-designed programmes for future research in Ny Ålesund. Generally, we found good conditions for scientific work. The lab was sufficiently well equipped for our purposes, and the well-working supply with running sea water allowed the construction of a flow-through system for maintaining live organisms - the most important prerequisite of the intended ecophysioligical studies. However, there were also some shortcomings which hampered the research work. The most severe drawbacks were the lack of temperature-adjustable cold rooms as well as of a vessel of sufficient size to deploy towed sampling gear - a fact impeding particularly the benthic investigations. We are confident, however, that the planned establishment of a large-scale research facility in Ny Ålesund will eliminate the small shortcomings we encountered in 1994 and improve the conditions for marine studies.

**Perspectives**

In July 1996, the IPÖ will organize a student's excursion to Svalbard which includes marine as well as terrestrial research activities. Based on the experiences gathered in 1994, future investigations are being planned, preferably to be performed in the framework of a larger (international and multidisciplinary) project as it was outlined in the BIODAF proposal in 1995. Our intended studies will cover all three marine sub-systems (sea ice, water column, and seabed) and focus on the interrelationships between the different ecological compartments.

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**Initiatives and planned activities by the Norwegian Polar Institute. The plans are summarized in point form below.**

by Stig Falk-Petersen

**1. ECOSYSTEM STUDIES IN THE NY-ÅLESUND AREA**

The biodiversity and fluxes in glacial arctic fjords (BIODAFF) Ny-Ålesund LSF

**2. A EUROPEAN PROGRAM FOR RESEARCH IN THE ICE-COVERED SEAS OF THE BARENTS REGION**

Transport processes, climatic change and contaminant transfer in the coastal zone of the Eurasian arctic (KAZAK)

**3. ECOLOGICAL PROCESSES IN THE MARGINAL ICE-ZONE OF THE NORTHERN BARENTS SEA (ICE-BAR)**

**1. ECOSYSTEM STUDIES IN THE NY-ÅLESUND AREA (BIODAFF)**

**1. Analyses of biodiversity**

Statistical analyses of biological and environmental change.

**2. Studies of the physical environment.**

Oceanographic-, glaciological - and Sedimentological processes

**3. Biodiversity and energy flow in the sympagic and pelagic communities.**

Primary production of pelagic and ice-associated algae

Structure and dynamics of Arctic fast ice communities

Macrofauna in ice- and sub-ice habitats

Mesozooplankton communities; seasonal succession, energy transfers

Lipid transformation processes

**4. System-ecology, taxonomy and diversity of benthic communities**

Successional change in benthic communities and the role of carbon supply, disturbance and post-glacial age in determining benthic diversity in glacial fjord

Ecology of rocky bottom organisms in the sublittoral and benthic fish communities

Comparative taxonomic studies of poorly known but ecologically important invertebrate groups in Arctic fjords

**5. Synhtesis:** Ecosystem dynamics in glacial Arctic fjords

**2. A EUROPEAN PROGRAM FOR RESEARCH IN THE ICE-COVERED SEAS OF THE BARENTS REGION**

**A. Climate, ice production and oceanography**

**B. Biogeochemical and carbon fluxes: riverine input and sedimentological processes**

**C. Biodiversity of arctic coastal ecosystems and biospheric processes**

**A. PHYSICAL OCEANOGRAPHIC PROCESSES**

Regional circulation and hydrography

Transport and spreading of river water on the shelf

Baroclinic wind-driven, coastal circulation

Tides and storm surges

Fast ice formation
Frazil ice production and sediment entrainment
Sea ice transport in the kara-barents region

**B. BIOGEOCHEMICAL AND SEDIMENTOLOGICAL PROCESSES**
Transport processes of particulate and dissolved matter
Organic-carbon-flux: surface-water productivity vs. Terrigenous input

**C. BIODIVERSITY OF ARCTIC COASTAL ECOSYSTEMS, AND BIOSPHERIC PROCESSES**
Determine how freshwater input in sediment loads from large rivers affect the primary production
Assess the occurrence of phytoplankton at a multitude of scales by satellite color scanning
Determine which physical and biological factors that most strongly structure ice-fauna and benthic communities in the vicinity of large rivers (i.e. Pechora, ob and yenisei)
Understand how the pulsed physical factors structure the primary production and biodiversity of ice-fauna and benthic communities in the coastal zone
Determine if strong coupling between pelagic and benthic production results in enhanced benthic diversity
Compare life cycles of ice-associated amphipods and determine which stages are critically linked to russian coastal water
Study major factors controlling the biodiversity of marine birds and mammals in the system
Study the development of autotropic vs. Hetrotrophic communities in coastal systems that are influenced by strong freshwater pulsing, and determine how availability of particulate matter and dissolved nutrients affect the hetrotrophic food web

**3. ECOLOGICAL PROCESSES IN THE MARGINAL ICE-ZONE OF THE NORTHERN BARENTS SEA (ICE-BAR)**
***To understand the importance of the marginal ice-zone (MIZ) for the productivity and biodiversity in the northern Barents Sea***
Determine how oceanographic and ecological processes change from open ice-covered waters
Determine how physical and biological processes associated with different types of ice-edges affect primary production
Determine whether there are links between primary productivity and biodiversity in the pelagic, cryopelagic, and benthic communities
Determine the importance of the production in miz for mammals and sea birds
Study the seasonal changes in communities and life cycle strategies of important species
Develop seasonal and annual budges for the fluxes of organic matter, coupling the pelagic - cryopelagic - benthic subsystems



## Planned and ongoing marine biological research of the Alfred Wegener Institute for Polar and Marine Research (AWI), Bremerhaven, Germany

CHRISTIAN WIENCKE

This article summarizes the contents of 4 projects of the AWI on the ecology of the Kongsfjord which have already started or will start 1996/97. There are two benthic projects, the first of which focusses on the effect of UV radiation on marine macroalgae and the second on seasonal and successional patterns in soft-bottom macrofauna. The third project deals with life cycles and reproduction of calanoid copepods, whereas the last project is devoted to sea ice biology.

Effects of ultraviolet radiation on marine macroalgae
(C. Wiencke)

Recent stratospheric ozone depletion has caused a significant increase of UV radiation especially in the Antarctic but also in the Arctic and other parts of the northern Hemisphere. Preliminary studies show the deleterious impact of UV radiation on primary production of marine macroalgae, which play an important trophic role and provide shelter for many marine organisms. The aim of the project is firstly, to study the effect of UV radiation on primary production of marine macroalgae on the ecosystem, organismic and (sub-)cellular level. Secondly, the existence and nature of strategies against potential UV damage in these organisms will be investigated. The studies will be performed both in the field and in the laboratory. In order to evaluate the effects of UV radiation in different latitudes, the field work will be carried out in the warm-temperate, the cold temperate, and in the Arctic region (Kongsfjord). This project is within the frame of the EU Environmental and Climate programme and involves partners from Spain, the Netherlands and Germany.

The main work content of the proposed study is: 1. To measure abiotic factors, especially photosynthetic active and UV radiation, temperature and nutrient levels and their tidal, daily and seasonal variations in the various communities of the different climatic regions. 2. To screen the community structure of littoral vegetation in order to select representative species for subsequent experimental work. 3. To perform transplantation and UV exclusion experiments in the field in order to assess the responses of individual species to UV radiation from the viewpoint of occupied niches. 4. To study the influence of UV radiation on growth, photosynthesis and nutrient uptake of eu- and sublittoral macrophytes from the various climate regions in the laboratory. 5. To assess the prevention of UV damage in selected macroalgae from these regions by dynamic photoinhibition, production of screening pigments and quenching of cytotoxic intermediates. 6. To study the employment of damage repair mechanisms in the laboratory. In the end, the results of these studies will allow 7. to predict alterations in the zonation and geographic distribution of individual species as well as changes of community structure in coastal ecosystems at different latitudes in view of global climate changes.

Seasonal and successional patterns in soft-bottom macrofauna
of shallow waters in the Kongsfjord (Carmen-Pia Günther)

Focus of the project BIODAFF is to study the effects of glaciers on the marine ecosystem of Arctic fjords (Svalbard and Franz Josef Land). Seasonal ice melt of glaciers drastically reduces salinity and increases contemporary sedimentation processes by releasing/transporting sediments with the ice. By this regularly occurring disturbing event considerable mortality of pelagic as well as benthic organisms is the rule. Such effects of glaciers on the pelagic as well as benthic system shall be studied on a gradient (transect) from heavily to not affected. Qualitative (biodiversity) as well as quantitative (fluxes) aspects will be investigated in relation to the strength of the disturbing event.

The AWI will especially investigate the seasonal development of soft-bottom communities after the disturbing event with special emphasis on the recovery potential of benthos due to recruitment processes such as the availability of dispersing stages as plaktonic larvae and mobile post-larvae or adults.
By studying meroplankton, driftfauna and benthos (early bottom stages) in temporal high resolution the following questions shall be answered:

- do successional patterns as primary and secondary succession develop?
- do opportunistic species dominate at least temporarily the associations?
- which stage of succession can areas close to the inlet of glaciers reach?
- how fast can succession proceed under the specific conditions?
- which stages of the macrofauna do contribute to the recovery of the disturbed areas?
- how mobile are the post-larval and adult stages of the soft-bottom macrofauna?
- can the successional sequence be explained by the distance to undisturbed areas, current speed and mobility of organisms?
- are there behavioural adaptations in the soft bottom macrofauna to avoid or sustain stress (e.g. burrowing deeper, closing shells?)

Life cycles and reproduction of the calanoid copepods
*Calanus finmarchicus* and *C. glacialis* (H.-J. Hirche)

Due to their size and abundance, the two calanoid copepods *Calanus finmarchicus* and *C. glacialis* are key species in the Atlantic and polar waters of the Greenland Sea, respectively. Although their life and reproductive cycles have been studied intensively in the past years, there is still a large gap of information especially for the winter time, as shiptime is not available to collect samples year-round, and as a large portion of the polar shelves is inaccessible during the winter due to heavy pack ice. In the Kongsfjord persistent populations of both species are found, on which we want to focus our studies. The major goals of our studies are to describe the seasonal growth and reproductive cycle of both species in relation to phytoplankton abundance. In particular, we want to compare the data for *C. finmarchicus* from Kongsfjord with similar experiments conducted in fjords of Western Norway. Special emphasis is on the effect of latitude on the timing of gonad development and egg production in spring.This project is within the frame of the EU TASC Project (Transatlantic Study of *Calanus*)

Sea ice studies in Ny-Ålesund
(J. Weissenberger)

After a period of taxonomic and inventory work about sea ice organisms biologists have strong interests on the function of sea ice communities. This requires experimental work with sea ice communities under natural and/or controlled conditions. Ice tank experiments conducted under natural climatic conditions allow a precise measurement of both, flux parameters inside the ice and exchange parameters with the water column. We will conduct ice tank experiments in the winter 1997-98 using large volume polyethylene containers placed in the field at Ny-Ålesund. The tanks will be continuously supplied with fresh sea water. In parallel we will investigate the pack ice in the vicinity of Ny-Ålesund. The climatic conditions in Ny-Ålesund may allow an experimental time from natural freezing to melting of 8 months. Questions to be answered are:

- do organisms migrate actively from water into ice and *vice versa*?
- "who eats who" in ice and what's are the grazing rates?
- what substances are exchanged from ice to the water and *vice versa*?
- which environmental factors are controlling the ice community?
- what is the succession in the ice community and how is the succession influenced by the underlying waters?

*Workshop:*
*New directions for Arctic Ecological Research*

Ecosystem Studies
in the Ny-Ålesund Area

Cambridge, 28 - 29 February 1996

# PEPORT FROM THE WORKING GROUP ON MARINE BIODIVERSITY

**Chairman Stig Falk-Petersen, reporter Mike Kendall**

**List of participants attached**

**Workshop Discussion on Marine Biodiversity Studies in Ny-Ålesund**
Discussion was based on the questions posed by Bill Heal and a summary of the discussion on each of these points is presented below.

**How can we make the maximum use of existing information ?**
There are a many disparate data sets which have been collected in the Ny-Ålesund area over the past years. These take many forms and are held in a number of differing formats. While some participants considered that it would be beneficial to bring these together in an open access data base the general opinion was that this would be too costly and impractical to set up and maintain. A far more achievable objective would be to set up a data inventory and directory which could be used to direct enquiries to the most appropriate information.

A suggestion was made that a Ny-Ålesund news letter be established, but as nobody could see how this might be co-ordinated or financed, the idea was shelved.

**Should a programme on population responses to change be established ?**
Population data is collected as an integral part of the majority of marine studies and the group saw no reason to performe this as special research.

**Define a minimum programme of long-term research.**
The group agreed that a long-term research programme was a necessity but, in the light of earlier discussions concerning the short term funding of most research, were unsure how such work might be financed. Nevertheless, it was noted that Prof.Bjorn Gulliksen at the university of Tromsø has already established a number of transects to be used for monitoring change in the fauna of hard substrata. This work is to be financed by Norwegian national funds.

**Should a Scandinavian transect be developed ?**
There is no advantage to developing marine studies along a Scandinavian transect. However, we would strongly support the establishment of a transect between Svalbard and Franz Josef and into the Kara Sea, i.e. along a gradient from the warm western Arctic towards colder areas / ice production versus ice melt area.

**What actions can be taken to develop a new programme ?**
A number of marine programs are already ongoing at Ny-Ålesund either as Norwegian funded research or in the context of international programmes. Topics currently covered include marine mammals, birds, ecotoxicology, copepod ecology (TASC), the effects of UV radiation on plant growth and biodiversity. In addition are

several geophysical programs with relevance for biodiversity studies covering oceanography, sedimentation and glaciology in progress. Other research is planned and if full value is to be obtained from these programmes some effort at co-ordination is highly desirable. It was very strongly recommended that any future research should be conducted within the context of a framework programme which should be set up as soon as it is practical to do so. To facilitate its establishment it was suggested that funds should be requested from NYSMC or the European Science Foundation. NYSMC should initiate the formation of the frame program. The framework programme would permit the establishment of Ny-Ålesund/Kongsfjord as an Arctic reference area for the marine environment. Studies of glacial fluxes and seabird ecology were envisaged as linking a marine programme to a similar programme on the terrestrial environment.

Considerable discussion centred around the discussion of the future of the BIODAFF (The biodiversity and fluxes in glacial Arctic fjords) project. This programme was developed by an international consortium and submitted to the last round of the EU MAST programme. Although it was not funded on that occasion (rating A/B) the science which it contains is considered to be of sufficient importance to merit its re submission after revision in the light of referees comments. To expedite the formulation of a revised programme an international committee containing scientists from Germany, Italy, UK and Norway was established. It was envisaged that the revised agenda would be focused more strongly on biodiversity and would include a significant component of seasonal studies. An ad hoc group consisting of Stig Falk-Petersen (co-ordinator, N); Guido di Prisca (I); Tom Pearson (UK); Dieter Pidenburg (D) were appointed to initiate the work with the new BIODAFF.

**Which questions can best be studied in Svalbard ?**
This question was answered only in terms of work which might proceed in at Ny-Ålesund or elsewhere in the Kongsfjord. The importance of the site was seen principally in the following terms

1) Logistics: Ny-Ålesund is particularly well suited for studies of Arctic biodiversity due to its all year round access from other European countries. This is of particular importance for seasonal studies which are urgently required, the bulk of earlier research having been carried out in summer.
The availability of a marine laboratory at such a high latitude facilitates the performance of experiments which cannot be carried out onboard a research vessel due to the sensitivity of either the equipment or the biological system under study. This is particularly important for physiology experiments. There are currently plans to expand and uppgrade the marine lab. which is a part of the NY-Ålesund LSF.

2) The long history of research in the area. Studies of glaciology and hydrography in the fjord were seen as particularly valuable

**Which questions require international collaboration. ?**
To marine scientists this seemed a rather strange question as in this field of research there is a long tradition of international collaboration. Not only does this ensure that the work is done by the most appropriate scientists but trans-national cross disciplinary research projects tend to have benefits over and above the sum of their component parts.



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# TERRESTRIAL group

Relevance to

**EU Themes**

**Global change**

**Human Environment interactions**

**Reference area** - simplicity applicable to more complex

**1 Integration of existing data and knowledge in models/ scenarios/ hypotheses**

Outcome

Establish inventory of data - historical site specific

Information on process rates to predict response to change, scale

Models that identify what knowledge is missing and which parameters are sensitive

Will avoid repetition

Data

Paleo-ecology record in freshwater sediments - very dynamic lots of recent change

Historical observations, mapping (1920's Oxford expeditions)

Long-term monitoring
- physical parameters
- plant community structure
- population size

Recent experimental work -changing temperature, water and nutrients on plants

## 2) Population (process) responses to changes and consequences

Adaptive strategies to natural and man-made environmental change
different approach to homeostatis in different groups of organisms

Resilience, responsiveness and stability

Integration and interdisciplinary

Scaling - spatial and temporal (seasonal and annual)

Herbivory - reindeer, geese, invertebrates

in a heirarchy

Ecosystem
I
Community
I
Population
I
Individual

Resolution

Individual variation (behavioural, ecological, genetics, physiology)
response to environmental changes which influence birth and death rates

Modelling



## 3) Long-term observations to detect rate/direction of change and consequences

Definition of minimal monitoring programme

- investigate LTR scheme and see what needed in Svalbard
- noise and signal
- permanent plots
- representative functional groups and processes
- indicator species and sensitivity of endemics

extinction and colonisation - biodiversity

**4) Transects - the role of Svalbard in comparative studies**

More Oceanic and Higher Arctic

? Systems rebounding

Changes along gradients:

Carbon fluxes - source/sinks
Tolerance to pollutants
Sensitivity to winter kill is damped down at lower latitudes
Incubation regimes in geese
Inter-specific competition - within and between sites

*Ny-Ålesund International Arctic Research and Monitoring Facility*

Ecosystem Studies
in the Ny-Ålesund Area

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## Ny-Ålesund International Arctic Research and Monitoring Facility

*The polar regions are key areas for studies of global change, and give unique opportunities for fundamental research in several disciplines. The European Arctic is the last large area of Europe with undisturbed ecosystems.*

*Within the European Arctic, the Ny-Ålesund International Arctic Research and Monitoring Facility on Svalbard is unique in its combination of high latitude localisation (79° N), easy accessibility (commercial flights almost daily with connection to Norway via Longyearbyen, access by ship much of the year), and well-developed infrastructure with highly specialised research facilities. In addition, Ny-Ålesund has prime location for environmental research such as climate change, long-range transportation of pollutants and conservation biology. The anthropogenic impacts on the surrounding environment are kept at a low level, and the ecosystems are to a large extent intact.*

*The Svalbard Treaty ensures equality of treatment of scientists from all member nations. Norwegian authorities welcome foreign research institutions to Ny-Ålesund. Germany, Great Britain, Japan and Italy have established national stations. Numerous European research groups and institutions run programmes in co-operation with the national stations. At present 150 persons can be accommodated in Ny-Ålesund.*

*The Norwegian aim is to make Ny-Ålesund into the leading high-arctic environmental research and monitoring station, where scientists from many different countries and institutions collaborate on research programmes and utilise common research facilities and infrastructure.*

Ny-Ålesund was built as a coal mining town 50 years ago. This activity ceased in 1962 after a severe accident in the KBKC mines. The first research station was established by the Norwegian Polar Institute (NP) in 1968, when the European Space Research Organisation (ESRO) opened a satellite telemetry station in Ny-Ålesund. The ESRO-station closed in 1974, and the small NP research station was the only remaining activity, apart from necessary maintenance work carried out by 3-4 persons working for KBKC.

However, research activities increased and NP moved into new facilities in 1982. In 1990, the atmospheric station at the Zeppeliner mountain (460m a.s.l.) was opened and new buildings were taken into use. The Norwegian Mapping Authority (NMA) has in 1995 established a Geodetic Station in Ny-Ålesund based on GPS and a radio telescope (Very Long Baseline Intereferometry Antenna - VLBI - 25m in diameter). The Andøya Rocket Launching Station plans to establish a facility at Ny-Ålesund to study the upper atmosphere.

The Alfred Wegener Institute for Polar and Marine Research (AWI), the National Research Council in Great Britain (NERC), the Japanese National Institute for Polar Research (NIPR) and the Italian Istituto Inquinamento Atmosferico all have their own stations in Ny-Ålesund. AWI has recently moved into a new specially constructed building. Other nations also plan stations, and several institutions from different countries run programmes in co-operation with the national institutions having infrastructure at their disposal. The Norwegian Parliament has decided that Ny-Ålesund shall be the main base for research in Svalbard and that other activities in Ny-Ålesund should be subordinated to research.

At present Ny-Ålesund offers accommodation for up to 150 persons in modern facilities. Available research installations include:

- wet and dry laboratories, and a marine biological laboratory
- electronic workshops, special rooms and buildings for electronic equipment, and instruments for ionospheric, stratospheric and tropospheric research
- atmospheric station at mountain location above the inversion layer (gondola access), ensuring minimum impacts from local pollution sources
- radiotelescope for research in astronomy and geodetic observatory
- modern data equipment with connection to the international data network (internet)
- modern telecommunication connections
- logistic support, i.e. field equipment, boats, snow-mobiles
- offices
- storage rooms

The station has two main purposes:

1. Observatory for long-term registrations of the physical and biotic environment.
2. Laboratory and research facilities for visiting scientists

## Ny-Ålesund as an observatory

- **Auroral observatory**: Riometer (Meteorological Institute in Denmark), imaging riometer (Univ. of Nagoya, Japan), VLF recorder (Univ. of Tokyo), fluxate magnetometer (Univ. of Tokyo), Magnetometer (Univ. of Tromsø, Norway), SDRS scintillometer (Phillips laboratory, USA), all-sky camera and video camera (University of Oslo), scanning spectrophotometer (Univ. of Oslo), ionosounder (Univ. of Mass., USA/ Univ. of Oslo)

- **Climate and meteorological observatory**: SAOZ - ozon in the stratosphere (Norwegian Institute of Air Research - NILU), sun radiation and albedo, long and short wave at two sites (NP, NIPR, AWI), ultrasonic detector for detection of polar low pressures (NP), Dobson spectrophotometer - ozon in the stratosphere (NP/ Univ. of Oslo), ozon sonde once a week (AWI), 2 Lidars for atmospheric research (Network for Detection of Stratospheric Change, AWI), standard meteorological parameters 3 times pr. day approx. at sea level and at 460m a.s.l. (Meteorological inst. of Norway, NIPR, AWI, NILU), aerosols in air (NILU, Meteorological Inst. of Norway, Stockholm Univ. - MISU), ozon in the troposphere (NILU), greenhouse gasses: CFC's, $NH_4$, $CO_2$, isotopes of $O_2$ and C (NILU, MISU, Univ. of Boulder, NIPR), fog/ cloud detector (MISU), cloud radar (NIPR).

- **Long range transportation of pollutants**: Pollutants in precipitation: acidity, $SO_4$, $NO_3$, $NH_3$, Ca, K, Mg, Na, Cl, radionuclides, isotopes of O and C (NILU), radioactivity in air (automatic station), ozon and greenhouse gasses as mentioned above, Hg in air, $SO_2$ in air, aerosols, PANalyzer - peroxyacetyl nitrat in air (all NILU), torpospheric ozone (NIPR), $NO_X$ in the stratos- and troposphere, different instruments (NILU, Univ. of Alaska), PUR-samplers for pesticides in air (DDT, PCB, etc., NILU), aldehyde (NILU), aethalometer for countings of soot particles.

- **Others:** Seismograph-station in the international network for detection of earthquakes (Univ. of Bergen, Norway/ AWI), reference station for GPS satellites (Tromsø satellite telemetry station), reference station for SPOT satellites (Institut Geographique National, France), hydrology - two stations for registrations of sediments and water flow in rivers (NVE), permafrost (Norwegian Hydrological Laboratory, SINTEF), arctic fox physiology (NP), continental drift, tidal water, geodetic observatory (NMA). Many visiting scientists conduct field studies in such disciplines as biology, hydrology, permafrost, glaciology, geology, sedimentation throughout the year.



## The Ny-Ålesund Science Managers Committee - NySMAC

Due to the extensive research activities and the great interest in using Ny-Ålesund as an international platform for environmental research and monitoring in the Arctic, the need for enhanced co-ordination and co-operation has emerged. To answer this need the Ny-Ålesund Science Managers Committee (NySMAC) was established in August 1994, involving all major parties with vested interests at Ny-Ålesund. NySMAC is a non-bureaucratic body with no mandate to approve or disapprove projects. The Committee has the following purpose:

- Contribute to the development of Ny-Ålesund as an internationally recognised site for Arctic research.

- Avoid negative impacts on research programmes from other activities at Ny-Ålesund.

- Minimise and mitigate environmental impacts of scientific activity conducted from Ny-Ålesund.

- Encourage co-operation between scientists and institutions present at Ny-Ålesund.

- Avoid unnecessary overlap of research programmes and negative competition between scientific institutions.

## The Ny-Ålesund Seminar

At regular intervals, NySMAC convenes Ny-Ålesund Seminars among scientists running research programmes or having an interest in Ny-Ålesund. The first Ny-Ålesund Seminar in Potsdam, May 4-5 1995, was the first in a row of seminars focusing on research at Ny-Ålesund and contributing to promote the place as an internationally leading Arctic research station.

## Future development and challenges

The aim is to make Ny-Ålesund into *the* internationally recognised Arctic environmental research and monitoring station, where European scientists and research groups can conduct high-quality research and monitoring of the natural environment.

Ny-Ålesund has most of the qualities to achieve this goal:

The high northern latitude is ideal for research on and monitoring of ozone depletion and the greenhouse effect (atmospheric chemistry), and to detect the finger-prints of climate change. Glaciers and sediments are archives of the past climate. Processes of great significance to the European climate, such as fluxes of cold water and ice out from the Polar Basin and creation of deep-bottom water in the Greenland Sea, take place around Svalbard, which is a bifurcation point for the ocean currents.

Ny-Ålesund may be characterised as a modern research station in a clean, natural laboratory. The ecosystems are simple and close to the natural situation, as human effects on the environment are minor. Local pollution sources are near-negligible. The excellent conditions for research on basic ecological and evolutionary processes may provide knowledge that has more general applications in understanding ecological theory and principles.

However, both ocean currents from south and north, riverine input from the Eurasian continent, and mid-altitude atmospheric winds bring pollution in from the heavy industrialised areas of central Europe and the eastern USA. Conditions for research on and monitoring of global pollution (transport, effects and levels) are therefore excellent, as they are in many other fields.

The Svalbard Treaty guarantees individuals from member nations equal rights of access to Svalbard for research purposes. A similar situation does not exist elsewhere in the Arctic. Svalbard's combination of remoteness, high latitude, easy accessibility, well-developed infrastructure, research facilities, and openness to foreign research institutions is unique.