Zackenberg Ecological Research Operations

13th Annual Report, 2007

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Front cover: During 2007, the field season at Zackenberg was extended until 30 October. The picture shows the new accommodation building from 2006 (rights) and the extension of the canteen from 2007 (left) on 30 September. Photo: Charlotte Sigsgaard, Department of Geography and Geology, University of Copenhagen.
Back of cover: A bifacial knife blade from the Independence I Culture (c. 2.500-2.000 BC).
The blade was found by the GeoArk Project on the south coast of Clavering Island, N.E. Greenland.
Photo: Bjarne Grønnow, SILA, 2007.

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This book is free of charge and may be ordered from
Danish Polar Center
Strandgade 102
DK-1401 Copenhagen K
Tel. (+45) 32880100
Fax (+45) 32880101
Email: dpc@fi.dk

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Executive Summary

Charlotte Sigsgaard, Niels Martin Schmidt and Morten Rasch

Zackenberg Research Station had its official ten years anniversary in 2007. However, due to very high interest among international politicians concerning climate change effects especially around the Illulissat Icefiord in central West Greenland the invited Danish and Greenlandic ministers and other notabilities were busy elsewhere in Greenland. The celebration of the anniversary has therefore been postponed to 2008.

The International Polar Year (IPY) had a slow start in 2007 due to the very late funding of the Danish contribution. The effect of IPY on the research activity level at Zackenebrg was therefore only limited in 2007. However, the field season at Zackenberg was extended by c. two months – as a Zackenberg contribution to IPY and to allow for measurements of especially carbon balance and snow related ecosystem processes during the autumn.

In 2007 we also finished the extension of the station that was initiated in 2006. The mess room was extended with c. 50 m^2 giving space for a better kitchen, a larger dinning room and a storage room for provision, and smaller changes were made in some of the older houses.

Despite the fact that the Danish IPY in practice did not really start before late in 2007, the number of scientists visiting Zackenberg in 2007 was still very high (48 Scientists visited the station in 2007) as compared to previous years (2005: 31, 2006: 33), and so was the number of bed nights spend at the station (2005: 1,091, 2006: 1,694; 2007: 1,511 (plus 173 related to the extended field season).

The field season in 2007 was characterized by a low accumulation of snow at the end of winter and an early snow melt. May was relatively cold whereas June with a mean monthly temperature of 3.3°C was the warmest registered since measurements began in 1996. July had a mean monthly temperature of 5.9°C which is average of the last twelve years. August was above average and warmer than July, – with a mean monthly temperature of 6.6°C which equals the so far warmest August in 2003. The maximum temperature of the summer was 16.4°C measured 10 July. The last part of July and the early part of August were characterized by overcast and rainy weather with primarily northern winds.

A maximum of only 0.48 meter of snow were registered at the meteorological station by the end of winter and by 13 June, the snow had disappeared at the climate station. In the two grid sites ZEROCALM-1 and ZEROCALM-2 where snow melt and soil thaw is measured throughout the field season, the onset of soil thaw was early due to the early melt and the subsequent soil thaw was above average at both sites, but not extreme. In ZEROCALM-2, the large seasonal snow patch, that normally disappears in late July or August was totally melted by 30 June.

Throughout the summer, the total precipitation (rain) was 20 mm which mainly fell in June and late July whereas August was relatively dry.

The river Zackenbergelven broke up 2 June which is relatively early compared to previous observations where break up have occurred between 30 May and 10 June. Water runoff peaked 28 July when a large flood from Store Sødal increased the discharge dramatically. A day after the peak, the runoff was back to normal. The sharp rise and fall of the water level indicate a drainage of a reservoir, -which could have been triggered by several rainy days up to the flood. Except from a small peak following a rainy period in early August an almost steady decline in runoff was observed until 19 September where another sudden increase in runoff took place. At that time, the river was covered by up to 10 cm of ice and temperatures in the valley were below freezing. The small flood followed, and may be associated with a snowfall 18 September. It was powerful enough to break up the ice and for several days the discharge was back to the same level as in the mid August.

Total runoff from the Zackenberg drainage basin in 2007 has been estimated to 184 mio. m^3.

During the flood in July, the suspended sediment concentration peaked at 2,448 mg/l and in total the transport of suspended sediment from the terrestrial to the marine ecosystem (Young Sund/Tyroler fiord) has been estimated to 51,118 ton.

The fiord ice between Zackenbergdalen and Clavering broke up 13 July, but not until 17 July there was open water all the way to the sea.

From 27 May to 28 October, CO_2 exchange between the well drained heath and the atmosphere was measured. There was a netto uptake of CO_2 from 22 June to 19 August and during these 59 days a total accumulation of 31.4 gC/m^2 was registered. Only in 2005, the period with an uptake lasted longer and the total accumulation was larger. Data from the early winter (September and October) will be presented in the next annual report together with measurements from a scheduled field season starting in March 2008

The methane flux monitoring in the fen was running from 24 June to 26 October. As for the CO_2-fluxes only data from the summer season will be presented in this report. In the period from 24 June to 30 August a total emission of 3.4 gC/m^2 was measured. Especially, the water table differed from the 2006 season by being much lower.

Compared to previous years, the snow melted early in the permanent monitoring plots in 2007. The early onset of spring was also reflected in early flowering, and 8 of 28 plots had the earliest flowering dates recorded hitherto. Also, dates of open seed capsules were generally early but no plot had a hitherto earliest date. The total number of flowers produced in 2007 was, however, low, and for some species with new minima.

Vegetation greening (NDVI) inferred from satellite images revealed that despite the early melting of the snow, landscape NDVI was around the average or below those of the previous years. In the permanent plant plots (NDVI) culminated relatively early in the season when compared to the previous years. However, 6 plots had later than average peak NDVI.

The number of arthropods caught in the window traps was the highest number caught at Zackenberg, and most arthropod species/groups were caught in very high numbers. In the pitfall traps, on the other hand, relatively few arthropods were caught. Numbers varied markedly between arthropod species/groups. The breeding bird census revealed relatively high numbers of Sanderling and Dunlin territories, whereas territories of Ruddy turnstone were found in average numbers. Red knot territories were a little above average in 2007. The number of long-tailed skua territories was found in near-average numbers, and fifteen pairs nested in the census area.

Corresponding to the early snow-melt, wader nest initiation in 2007 was fairly early, and median first egg dates were before 16 June in all four species. For ruddy turnstone, 2007 was the earliest year in terms of median first egg dates recorded so far. Wader nest success, however, was extremely low, and most nests were depredated. The mean clutch size was 3.9.

Also the long-tailed skua nests were initiated early. The average clutch size was 1.64 eggs per nest. Long-tailed skua nest success was just below average.

High numbers of barnacle goose broods were observed, but mean brood size was relatively low.

Collared lemming winter nest density was relatively high, and the second highest number registered so far. As in the last years, no nests were found depredated by stoats, although stoats were seen in the area.

The pattern of musk oxen occurrence within the musk ox census area was similar to previous years. Mean number of musk oxen per observation day were the highest hitherto. The increase in the overall proportion of younger animals, which have been ongoing since 2003, seem to have slowed down. Twelve fresh musk ox carcasses were registered, which is the second highest number so far.

Breeding by arctic foxes was verified in four dens, and a minimum of 23 arctic fox pups were registered in 2007, which is the highest minimum number recorded so far.

Arctic hares were observed in intermediate numbers.

As in the terrestrial environment, the two monitoring lakes had the earliest dates of 50% ice-free recorded so far. Lake temperature was also high. Water chemistry and chlorophyll levels, however, remained within the average values of previous years. The phytoplankton communities were dominated by chrysophytes, while Dinophytes constituted the bulk of the remaining biovolume. *Daphnia pulex* was recorded in Sommerfuglesø (no fish) and was absent in Langemandssø (with fish). The recorded densities were similar to previous years.

A total of 17 research projects were carried out at Zacckenberg Research Station in 2007. Of these four projects were parts of the Zackenberg Basic monitoring. Eleven projects used Zackenberg Research Station as a base, four projects used Daneborg as a base and two projects worked both out of Zackenberg Research Station and Daneborg.

1 Introduction

Morten Rasch

On 14 August 2007, it was ten years since Zackenberg was officially opened by the Danish and Greenlandic ministers of research, Jytte Hilden and Marianne Jensen. It was therefore originally the plan to celebrate the anniversary with a visit at Zackenberg of Danish and Greenlandic ministers and other notabilities. However due to the very high interest among international politicians concerning climate change effects especially around the Illulissat (Jakobshavn) in central West Greenland it was not possible for the invited Danish and Greenlandic ministers to pay Zackenberg a visit in 2007, because they were busy elsewhere in Greenland. As a result the celebration of the anniversary was postponed to 2008.

2007 was also the start of The International Polar Year (IPY). However, due to the very late funding of the Danish IPY contribution, the effect of IPY on the research activity level at Zackenberg was only limited in 2007. However, several Zackenberg relevant projects have received IPY funding, Danish Polar Center has received an extended funding to research logistics in relation to IPY and it is therefore expected that 2008 will be among if not the busiest year at Zackenberg ever.

In 2007 we also finished the extension of the station that was initiated in 2006 based on generous funding from Aage V. Jensen Charity Foundation. The mess room was extended with c. 50 m^2 giving space for a better kitchen, a larger dinning room and a storage room for provision. Further, two old bathrooms were converted into two new laboratories, the old provision storage was converted to a logistics storage room and a bed room, and the flooring was changed in all older buildings.

In 2007, the field season at Zackenberg was extended by c. two months – as a Zackenberg contribution to IPY and to allow for extended measurements of especially carbon balance (as part of the Zackenberg Basic monitoring) during the autumn. This autumns extension of the season will be followed by an early opening of Zackenberg Research Station in 2008 at c. 1 March.

Despite the fact that the Danish research activities related to IPY did not really start before late in 2007 (due to late funding), the number of scientists visiting Zackenberg was still pretty high in 2007 (48 Scientists visited the station in 2007) as compared to previous years (2005: 31, 2006: 33), and so was the number of bed nights spend at the station during the normal field season (2005: 1,091, 2006: 1,694; 2007: 1,511). The number of bed nights related to the extended field season was 173, giving a total of 1,684 bed nights spend at Zackenberg in 2007.

1.1 The International Polar Year

The International Polar Year (IPY) started on 1 March 2007 and will continue until 28 February 2009. For Denmark most of the activities will probably be concentrated in the late part of IPY due to a very late allocation of the Danish contribution (i.e. funding) to IPY. Some of these means were however allocated to research logistics and of them a considerable amount to extended logistics at Zackenberg during IPY. With these means it has become possible to extend the field season in 2007 with c. 2 months (i.e. until c. 1 November) and to start the field season in 2008, two months earlier than normal (i.e. around 1 March).

1.2 Extended field season

It has for long been a wish among the Zackenberg scientists (and especially the ones involved in the monitoring programs) to extend the field season and to have continuous measurement of most relevant monitoring parameters for at least one full year. Much is known about arctic ecosystem dynamics during the very short summer season. Traditionally this period has been in focus among polar scientists mainly because this is the growing season but probably also because many polar scientists are involved in teaching at universities during autumn, winter and spring. During the last years it has however become apparent that from a carbon balance perspective it does not seem that the carbon exchange in for example high arctic Northeast Greenland is limited to three summer months. Further, it is a major result from our first ten years of studies at Zackenberg that the processes controlling snow depth, density and distribution probably are among the most important physical processes in arctic ecosystems. Therefore, and despite the fact that most biological processes in arctic ecosystems definitely decelerates significantly during the winter, winter is still the season in which we can learn the most due to our present very limited knowledge about this period as compared to the summer season.

For these reasons it was decided to apply for funding for keeping Zackenberg Research Station open for the entire winter of 2007-8. However, due to limited funding we had to prioritise and it was therefore decided to keep the station open until 30 October 2007 and to open again on c. 1 March 2008. The winter opening of Zackenberg was defined as one coordinated project, '*The influence of snow and ice on the winter functioning and annual carbon balance of a high-arctic ecosystem (ISICaB)*', including several smaller research projects as well as the logistics (see section 5.4). Prioritisation between research topics and logistics issues were taken after discussions between all the relevant scientists, and we ended up with seven smaller research projects, with a logistics based on a reduced service level compared to the level during the summer and with only one logistician stationed at the station throughout the extended field season.

During the autumn of 2007 efforts were concentrated on maintaining some of the monitoring that is normally confined to the summer season and especially phenology and carbon exchange (Fig. 1.1). The extended field season ended as planned on 30 October, when Charlotte Sigsgaard from GeoBasic and Henrik Philipsen from Danish Polar Center left Zackenberg with a suitcase full of new results (Fig. 1.2). In total four scientists and two logisticians were involved at Zackenberg in the run of the extended field season. The total number of bed nights was 173.

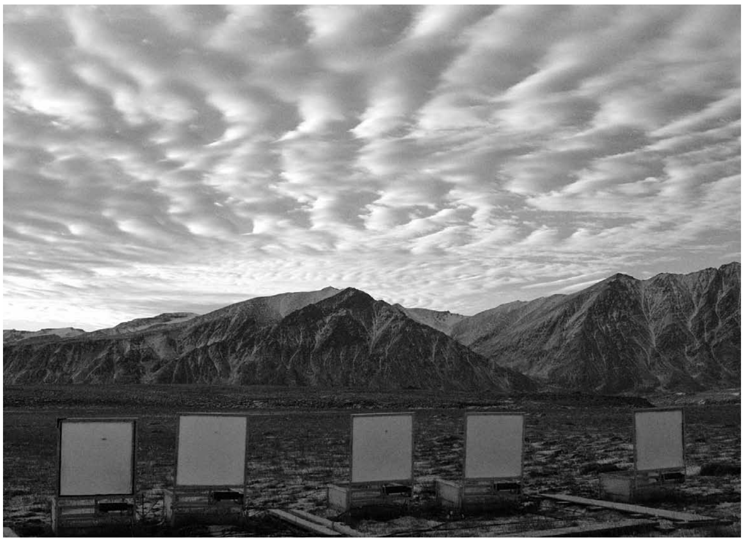


Fig. 1.1. In 2008, the field season at Zackenberg was extended by two months. During the period measurements of methane exchange was carried out using the automatic chambers that are also used during the summer. Photo Charlotte Sigsgaard.

1.3 Memorandum of Understanding with The Austrian Society for Polar Research

In 2007 The Austrian Society for Polar Research decided to place the Austrian polar research activities for the period 2008-2010 in Greenland, mostly at Zackenberg. The decision was taken shortly before the start of the field season but still it was possible for a pilot team of six Austrian scientists to visit the station for 15 days (7-22 August) in 2007. Much more

Fig. 1.2. During the extended field season people were living in the new accommodation building which temporarily also was used for laboratory, office and canteen. Photo Henrik Spanggård Munch.

activity is expected in 2008 when several Austrian research teams plan to place their arctic research field work at Zackenberg. The cooperation with the Austrian scientists will be formalised in a Memorandum of Understanding between The Austrian Society for Polar Research and the Danish Polar Center to be signed early in 2008.

1.4 Extension and restoration of the facilities

The restoration and extension of Zackenberg Research Station, initiated in 2006, was continued in 2007. In 2006 a new accommodation building (housing 18 scientists) and a new combined power station, garage and workshop were erected at Zackenberg while a boat house was built in Daneborg. In 2007 the following construction and restoration was made:

– The canteen was extended with 50 m^2 giving space for a new provision storage, a new and larger kitchen and a larger dinning room (Fig. 1.3)
– The two bathrooms in the wet laboratory building were replaced with two smaller laboratories
– The provision storage in the logistics house was replaced with an extra bed room and a storage room for logistics equipment
– New floorings were fitted in the six older houses

A group of six construction workers from the company Venslev carried out the construction and restoration work in the period 14 August-6 September. The building materials for the construction were brought to Zackenberg with the cargo ship Kista Arctica from Royal Arctic Line. Transport between the ship and the research station was accomplished by helicopter. A total of 226 helicopter slings were carried trough during the period 28-30 August to bring the building materials and the fuel for the extended field season from Kista Arctica in to Zackenberg Research Station. The construction work in 2007 was financed trough a generous funding from Aage V. Jensen Charity Foundations who also paid for the extensive construction work at Zackenberg in 2006.

1.5 Nuuk Basic, a new monitoring program in West Greenland

The Nuuk Basic monitoring program is a low arctic equivalent to the high arctic climate change effects monitoring pro-

Fig. 1.3. The new extension of the canteen building (right) and the new accommodation building (left) at Zackenberg. The canteen building was extended with c. 50 m^2 in 2008. This gave space for an extended kitchen, a new storage room for provision and a larger dinning room. The extension of the canteen building was completed on 5 September 2008. Photo Niels Martin Schmidt.

gram Zackenberg Basic, at Zackenberg Research Station. The program was established in 2006 based on a request from the Danish Environmental Protection Agency to the operators of Zackenberg Basic concerning establishment of a low arctic equivalent to Zackenberg Basic in West Greenland, near the Nuuk, and with the same components as Zackenberg Basic. The preparation for the establishment of the program started already in 2005. In 2007 the program was established in Kobbefjord close to Nuuk. The establishment of Nuuk Basic did not directly affect the work at Zackenberg, though many of the Zackenberg scientists experienced a very busy summer due to field activities at both sites.

The program has its physical base on The Greenland Institute of Natural Resources, and the institute also takes care of the logistics. The scientific coordination of the program is maintained by the Danish Polar Center.

Nuuk Basic includes mainly the same sub-programs as Zackenberg Basic (i.e. ClimateBasic, GeoBasic, BioBasic and MarineBasic but currently not GlacioBasic) and involves, on the management side, more or less the same group of people and institutions as Zackenberg Basic. The 2007 results of the program will be published in '*Nuuk Ecological Research Operations 1st Annual Report*' (Jensen and Rasch in press) that is planned to be published concurrent with the publication of this report.

1.6 GlacioBasic – a new glaciological monitoring program at Zackenberg

Approximately 20% of the Zackenberg study area is covered by glaciers. Despite that, almost no investigations have been carried out so far on the glaciers within the study area. Since the glaciers in themselves are indicators of climate change and since their response to climate change will affect other important compartments of the ecosystem (i.e. for example the water balance of the Zackenberg catchment area and accordingly also the sediment, solute and carbon flux trough Zackenbergelven), it has been considered a major lack that Zackenberg Basic does not comprise any glaciological component. For this reason, The Danish Environmental Protection Agency decided in 2007 to fund a GlacioBasic program to become an integrated part of Zackenberg Basic. The program is operated by The Geological Survey of Denmark and Greenland and will among other things study the mass balance of one of the glaciers on A. P. Olsen Land north of Zackenberg Research Station. The establishment of the program is planned for the spring of 2008 and will as such take advantage of the early opening of Zackenberg Research Station in 2008.

1.7 'High Arctic Ecosystem Dynamics in a Changing Climate'

The writing of the manuscript for the book, '*High Arctic Ecosystem Dynamics in a Changing Climate*', concerning the first ten years of monitoring and research at Zackenberg Research Station, is progressing according to the plan. We expect the book to be published in late 2007. The book will address ecosystem processes at Zackenberg in 21 chapters prepared by 63 co-authors. The book is edited by Dr. Hans Meltofte, Professor Bo Elberling, Professor Torben Røjle Christensen, Professor Mads Forchhammer and Dr. Morten Rasch and will be published as Volume 40 in Advances in Ecological Research published by Academic Press (Meltofte et al. in press).

1.8 Plans for the 2008 field season

In 2008 we expect a high activity level at Zakenberg due to the International Polar Year. The station is already booked for c. 1.800 bed nights, so we expect 2008 to be the busiest season ever. We will start the season already by 1 March when the extended spring season is initiated with a group of c. 10 scientists visiting the station. We expect the field season to continue until 1 September and if funding allows it also beyond that.

In 2008 we will not start new initiatives concerning further improvement of the facilities/logistics at the station but will instead allocate man hours on cleaning up the station after the construction work and on becoming familiar with all the new facilities.

1.9 Further information

Details about Zackenberg Research Station and the study area are collected in previous annual reports (Meltofte and Thing, 1996, 1997; Meltofte and Rasch 1998; Rasch 1999; Canning and Rasch 2000, 2001, 2003; Rasch and Canning 2003, 2004, 2005; Klitgaard, Rasch and Canning 2006, 2007) and the information is also available on the Zackenberg website (www.zackenberg.dk). On www.zackenberg.dk you can also find manuals for each of the four monitoring programs at Zackenberg together with a complete collection of all data from the Zackenberg Basic monitoring programs 1995-2007. Data can be downloaded free of charge after a simple registration of name, institution and purpose of the use of the data.

The ZERO Site Manual, also available on www.zackenberg.dk, contains information for scientists concerning more practical issues in relation to their possible stay at Zackenberg. On the same site you can also find a collection of maps from Zackenberg, a Zackenberg bibliography (1995-2007) and a collection of diaries (1998-2007) written by the Zackenberg researchers mainly in Danish.

The address of The Zackenberg Research Station Secretariat is:

The Zackenberg Research Station
Secretariat
Danish Polar Center
Strandgade 102
DK-1401 Copenhagen K
Denmark
Phone: +45 32880100
Fax: +45 32880101
E-mail: mr@fi.dk

2 ZACKENBERG BASIC
The ClimateBasic and GeoBasic programmes

Charlotte Sigsgaard, Kisser Thorsøe, Karl Martin Iversen, Mikhail Mastepanov, Julie Maria Falk, Maria Rask Pedersen, Mikkel P. Tamstorf, Søren Højmark Rasmussen, Birger Ulf Hansen, Lena Ström and Torben Røjle Christensen

GeoBasic and ClimateBasic provide long term data of climate, hydrology and physical landscape variables describing the environment at Zackenberg. GeoBasic is operated by the Department for Arctic Environment at National Environmental Research Institute, University of Aarhus, in collaboration with Department of Geography and Geology, University of Copenhagen. GeoBasic was in 2007 funded by the Danish Environmental Protection Agency as part of the environmental support programme Dancea – Danish Cooperation for Environment in the Arctic. ClimateBasic is funded by the Greenland Home Rule and run by ASIAQ, Greenland Survey. ClimateBasic includes operation and maintenance of the climate station and the hydrometric station.

The authors are solely responsible for all results and conclusions presented in the report, which does not necessarily reflect the position of the Danish Environmental Protection Agency.

The monitoring includes climatic measurements, seasonal and spatial variations in snow cover and local microclimate in the Zackenberg area, the water balance of Zackenbergelven drainage basin, the sediment, solute and organic matter yield of Zackenbergelven, the carbon dioxide (CO_2) and methane (CH_4) fluxes from a well drained heath and a fen area, the seasonal development of the active layer, temperature conditions and soil water chemistry of the active layer, and the dynamics of selected coastal and periglacial landscape elements (Fig. 2.1).

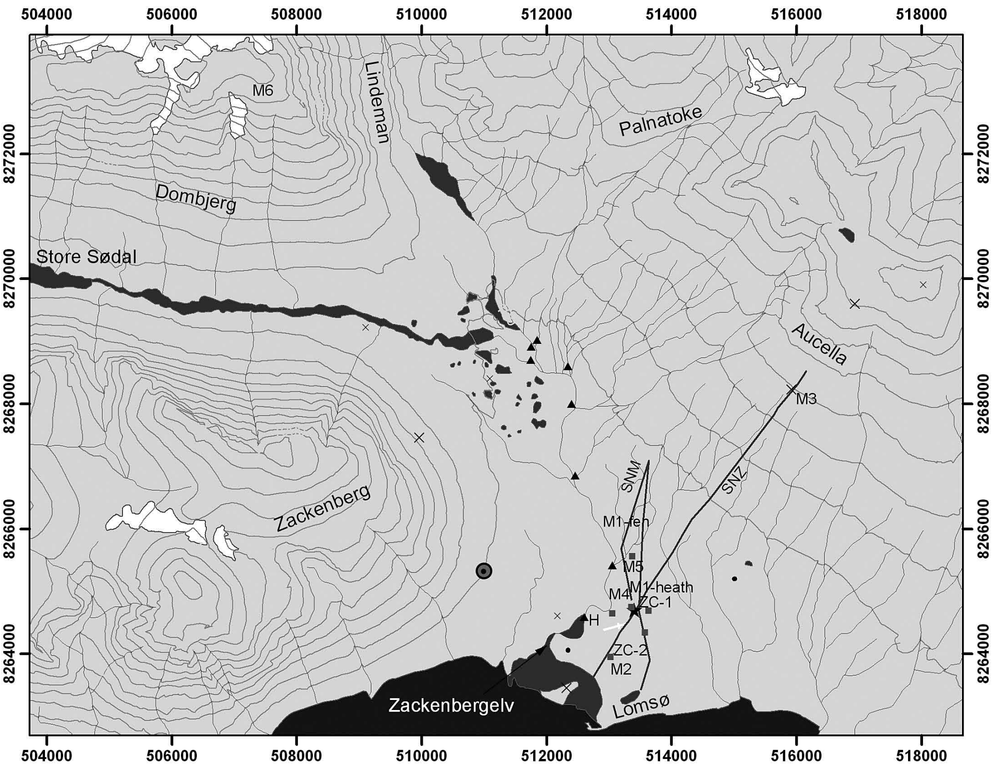


Fig. 2.1. Location of GeoBasic and ClimateBasic stations and plots. The meteorological station is marked with an asterix. H= Hydrometric station. M1= Micrometeorological stations (CO_2), fen and heath sites. M2, M3 and M6= Snow- and micrometeorological stations. M4= Soil and micrometeorological station. M5= Methane site. Triangles = Water sampling sites from tributaries to Zackenbergelven. Circle= Nansenblokken. Squares= Soil water sites. Crosses= TinyTag temperature sites. SNM and SNZ=Snow depth transects.

More details about the GeoBasic programme, sampling procedures, instrumentation, locations and installations are given in the GeoBasic Manual which can be downloaded from the Zackenberg homepage: www.zackenberg.dk. All validated data from the Zackenberg Basic monitoring are also accessible from this homepage. If some data collected by ClimateBasic and GeoBasic are not available through the database, they can be ordered from ASIAQ (kit@asiaq.gl) and Department of Geography and Geology (cs@geogr.ku.dk), respectively.

In the following section, ClimateBasic and GeoBasic monitoring data from 2007 are summarised. For the first time in Zackenberg, the field season was prolonged into the autumn and lasted from 25 May to 30 October 2007. This report mainly focus on the data collected during the ordinary season whereas a synthesis of the findings from the early winter and the coming spring will be presented in the next annual report.

2.1 Meteorological data

The meteorological station at Zackenberg was constructed in summer 1995. Technical specifications of the station are described in Meltofte and Thing (1996). Once a year the sensors are calibrated and checked by Asiaq, Greenland Survey. For the period from 29 October to 31 December 2007 where data have only been available by satellite transfer from the east mast, data are provisional until data from the west mast have been retrieved in the summer 2008. Some parameters are only measured at the west mast (e.g. precipitation) and these will be presented in the next annual report. The provisional climate data covering the period from 28 August 2006 to 31 December 2006 are re-evaluated and therefore data in Table 2.1 and 2.3 may differ from earlier publications.

Table 2.1. Yearly mean, maximum and minimum values of climate parameters for 1996 to 2007. Data for 2007 are preliminary. Some of the figures differ from earlier publications due to re-evaluation of data.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Yearly mean values												
Air temperature, 2 m above terrain (°C)	-9.0	-10.1	-9.7	-9.5	-10.0	-9.7	-8.6	-9.2	-8.5	-7.7	-8.1	-8.7
Air temperature, 7.5 m above terrain (°C)	-8.4	-9.3	-9.1	-8.9	-9.4	-9.2	-	-8.7	-7.9	-6.9	-7.6	-8.2
Relative air humidity 2 m above terrain (%)	67	68	73	70	70	71	72	71	72	71	72	69
Air Pressure (hPa)	1009	1007	1010	1006	1008	1009	1009	1008	1007	1008	1007	1006
Incoming shortwave radiation (W/m²)	113	104	101	100	107	112	105	104	99	101	107	107
Outgoing shortwave radiation (W/m²)	52	56	55	56	52	56	54	49	42	43	54	45
Net Radiation (W/m²)	16	9	6	4	14	13	-	8	-	-	10	13
Wind Velocity, 2 m above terrain (m/s)	2.7	3.0	2.6	3.0	2.9	3.0	2.8	2.6	3.0	2.9	2.8	2.6
Wind Velocity, 7.5 m above terrain (m/s)	3.1	3.4	3.2	3.7	3.3	3.4	3.3	3.1	3.6	3.5	3.4	3.1
Precipitation (mm w.eq.), total	223	307	255	161	176	236	174	263	253	254	171	135*
Yearly maximum values												
Air temperature, 2 m above terrain (°C)	16.6	21.3	13.8	15.2	19.1	12.6	14.9	16.7	19.1	21.8	22.9	16.4
Air temperature, 7.5 m above terrain (°C)	15.9	21.1	13.6	14.6	18.8	12.4	-	16.7	18.5	21.6	22.1	15.6
Relative air humidity 2 m above terrain (%)	99	99	99	99	100	100	100	100	100	99	99	99
Air Pressure (hPa)	1042	1035	1036	1035	1036	1043	1038	1038	1033	1038	1038	1037
Incoming shortwave radiation (W/m²)	857	864	833	889	810	818	920	802	795	778	833	769
Outgoing shortwave radiation (W/m²)	683	566	632	603	581	620	741	549	698	629	684	547
Net Radiation (W/m²)	609	634	556	471	627	602	-	580	-	-	538	469
Wind Velocity, 2 m above terrain (m/s)	20.2	22.6	25.6	19.3	25.6	20.6	21.6	20.6	22.2	19.9	20.8	27.6
Wind Velocity, 7.5 m above terrain (m/s)	23.1	26.2	29.5	22.0	23.5	25.0	25.4	23.3	25.6	22.0	22.8	29.6
Yearly minimum values												
Air temperature, 2 m above terrain (°C)	-33.7	-36.2	-38.9	-36.3	-36.7	-35.1	-37.7	-34.0	-34.0	-29.4	-38.7	-33.9
Air temperature, 7.5 m above terrain (°C)	-31.9	-34.6	-37.1	-34.4	-34.1	-33.0	-	-32	-32.1	-27.9	-37.2	-32.5
Relative air humidity 2 m above terrain (%)	20	18	31	30	19	22	23	21	17	22	21	18
Air Pressure (hPa)	956	953	975	961	969	972	955	967	955	967	968	969
Incoming shortwave radiation (W/m²)	0	0	0	0	0	0	0	0	0	0	0	0
Outgoing shortwave radiation (W/m²)	0	0	0	0	0	0	0	0	0	0	0	0
Net Radiation (W/m²)	-86	-165	-199	-100	-129	-124	-	-98	-	-	-99	-99
Wind Velocity, 2 m above terrain (m/s)	0	0	0	0	0	0	0	0	0	0	0	0
Wind Velocity, 7.5 m above terrain (m/s)	0	0	0	0	0	0	0	0	0	0	0	0

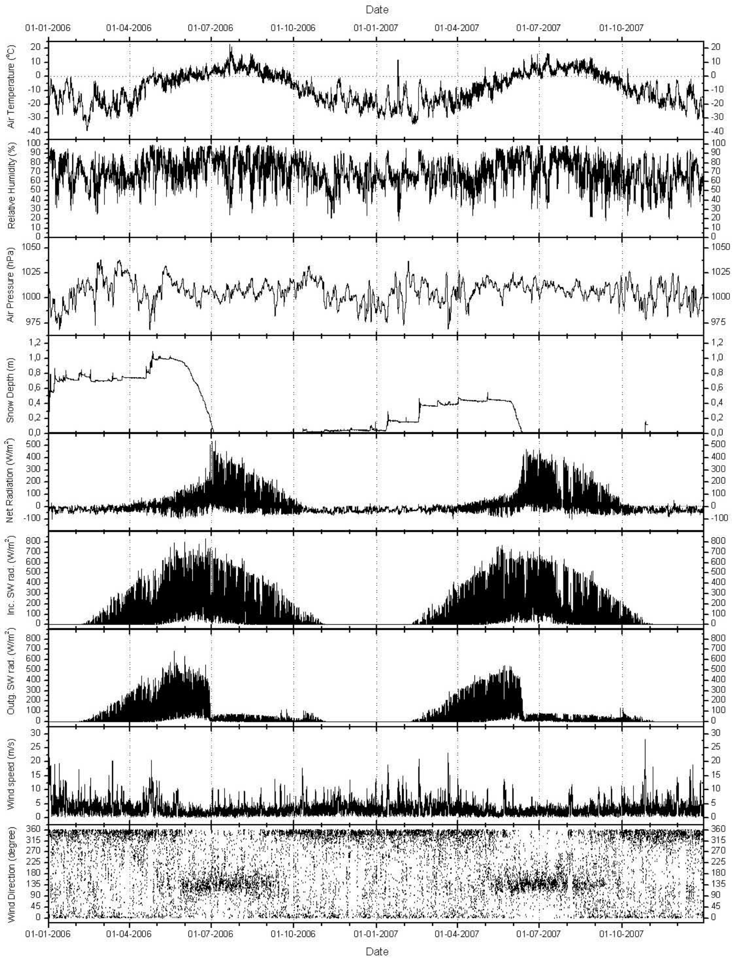
* only valid data until October 29th

Meteorological data from 2007

Annual mean air temperature measured 2 m above terrain was -8.7°C which is a little warmer than average of the last 12 years (-9.1°C). The maximum air temperature reached 16.4°C and occurred on 10 July. The minimum temperature of -33.9°C was measured 12 February (Table 2.1). The maximum air temperature was the lowest since 2002; this is unlike the previous two years where the maximum air temperature has been the highest measured. In the period from late April to late September the temperature was frequently above 0°C (Fig. 2.2). January, February and May were colder than average for the last 12 years whereas March, June and August were considerably warmer than average (Fig. 2.3). June was the warmest month registered and August was warmer than July and just as warm as the record in 2003.

A typical *Föhn* situation took place 24 January. Temperatures up to 11.8 °C were registered at the climate station and the relative humidity dropped significantly. Temperatures were positive for 16 hours and resulted in the highest positive degree days in January so far (Table 2.2). For the first time, there were no positive degree days in May.

The mean relative humidity was 69%, and was highest during the summer period. The mean air pressure was 1007 hPa and was generally more stable during summer than winter. Monthly mean net radiation was positive from May to September 2007 and negative from October to April (Table 2.3).



The mean wind speed 7.5 m above ground was 3.1 m/s (Table 2.1). Highest 10 minute mean value was 29.6 m/s and occurred during a powerful snow storm on 26 October where wind gusts up to 50 m/s were registered. In fact, this is the

Fig. 2.2. Variation of selected climate parameters during 2006 and 2007. From above: Air temperature, relative humidity, air pressure, snow depth, net radiation, incoming short wave radiation, outgoing short wave radiation, wind speed and wind direction. Wind speed and direction are measured 7.5 m above terrain; the remaining parameters are measured 2 m above terrain. Data from 29 October to 31 December 2007 are preliminary.

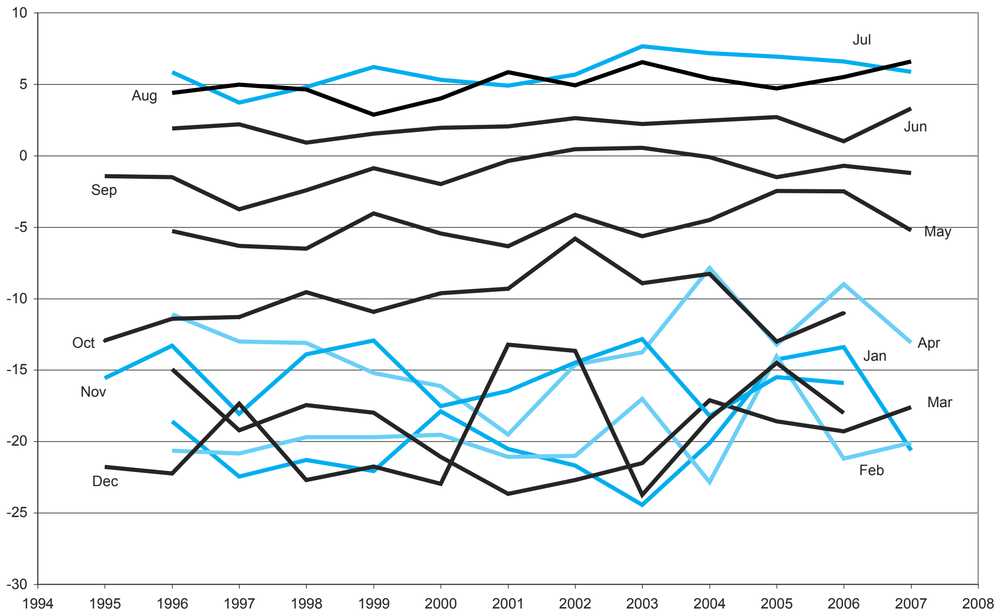


Fig. 2.3. Monthly mean air temperatures during the period from September 1995 to October 2007.

Degree days	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
January											1.5		3.6
February													
March													
April									0.2	1.1		2.9	
May		1.1	1.3	0.1	3.6	0.5	0.5	18.2	3.3	4.1	5.40	3.1	
June		63.7	74.6	32.5	52.9	71.8	68.2	81.8	74.2	73.9	84.6	37.2	99.7
July		181.0	115.4	147.36	192.7	164.4	152.0	175.6	237.2	222.2	214.7	205.3	182.2
August		140.5	154.2	143.6	89.2	127.3	181.2	152.5	203.2	169.4	141.5	171.5	*204.5
September	11.7	15.3	4.5	11.3	19.7	5.7	31.1	41.2	42.5	41.4	17.7	15.7	*10.1
October			1.5				0.3	1.8					
November													
December													
Sum	**11.7**	**401.7**	**351.5**	**334.8**	**358.0**	**369.7**	**433.2**	**471.1**	**560.6**	**514.8**	**466.4**	**435.7**	***500.1**

*Table 2.2. Positive degree days calculated on a monthly basis as the sum of daily mean air temperatures above 0°C. Calculations are based on air temperatures from the climate station (2 m above ground). *) Preliminary values.*

Year	Month	Air Temperature °C 2.0 m	Air Temperature °C 7.5 m	Rel. humidity %	Air Press. hPa	Net Rad. W/m²	Shortwave Rad. W/m² In	Shortwave Rad. W/m² Out	Wind Velocity m/s 2.0 m	Wind Velocity m/s 7.5 m	Dominant Wind Dir. 7.5 m
2006	Jan	-13.4	-12.7	72	991.2	-18	0	0	4.4	5.4	N
2006	Feb	-21.2	-20.0	65	1013.3	-20	7	5	3.1	3.8	N
2006	Mar	-19.3	-18.4	68	1020.8	-16	56	45	3.1	3.7	N
2006	Apr	-9.0	-8.4	73	1001.5	-4	137	114	3.6	4.4	NNW
2006	May	-2.5	-2.4	76	1015.5	11	260	207	2.4	3.1	N
2006	Jun	1.0	0.7	82	1003.8	54	312	208	1.3	1.7	SE
2006	Jul	6.6	5.9	77	1004.5	131	256	28	2.1	2.5	SE
2006	Aug	5.5	5.3	75	1008.2	61	158	21	2.2	2.6	SE
2006	Sept	-0.7	-0.7	76	1007.4	6	75	13	2.4	3.1	N
2006	Oct	-11.0	-9.9	72	1017.2	-28	15	7	2.8	3.5	N
2006	Nov	-15.9	-14.8	60	1001.0	-30	0	0	3.2	3.8	NNW
2006	Dec	-18.0	-16.7	66	995.5	-26	0	0	3.0	3.5	NNW
2007	Jan	-20.6	-19.2	64	997.2	-24	0	0	3.3	3.9	NNW
2007	Feb	-20.1	-18.5	70	1012.4	-23	7	5	3.1	3.7	N
2007	Mar	-17.6	-16.6	67	1000.3	-17	56	45	2.9	3.5	NNW
2007	Apr	-13.1	-12.0	62	1007.0	-11	167	133	2.2	2.7	NNW
2007	May	-5.2	-5.1	76	1011.8	7	262	202	2.2	2.7	SE
2007	Jun	3.3	3.0	79	1012.4	116	287	86	1.8	2.2	SE
2007	Jul	5.9	5.3	79	1010.5	124	251	32	1.8	2.2	SE
2007	Aug	6.6	6.1	72	1007.1	56	149	20	2.1	2.7	SE
2007	Sept	-1.2	-1.3	68	1007.1	5	75	12	2.3	3.0	NNW
2007	Oct	-10.1	-9.7	62	1002.7	-26	18	8	3.3	4.0	NNW
2007	Nov	-14.9	-14.0	59	1005.7	-26	0	0	2.9	3.3	NNW
2007	Dec	-17.8	-16.8	69	999.5	-25	0	0	3.2	3.8	NNW

Table 2.3. Monthly mean values of climate parameters 2006 and 2007. Data for 2007 are preliminary. Some of the figures differ from earlier publications due to re-evaluation of data.

highest wind speed ever recorded at the Zackenberg Research Station.

The yearly wind statistic for 2007 is in good agreement with the statistics from 2006. In 2007, the winds were coming from N and NNW 36% of the time, mainly during the winter period, and from ESE to SSE 24% of the time, mainly during the summer period (Table 2.4 and 2.5). By the end of July the wind direction shifted to S-W and the incoming radiation dropped because of overcast weather with rain. After seven days the wind shifted back to ESE-SSE and the sky became clear. Five days later the wind shifted to NW-N with clouds, rain and low radiation. This weather type lasted for four days before returning to the dominating summer wind direction ESE-SSE and clear sky. The total amount of summer precipitation was 20

Year	Month	Shortwave Rad. W/m² mean in	Shortwave Rad. W/m² mean out	Net Rad. W/m² mean	PAR µmol/m²/s mean	Air temperature °C mean 2 m	Air temperature °C minimum 2 m	Air temperature °C max 2 m	Precipitation mm total	Wind velocity m/s mean 7.5 m	Wind velocity m/s max[1] 7.5 m	Vind direction dominant 7.5 m
	Jun	332	133	113	-	1.9	-3.7	13.6	4	1.8	9.9	ESE
1996	Jul	238	24	145	-	5.8	-1.5	16.6	7	2.7	12.1	SE
	Aug	162	23	74	-	4.4	-4.0	14.1	2	2.9	12.5	SE
	Jun	222	111	85	-	2.2	-4.4	12.0	23	2.4	14.1	ESE
1997	Jul	225	23	130	-	3.7	-1.0	15.3	28	2.7	13.8	SE
	Aug	159	20	74	-	5.0	-3.0	21.3	16	2.8	13.3	SE
	Jun	270	172	51	-	0.9	-3.0	9.6	5	1.6	8.1	SE
1998	Jul	204	20	125	-	4.7	-2.6	13.8	33	2.3	12.1	SE
	Aug	114	12	64	-	4.6	-1.8	11.5	55	2.4	12.2	ESE
	Jun	294	206	33	-	1.5	-4.5	10.4	2	2.3	15.0	-
1999	Jul	212	32	123	-	6.2	-0.7	15.1	21	2.6	14.8	-
	Aug	143	16	73	-	2.9	-2.7	15.2	11	2.5	14.9	SE
	Jun	294	103	126	-	1.9	-6.2	11.7	10	2.1	15.1	SE
2000	Jul	228	27	141	-	5.3	-1.2	19.1	13	2.9	15.9	SE
	Aug	153	19	82	-	4.0	-3.5	11.6	0	2.3	13.4	SE
	Jun	293	168	67	-	2.1	-4.9	11.9	26	2.1	13.3	-
2001	Jul	231	27	146	-	4.9	-1.5	11.8	7	2.9	13.1	-
	Aug	180	20	84	-	5.8	-0.8	12.6	21	2.9	14.4	-
	Jun	344	151	113	-	2.6	-2.8	14.9	1	1.6	6.8	SE
2002	Jul	205	23	105	424	5.7	-0.9	13.8	11	2.6	9.9	SE
	Aug	129	16	51	272	4.9	-3.1	11.6	15	2.8	12.9	SE
	Jun	294	108	106	612	2.2	-4.8	14.7	7	1.6	5.4	SE
2003	Jul	210	26	96	431	7.7	1.8	16.7	6	2.8	14.2	SE
	Aug	151	20	56	313	6.6	-0.5	15.4	3	2.5	10.1	SE
	Jun	279	73	111	571	2.5	-3.4	19.1	3	2.3	13.6	SE
2004	Jul	225	30	95	464	7.2	-0.7	19.0	10	2.8	10.5	SE
	Aug	150	20	62	302	5.6	-1.4	17.2	4	2.4	12.6	SE
	Jun	261	53	-	519	2.7	-3.5	13.4	6	2.4	11.8	SE
2005	Jul	215	29	-	428	6.9	-0.6	21.8	28	2.9	13.3	SE
	Aug	153	21	51	321	4.6	-2.7	14.0	4	3.2	10.9	SE
	Jun	312	208	54	675	1.0	-4.4	9.5	0	1.7	6.9	SE
2006	Jul	256	28	131	550	6.6	-1.2	22.8	12	2.5	11.3	SE
	Aug	158	21	61	336	5.5	-4.5	16.3	2	2.6	12.0	SE
	Jun	287	86	116	609	3.3	-2.4	15.8	9	2.2	14.8	SE
2007	Jul	251	32	124	531	5.9	-1.8	16.4	8	2.2	6.5	SE
	Aug	149	20	56	318	6.6	-2.5	13.6	3	2.7	12.3	SE

Table 2.4. Climate parameters for June, July and August, 1996 to 2007.
[1] "Wind velocity, max" is the maximum of 10 minutes mean values.

mm and occurred mostly in June and July whereas August was rather dry (Table 2.4).

2.2 Climate gradients, snow, ice and permafrost

Snow and micrometeorological stations

Monthly mean values of selected parameters from the snow- and micrometeorological stations M2 (17 m a.s.l.), M3 (420 m a.s.l.) (section 2.2 in Rasch and Caning 2004 and M6 (1282 m a.s.l.) (2.1 in Klitgaard, et al. 2007) are reported in Table 2.6 and Fig. 2.4. The temperature is often higher at M3 than at M2. This temperature inversion is most pronounced during the winter months, whereas May, August and September have the lowest occurrence (Table 2.7). The largest temperature inversion from September 2006 to September 2007 was measured 23 January with a deviation of 21.7 °C. Only October was colder at M3 than at the other stations. When temperatures from the climate station in the valley (38 m a.s.l.) and M6 (1282 m a.s.l.) at Dombjerg are compared, more than half of the temperature registrations are warmer at M6 in December, February, March and June whereas only 3-5% of the measurements are warmer at M6 in August and September. The largest temperature inversion between these two sites were measured 3 April 2007 when it

Table 2.5. Mean wind statistics based on wind velocities and directions measured 7.5 m above terrain in 1997, 1998, 2000, 2002, 2003, 2004 and 2005. Wind statistics for the years 2006 and 2007. Calm is defined as wind speed lower than 0.5 m/s. Max speed is maximum of 10 minutes mean values. "Mean of maxs" is the mean of the yearly maximums. The frequency for each direction is given as percent of the time for which data exist. Missing data amount to less than 8% of data for the entire year and less than 20 days within the same month.

Year	Mean[1]				2006			2007		
Direction	Frequency	Velocity, m/s			Frequency	Velocity, m/s		Frequency	Velocity, m/s	
	%	mean	mean of maxs	max	%	mean	max	%	mean	max
N	14.7	4.4	24.1	29.5	20.8	5.0	22.3	16.5	5.0	22.3
NNE	3.6	2.7	17.7	25.4	3.9	2.6	17.8	3.8	2.6	17.8
NE	2.5	2.4	14.7	19.4	2.5	2.2	12.1	2.4	2.2	12.1
ENE	2.8	2.5	13.4	17.4	2.5	2.2	11.3	2.7	2.2	11.3
E	4.0	2.1	9.4	10.7	3.5	2.1	8.5	3.7	2.1	8.5
ESE	6.9	2.3	9.1	10.3	6.4	2.3	9.4	6.8	2.3	9.4
SE	8.5	2.5	10.0	18.1	8.8	2.4	9.8	10.5	2.4	9.8
SSE	5.6	2.4	9.8	16.2	5.9	2.5	8.4	6.7	2.5	8.4
S	4.0	2.5	8.1	9.9	4.0	2.6	8.0	4.2	2.6	8.0
SSW	2.9	2.3	9.0	13.4	2.8	2.4	6.9	3.0	2.4	6.9
SW	2.5	2.2	8.4	12.2	2.7	2.1	8.2	2.6	2.1	8.2
WSW	2.9	2.4	10.0	15.9	3.3	2.3	7.8	2.9	2.3	7.8
W	2.9	2.6	18.5	23.5	2.8	2.2	6.5	2.9	2.2	6.5
WNW	3.3	2.7	17.2	19.3	3.1	2.3	11.7	3.6	2.3	11.7
NW	6.5	3.7	20.0	25.1	5.9	3.4	19.8	6.4	3.4	19.8
NNW	23.2	5.1	23.1	25.8	19.4	4.9	22.8	19.5	4.9	22.8
Calm	3.9				1.7			1.7		

1) Data from 1997, 1998, 2000, 2002, 2003, 2004, 2005

was 22.9 °C warmer at M6 than at the climate station.

The hot spell in January, measured at the climate station (see above section), was also registered at M2, M3 and M6, where the max temperature reached 11.5 ºC, 8.3 ºC and 3.1 ºC respectively and temperatures were above freezing for respectively 15 hours, 25 hours and 16 hours.

Wind speed was significant higher at M6 than at M2 and M3 throughout the entire period (Fig. 2.4).

Snow depth

In 1997, automatic measurements of snow depth were started in Zackenbergdalen near the meteorological station; see Meltofte and Rasch (1998). In the winter 2006/2007 a continuous snow cover started to build up 22 September but it was not above 0.1 m thick before 12 January (Table 2.8 and Fig. 2.5). Most of the snow fell during snow events on 12-13 January and on 16 February. With a maximum snow depth of 0.48 m, this winter had the lowest snow depth measured so far. Snow melt took place from the end of May and was complete below the sensor by 13 June. Only 2005 had an earlier snow melt.

At M3 (420 m a.s.l.) and M2 (17 m a.s.l) where snow depth is measured automatically the snow melt completed 1 June and 21 June, respectively. Due to an error in the datalogger programme no snow depth

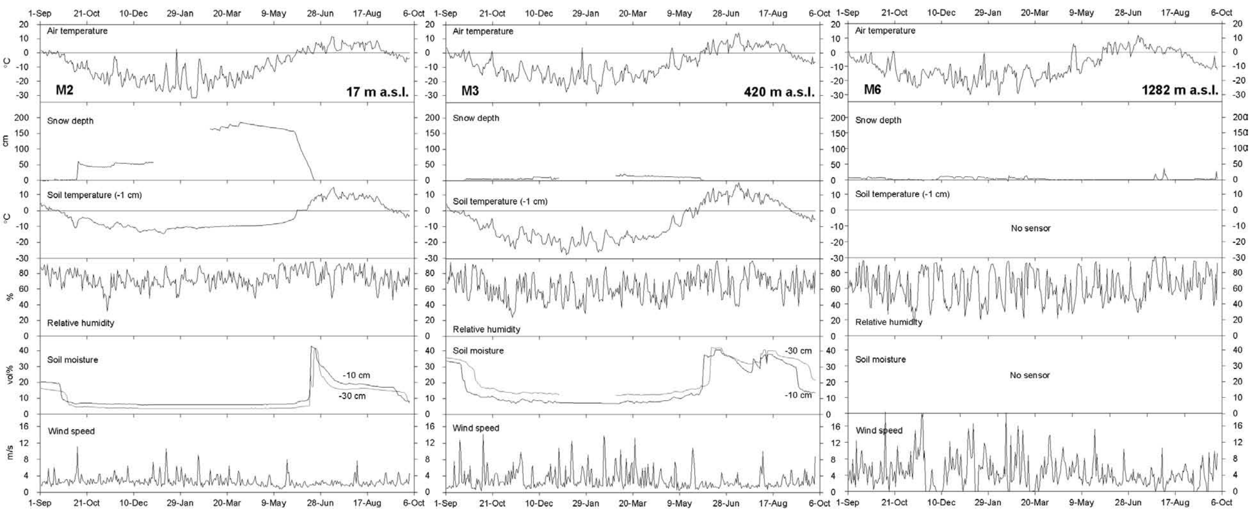


Fig. 2.4. Daily mean values of selected parameters from snow- and micrometeorological station M2 (17 m a.s.l.), M3 (420 m a.s.l.) and M6 (1282 m a.s.l.) in the period 1 September 2006 to 30 September 2007.

M2	Month	Year	Wind speed 2.5 m m/s	Rel. hum 2.5 m %	Air temp 2.5 m °C	Soil temp -1 cm °C	Soil temp -10 cm °C	Soil temp -30 cm °C	Soil temp -60 cm °C	Soil moist -10 cm %	Soil moist -30 cm %
	Aug	2006	2.4	77.0	5.0	7.3	6.5	4.8	1.5	21.6	16.8
	Sep	2006	2.7	78.3	-1.2	0.2	0.7	0.9	0.4	16.8	14.5
	Oct	2006	3.0	74.2	-11.2	-6.3	-5.5	-3.8	-1.7	6.9	4.7
	Nov	2006	3.0	63.3	-15.9	-9.4	-8.8	-7.5	-5.4	6.4	4.0
	Dec	2006	2.9	69.2	-18.2	-11.7	-11.0	-9.7	-7.6	6.0	3.6
	Jan	2007	3.3	68.6	-21.0	-12.1	-11.6	-10.7	-9.0	5.8	3.5
	Feb	2007	2.8	74.4	-20.9	-10.7	-10.4	-9.8	-8.7	5.8	3.5
	Mar	2007	2.9	71.8	-18.4	-10.0	-9.8	-9.3	-8.5	6.0	3.6
	Apr	2007	2.2	68.3	-13.8	-9.5	-9.3	-9.0	-8.3	6.0	3.6
	May	2007	2.2	79.7	-5.7	-7.4	-7.5	-7.7	-7.7	6.3	3.7
	Jun	2007	1.9	81.8	2.5	4.2	2.8	0.4	-2.5	21.8	17.1
	Jul	2007	2.0	81.6	4.9	9.9	8.5	6.0	1.2	21.6	16.9
	Aug	2007	2.4	73.7	5.7	7.9	7.1	5.3	1.9	18.2	15.8
	Sep	2007	2.6	71.1	-1.8	-0.3	0.4	0.7	0.3	13.5	13.6

M3	Month	Year	Wind speed 1.5 m m/s	Rel. hum 1.5 m %	Air temp 1.5 m °C	Soil temp -1 cm °C	Soil temp -10 cm °C	Soil temp -30 cm °C	Soil temp -60 cm °C	Soil moist -10 cm %	Soil moist -30 cm %
	Aug	2006	2.6	67.7	3.8	5.6	5.2	4.3	2.8	13.6	14.4
	Sep	2006	2.9	70.7	-2.2	-1.4	0.1	0.4	0.2	25.2	33.3
	Oct	2006	3.8	53.1	-15.1	-17.1	-14.9	-13.4	-11.2	8.4	13.6
	Nov	2006	3.3	62.2	-9.8	-10.9	-7.8	-5.3	-2.8	10.7	16.9
	Dec	2006	3.3	57.6	-15.2	-17.2	-15.6	-14.6	-13.0	8.1	13.2
	Jan	2007	3.9	53.1	-17.8	-21.0	-19.7	-18.6	-16.9	7.9	12.8
	Feb	2007	3.4	60.7	-16.2	-18.6	-17.9	-17.3	-16.4	7.9	12.8
	Mar	2007	4.2	60.2	-16.0	-17.4	-17.0	-16.6	-15.9	7.6	12.4
	Apr	2007	2.9	53.6	-11.4	-14.5	-15.1	-15.1	-15.0	8.3	12.7
	May	2007	2.6	71.2	-5.4	-2.6	-5.2	-6.7	-8.5	11.8	15.2
	Jun	2007	1.9	70.5	4.1	9.0	5.7	2.0	-1.4	36.8	33.5
	Jul	2007	1.8	70.4	6.6	11.1	9.1	6.7	3.3	31.0	33.5
	Aug	2007	2.7	66.7	5.1	6.2	5.9	4.9	3.1	35.1	37.9
	Sep	2007	3.0	67.3	-3.9	-2.7	-0.8	0.1	0.1	20.2	31.5

M6	Month	Year	Wind speed 2 m m/s	Rel. hum 2 m %	Air temp 2 m °C	Soil temp -1 cm °C
	Aug	2006	3.9	62.9	2.2	4.4
	Sep	2006	4.7	67.9	-5.4	-5.2
	Oct	2006	5.0	60.8	-12.0	-14.2
	Nov	2006	6.8[1]	57.1	-17.9	-20.6
	Dec	2006	4.2[1]	63.4	-16.4	-19.4
	Jan	2007	6.4[1]	57.6	-19.4	-22.5
	Feb	2007	5.2[1]	66.3	-17.0	-20.9
	Mar	2007	3.9	66.1	-16.8	-19.0
	Apr	2007	6.0	50.5	-13.2	-13.1
	May	2007	4.7	63.9	-6.8	-3.5
	Jun	2007	3.5	59.0	3.0	6.9
	Jul	2007	2.8	63.2	4.6	8.3
	Aug	2007	3.7[1]	68.9	1.8	4.2
	Sep	2007	3.8[1]	72.0	-8.5	-7.6

Table 2.6. Monthly mean values of selected meteorological parameters from M2 (17 m a.s.l.), M3 (420 m a.s.l.) and M6 (1282 m a.s.l.) from 1 August 2006 to 30 September 2007. [1)] The wind speed sensor was frozen for several periods, and mean monthly wind speeds should therefore be used with caution.

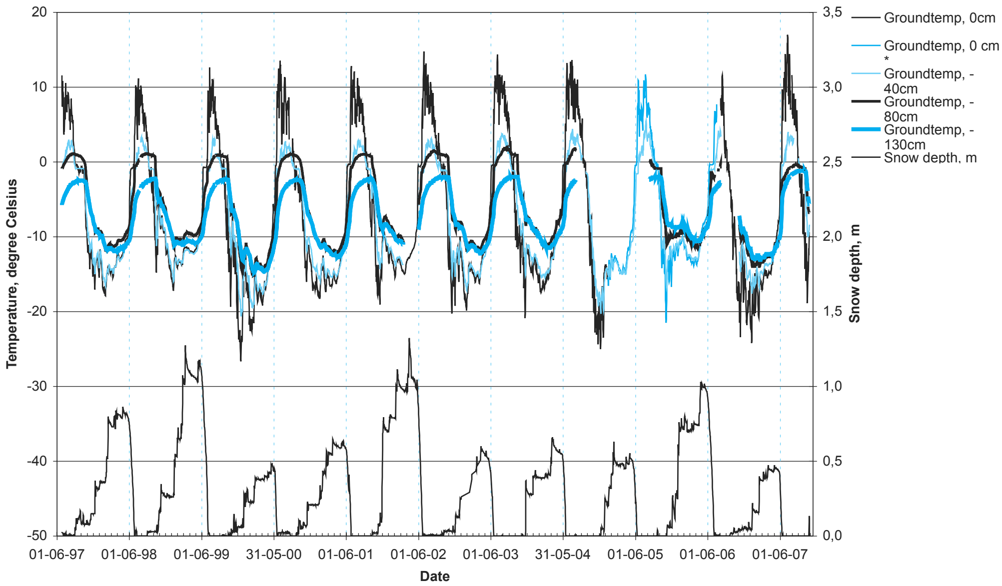


*Fig. 2.5. Daily mean temperatures at surface of the ground and at 40 cm, 80 cm and 130 cm below the surface. In the lower half of the figure, snow depth is shown. In August 2006, the sensors at 40, 80 and 130 cm below the surface were replaced. *Data from the sensor at the snow depth station is not valid in this period.*

measurements were collected in the period from 1 January 2007 to 28 February 2007 (Fig 2.4). At M6, snow accumulation was very limited due to the exposed location of the station. The last snow disappeared 24 April.

During the ablation period, snow depths were measured in the gridnet ZEROCALM-1 every week to see the spatial variation inside a relatively homogenous 100x100 m site with 121 grid nodes. When the last measurement was made 9 June, 24 of the grid nodes were free of snow and the maximum snow depth was 36 cm.

Between 26 May and 28 May 2007, "end of winter" snow depths were measured along two main transects; SNM starting from Lomsø following a line into the valley and SNZ following the ZERO-line from the old delta up to M3, 420 m a.s.l. (Fig. 2.1). Snow depths were measured for every 20 meter and data are available along with GPS position and altitude for each point. During the ablation period these measurements were repeated every week.

After a snow storm 26 October 2007, there was 27 cm of snow at the climate station and 113 cm of snow accumulated in the river bed at the hydrometric station.

	2003	2004	2005	2006	2007
Jan		–	–	48.6	64.9
Feb		–	–	–	77.0
Mar		56.0	–	67.3	71.0
Apr		29.1	–	46.1	69.2
May		30.5	–	36.4	50.8
Jun		45.0	57.4	53.1	62.3
Jul		47.9	46.4	58.8	73.7
Aug		34.2	19.4	35.8	39.1
Sep	10.0	16.9	14.2	32.5	13.0
Oct	35.9	41.8	55.9	60.0	
Nov	45.6	66.8	63.8	55.5	
Dec	79.4	60.6	56.7	74.6	

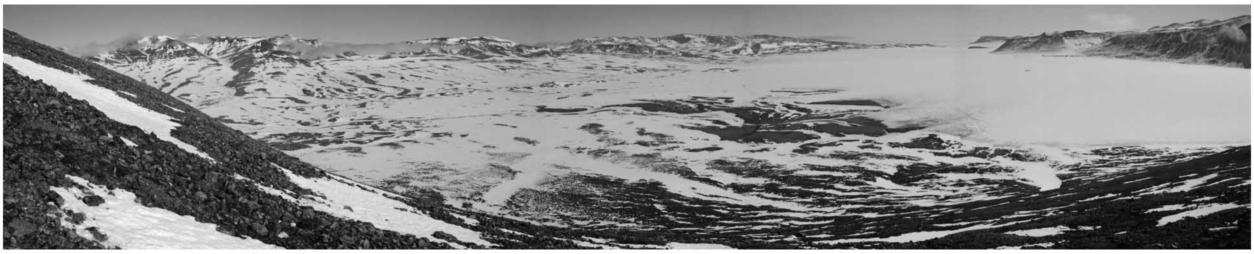
Table 2.7. Percentage of temperature records being higher at M3 (420 m a.s.l.) than at M2 (17 m.a.s.l.)

Snow density

In order to calculate snow water equivalent (SWE), snow densities were measured at all permanent soil sites still covered by snow at the beginning of the season (the two sites, Sal-1 and Dry-1 were free of snow when we arrived 25 May). At the end of May, densities ranged from 0.30-

Winter	1997/1998	1998/1999	1999/2000	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005	2005/2006	2006/2007
Max. snow depth, meter	0.88	1.30	0.49	0.68	1.33	0.60	0.69	0.73	1.10	0.48
Max. snow depth reached	29 Apr	11 Mar	19 May	25 Mar	15 Apr	13 Apr	13 Apr	12 Feb	26 Apr	4 May
Snow depth exceeds 0.1m from	19 Nov	27 Oct	1 Jan	16 Nov	19 Nov	6 Dec	24 Nov	27 Dec	19 Dec	12 Jan
Snow depth is below 0.1m from	25 Jun	3 Jul	14 Jun	24 Jun	20 Jun	14 Jun	13 Jun	7 Jun	1 Jul	8 Jun

Table 2.8. Key figures describing the amount of snow in ten winters.



0.42 g/cm^3 in the area around the climate station.

In ZEROCALM-1, densities were measured on a regular basis throughout the ablation period. A snow pit was made in the large seasonal snow patch in ZEROCALM-2 and densities were measured for every 50 cm (ranging from 0.37-0.64 g/cm^3 (30 May). Temperatures were measured for every 10 cm throughout the 230 cm deep profile showing isothermal conditions above 80 cm and -4°C at the ground surface. Several ice layers were observed in the snow. The most significant ice layer was up to 5 cm thick and located 60-70 cm below the snow surface – probably a result of the Föhn situation 24 January.

Snow cover

The extent of spring snow cover at Zackenberg was among the lowest observed due to the shallow snow depths. A more detailed analysis of the snow extent in different sub-zones in the valley, based on the photos from 10 June will be reported in the next annual report together with updated snow depletion curves for 2005, 2006 and 2007. Right now we are in a process of calibrating new cameras from Nansenblokken. New software will be applied during the coming year to obtain snow cover distribution data for the entire Zackenberg valley.

The snow cover extention in the valley at the "end of winter" is shown in the photo from Nansenblokken 29 May (Fig. 2.6). A thin snow cover was present in the valley from 28 September 2007 and after a snow storm 26 October 2007 a continuous snow cover of more than 0.1 m was established.

A near infrared, multi spectral camera, used for observing the greenness of the vegetation in the valley was installed at Nansenblokken 31 May and daily photos of the central valley were captured until 24 October where the camera was removed.

Fig. 2.6. Snow cover in Zackenbergdalen 29 May 2007. View from Nansenblokken 480 m a.s.l.

Active layer depth

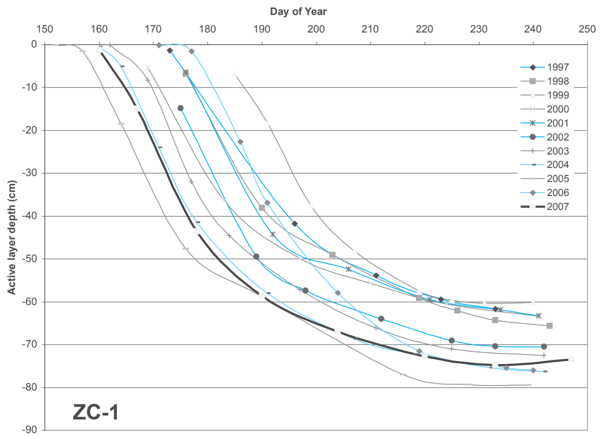
Development of the seasonal active layer starts as soon as snow disappears from the ground and air temperatures become positive. The thaw rate of the soil was monitored throughout the season at two grid-plots; the homogenous ZEROCALM-1 grid (ZC-1) and the heterogeneous ZEROCALM-2 grid (ZC-2). Point measurements of thaw depth progression were also made throughout the season at all the soil water sites. A detailed description of the two ZEROCALM sites was given in section 5.1.12 in Meltofte and Thing (1997).

In ZC-1, the first grid node was free of snow 6 June and snow melt was complete 18 June. The north eastern corner and the southern part of ZC-2 were free of snow when we arrived 25 May and 61 out of 208 grid nodes were snow free. Normally, the seasonal snow patch in ZEROCALM-2 last until mid July or mid August but in 2007 all snow was melted by 30 June. The early melt of the snow patch is easily recognized in the steep slope of the thaw progression in ZC-2 (Fig. 2.7). Maximum thaw depth by the end of August is given in Table 2.9. When the sites were re-measured 5 September, the soil had started to refreeze and later measurements were not possible as the soil surface was frozen at most grid nodes.

Data from the two ZEROCALM-sites are reported to the circumpolar monitor-

Table 2.9. Maximum thaw depth in ZEROCALM-1 and ZEROCALM-2 measured late August, 1997-2007.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
ZEROCALM-1	61.7	65.6	60.3	63.4	63.3	70.5	72.5	76.3	79.4	76.0	74.8
ZEROCALM-2	57.4	59.5	43.6	59.8	59.7	59.6	63.4	65.0	68.6	67.6	67.1



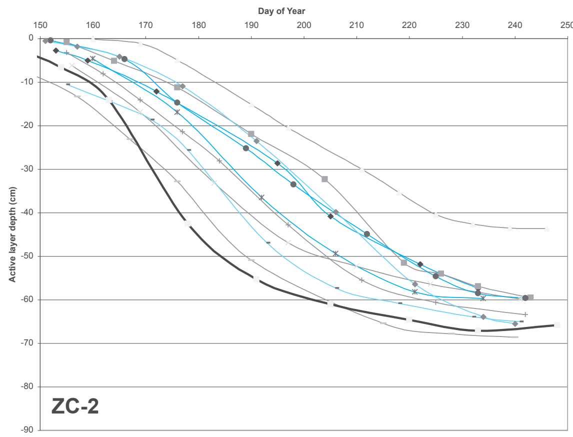


Fig. 2.7. Thaw depth progression in ZEROCALM-1 and ZEROCALM-2, 1997-2007. Thaw depth progression is based on 8 and 9 re-measurements during the season in ZC-1 and ZC-2, respectively.

ing programme CALM (Circumpolar Active Layer Monitoring-Network-II (2004-2008) maintained by the University of Delaware, Centre for International Studies (www.udel.edu/Geography/calm).

Temperature in different settings and altitudes

GeoBasic operates a total of 40 TinyTag dataloggers for year-round temperature monitoring in different altitudes and different geomorphological settings in the landscape at Zackenberg. Positions and a short description of the sites are given in the GeoBasic manual. In 2007, new sensors were installed at the Sal-1 site in 0, 10 and 30 cm below the soil surface (12 July) in order to replace the old ones in 0 and 15 cm that were lost during winter (cables eaten by foxes). The new installation depths were chosen to make the site comparable to the other soil water sites.

At the methane site (M5), three temperature loggers were installed into the organic soil at 5, 10 and 15 cm below the water table (4 July 2007).

Ice on ponds and lakes

In early September, the ponds and lakes started to freeze and ice formed on the surface. The lakes Langemandssø and Sommerfuglesø where water sampling is carried out by BioBasic (section 3.5) were 75-90% covered by ice on 14 September. From 20 September to 14 October, the ice thickness increased from 20 cm to 44 cm. In the pond Tørvedammen, the ice thickness was 8 cm thick on 15 September.

Break up of the fjord ice in Young Sund

The fiord ice between Zackenbergdalen and Clavering Ø broke up during 8-9 July but there was not open water all the way to the sea before 17 July (Table 2.10). This is only a few days earlier than last years observations. Around Sandøen in the outer part of Young Sund ice break-up was complete 17 July. In the period from 28 July to 2 August and from 30 August to 7 September a lot of drift ice was present in Young Sund.

2.3 River water discharge and chemistry

Spring break up of Zackenbergelven and secondary streams

Zackenbergelven broke up 2 June 2007, when water slowly but steady worked its way through the snow covered river bed and passed below the hydrometric sensor in the evening. The first water mainly came from Lindemansdalen. All tributaries except the southern stream from Aucellabjerg ("AucellaS") were running when water samples were collected from the different streams on 8 June (Table 2.10 and 2.12).

Zackenbergelven

The drainage basin for Zackenbergelven includes Zackenbergdalen, Store Sødal, Lindemansdalen and Slettedalen. The basin covers an area of 514 km^2, of which approx. 106 km^2 are covered by glaciers (Fig 2.12 in Klitgaard et al. 2006).

At the station, water level, water temperature, air temperature, suspended sediment, and conductivity are logged

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
West pond		4.6	Dry	5.6	10.6	30.5	8.6	2.6	9.6	<26.5	Dry	3.6	<25.5
East pond		3.6	Dry	6.6	16.6	1.6	6.6	3.6	12.6	28.5	22.5	6.6	25.5
South pond		<3.6	30.5	7.6	12.6	1.6	8.6	3.6	8.6	<26.5	<21.5	8.6	31.5
Lomsø		4.7	2.7	8.7	10.7	1.7	4.7	30.6	29.6	22.6	17.6	3.7	24.6
Rivulets		<6.6	11.6	11.6	15.6	4.6	10.6	4.6	3.6	31.5	4.6	13.6	31.5
Zackenbergelven	<26.5	<3.6	4.6	10.6	20.6	8.6	8.6	4.6	30.5	1.6	3.6	12.6	2.6
Young Sund (Zac.)		13.7	19.7	14.7	14.7	8.7	13.7	1.7	5.7	1.7	3.7	14.7	13.7
Young Sund (all)	12.7	13.7	22.7	22.7	24.7	17.7	23.7	8.7	8.7	8.7	7.7	23.7	17.7

Table 2.10. Visually estimated dates of 50% ice cover on selected ponds and lakes around the research station, together with start of running water in rivers and break up of the fjord ice in Young Sund during 1995- 2007. "West pond" and "East pond" are the two ponds in Gadekæret north of the runway, "South pond" is the major pond in Sydkærene south of the runway. "Rivulets" are the streams draining the slopes of Aucellabjerg through Rylekærene. "Zackenbergelven" gives the initial date of genuine flow in the river. Young Sund break up is divided between break up of the fiord ice off Zackenbergdalen, "Young Sund (Zac.)" and in the fiord in general "Young Sund (all)". The 50% ice cover date for Lomsø is tentative, as it is estimated from the research station.

automatically every 15 minutes. The water level is both measured by use of a sonic range sensor and by two pressure sensors. Discharge data for 2007 are based only on data from the sonic range sensor. The measured water level can be transformed to a discharge using the relation between water level and discharge (a Q/h-relation).

Q/h-relation

A new Q/h-relation was calculated after a flood 25 July 2005 changed the river cross profile (Fig 2.15 in Klitgaard et al. 2006). As the velocity in the deep part of the new cross section is very strong only a limited number of manual measurements were made throughout the total cross profile. The aim for 2007 was to make a number of discharge measurements to confirm the preliminary Q/h-relation made in 2006. Unfortunately, it turned out, that the river cross section is unstable and the Q/h-relation established last year is not valid any more.

In 2007, 17 discharge measurements ranging from 1.31 to 31.18 m^3/s were carried out under ice free conditions. Based on these measurements a new Q/h-relation valid from June 2007 has been established (Fig. 2.8). The Q/h-relation is only valid when the riverbed and riverbanks are ice and snow free, because snow covering the banks changes the cross profile of the river and ice layers at the bottom of the river gives a false water level. To avoid the deeper part of the cross section where manual discharge measurements normally are made the discharge were measured a few hundred meters downstream from the hydrometric station.

River water discharge

The water discharge in Zackenbergelven for the season 2007 is shown in Fig. 2.9. In the first period – from the river started flowing 2 June and until 13 June – the riverbed and -banks were covered with ice

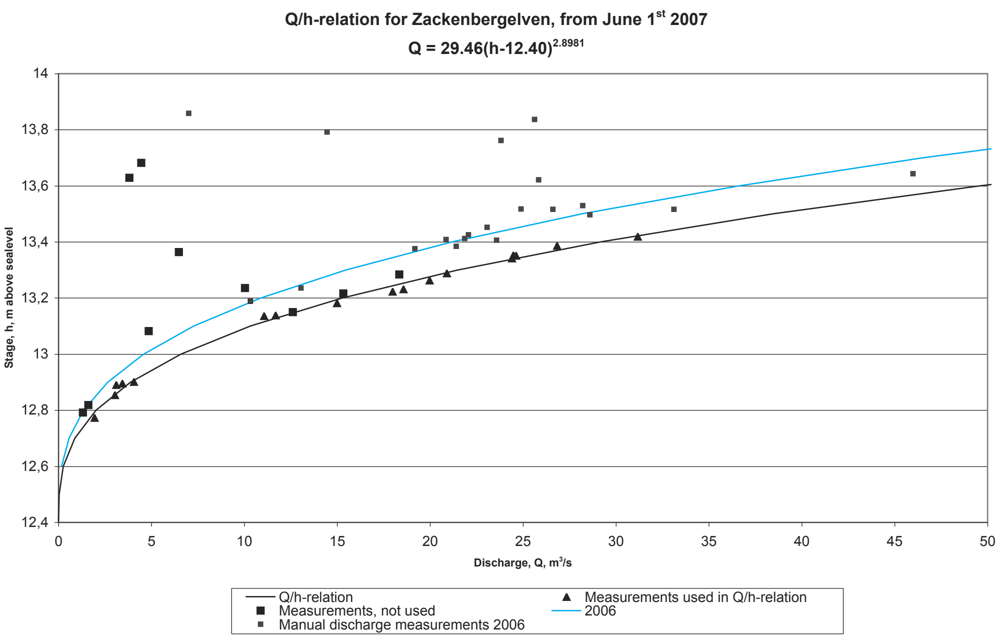


Fig. 2.8. Water level – discharge relation curve (Q/h-relation) for Zackenbergelven at the hydrometric station after 1 June 2007. The coefficient of correlation (R^2) for the curve is 0.995.

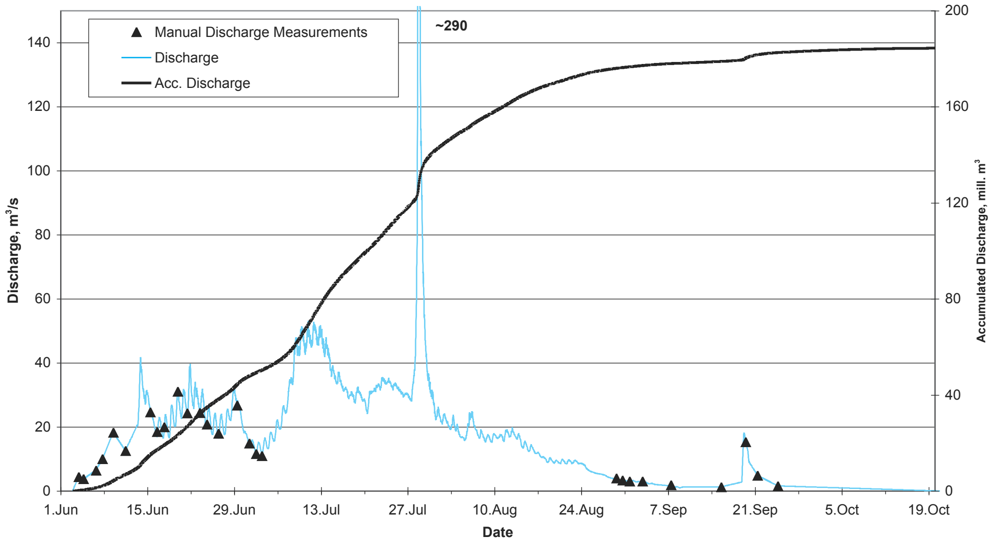


Fig. 2.9. River water discharge in Zackenbergelven during 2007.

and/or snow and the Q/h-relation therefore not valid. Instead, the discharge in this period is approximated by linear increase from zero to the discharge found at the manual measurement on 3 June, and again by linear interpolation between the manual measurement on 4 June, 6 June, 7 June, 9 June, 11 June and 13 June.

A large flood was observed in late July. After midnight between 27 and 28 July the river discharge increased dramatically and the water level rose 1.24 m until it peaked 28 July 16:00. During the next 24 hours a steady recession took place and by 30 July, the water level was back to the starting point (Fig. 2.9 and 2.10). According to the current Q/h-relation the peak discharge was approximately 290 m^3/s. This is, based on an extrapolation of the Q/h-relation, far beyond the range of manual discharge measurements and the total discharge for 2007 should only be regarded as a rough estimate. The flood followed a rainy period and even though the precipitation measured at the climate station was only 6 mm (24-27 July) it might have induced the flood.

As the field season was prolonged it was possible to follow the formation of ice cover in the river. From 24 August the river stopped running under the sonic range sensor but water was still running in the deeper part of the riverbed. After this date the discharge was approximated by linear interpolation between measured discharges and discharges calculated by use of the gauge readings. As late as 19 September a minor flood occurred, which resulted in the break up of an up to 10 cm thick ice cover (Fig 2.10). The sudden rise in runoff happened after a snow fall 18 September and may be associated with that. The last manual discharge measurements were carried out 24 September; later measurements were not possible due to ice. However, some water was still running below the ice until 20 October. At several occasions water was squeezed out on top of the ice where it froze (Fig 2.10).

The total runoff from the drainage basin in the period from 2 June until 20 October was approximately 184 mio. m^3 (Table 2.11). Precipitation for the hydrological year 2007 (1 October 2006 to 30 September 2007) was 133 mm – the lowest registered value for the years 1995-2007.

Suspended sediment

Water samples were collected both in the morning 8:00 and in the evening 20:00 in order to determine suspended sediment concentrations. Except for a few occasions, the sediment concentration was highest in the evening and showed the largest diurnal variation in the early season (Fig 2.11 c). During the flood, water was sampled every second hour and likewise water samples were collected every second hour during two diurnal observation campaigns on 10-11 July and 5-6 August. The highest concentration of 2,448 mg/l was measured an hour before peak discharge 28 July.

In the period from 2 June to 20 October a total of 51,118 ton suspended sediment was transported from the Zackenberg drainage basin to the fiord (Tabel 2.11). Out of the total transport only 1,041 ton occurred after 1 September where meas-

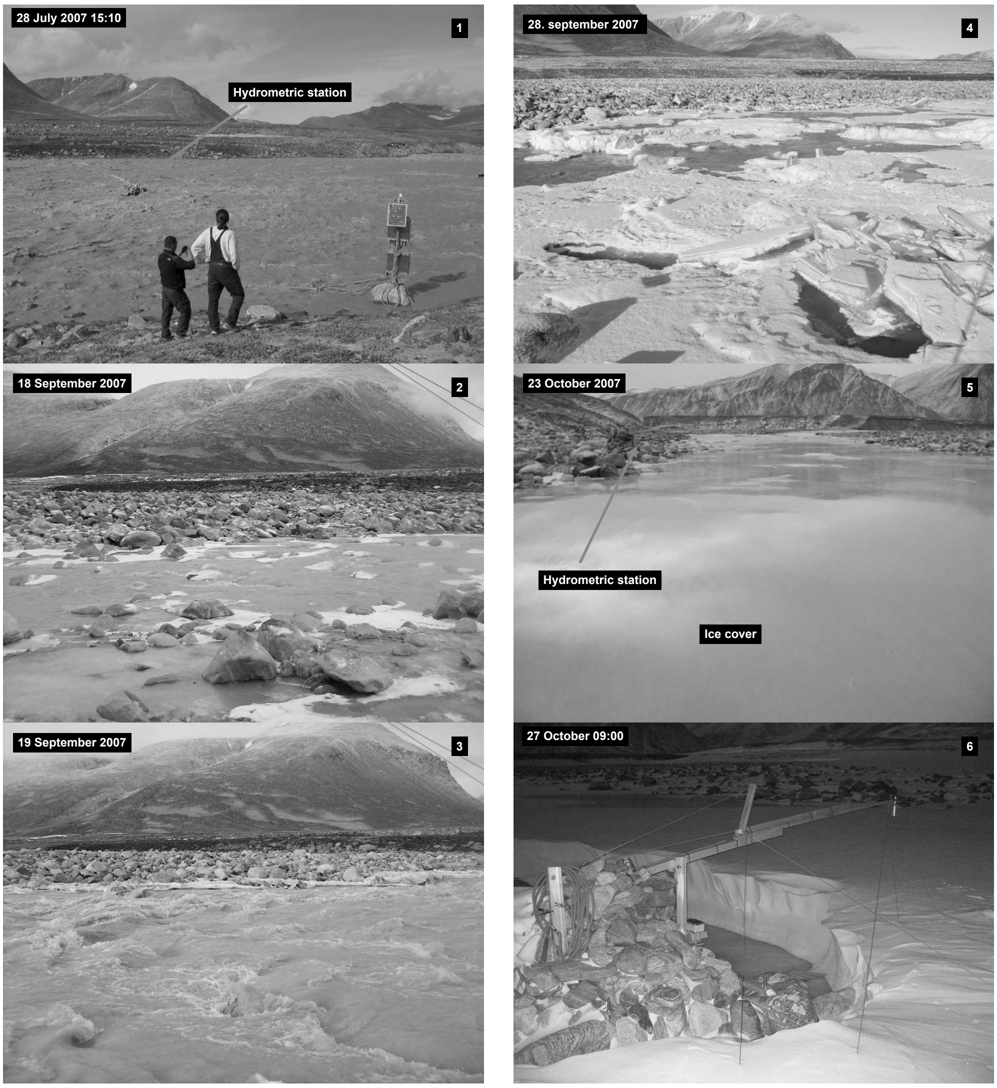


Fig 2.10. The river Zackenbergelven at different times throughout the season. 1) On 28 July we had the large flood. 2) Refreeze of the river on 18 September. 3) Small flood on 19 September. 4) More freezing and brake up of ice cover on 28 September. 5) A smooth ice surface on 23 October. 6) 113 cm of snow below the sensor after the snow storm. Photos: Maria Rask Pedersen and Charlotte Sigsgaard

urements normally stop. As mentioned in the above section, the high discharges during the flood are rough estimates and therefore, the total transport of sediment is also subject to some uncertainties. The yield of suspended sediment during the flood (28-29 July) constitutes approximately 22,000 ton of the total.

A new depth integrating water sampler (US DH-48) was used from august 2007. The new sampler collects up to 470 ml of water whereas samples of around 800 ml were collected with the old one. To compare the new and the old sampler several double measurements were carried out and the results were very alike.

Daily water samples collected in the morning are also being analyzed for

Table 2.11. Total discharge in Zackenbergelven in the years 1996-2007, corresponding water loss for the drainage area (514 km²) and precipitation measured at the climate station.
[1] The hydrological year is 1 October to 30 September. [2] For 2005, no data is available during the flood from 25 July 05:00 until 28 July 00:00. After this date and until the new hydrometric station was set up on 5 August, the discharge were estimated from manual readings of the water level from the gauge.

Hydrological year[1]	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total Discharge, mill m³	132	188	232	181	150	137	338	189	212	200[2]	172	184
June	43	45	50	41	41	53	143	71	46	66	31	47
July	67	80	98	123	61	47	150	71	100	100	98	96
August	21	61	78	17	47	34	46	43	64	34	40	34
September	1	2	4	0	0	3	0	4	2	??	??	7
Water loss, mm	257	366	451	352	292	267	658	368	412	389	335	358
Precipitation, mm	239	263	255	227	171	240	156	184	279	258	206	133
Total annual transport												
Suspended sediment (ton)		29,444	130,133	18,716	16,129	16,883	60,079	18,229	21,860	71,319	27,214	51,118
Suspended organic matter (ton)		1,643	11,510	2,297	1,247	1,098	3,267	1,351	1,388	3,475	1,807	2,419

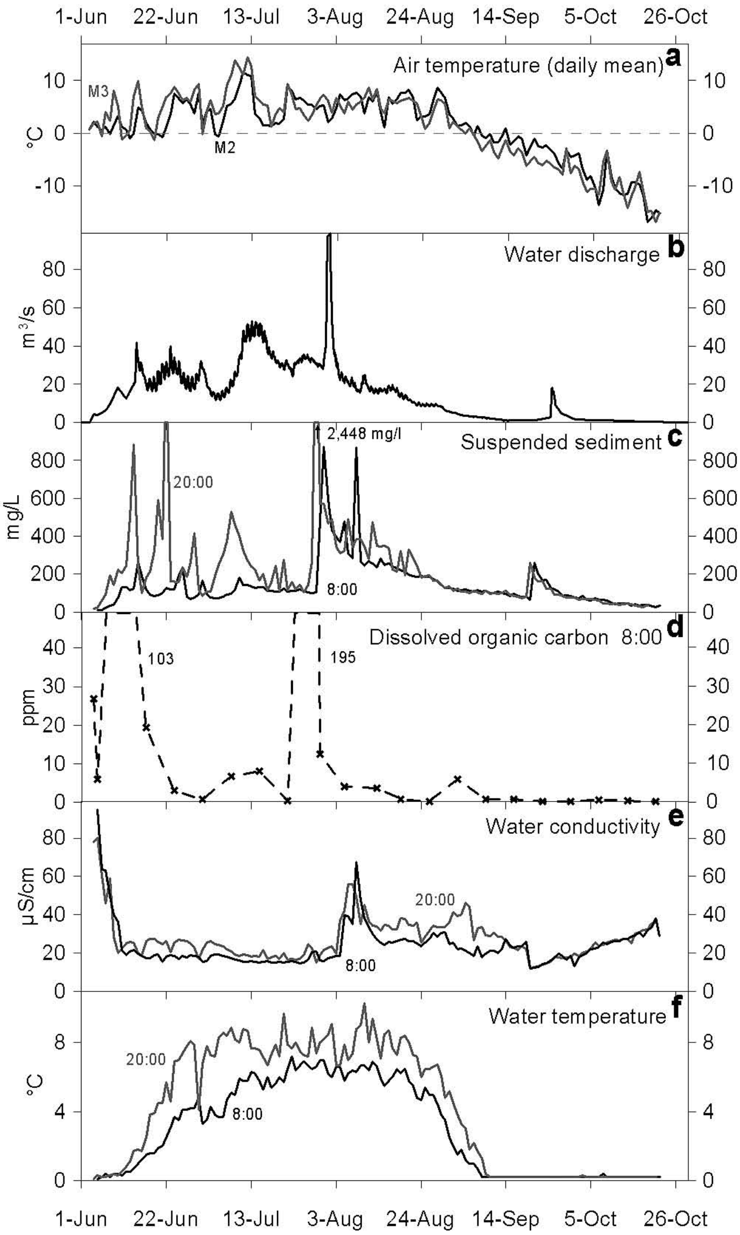


Fig. 2.11. a) Daily mean air temperatures at M3 420 m a.s.l. and at M2 17 m a.s.l. b) water discharge, c) concentration of suspended sediment, d) dissolved organic carbon e) conductivity and f) water temperature, in Zackenbergelven 2007.

chemical composition (conductivity, pH, alkalinity and major anions and cations) and at a lower frequency (approximately once a week) for DOC, NH_4-N, DTN and DON.

Suspended sediment and solutes in tributaries to Zackenbergelven

During 2007, water was sampled nine times from the main tributaries to Zackenbergelven. Locations of sample sites are given in Fig. 2.1. Water temperature and conductivity were measured on location, whereas water chemistry, suspended sediment and diluted organic matter concentration were determined from collected samples (Table 2.12). When the first samples were taken all tributaries except from "AucellaS" was running. It was not possible to cross "PalanatokeNW" and therefore no data from "Lindeman" and "Store Sødal" were obtained at this occasion. In September, all the streams were dry or ice covered and during the last sampling (22 September) water was only running from "Store Sødal". The stream from "Lindeman" was ice covered but a little water was still running below the ice.

A CTD diver, capable of measuring water level, water temperature and conductivity, was installed c. 300 m upstream from the junction between Lindemanselven and Store Sødal (UTM: 511662 E, 8269094 N, 82 m a.s.l.). The diver was installed 22 June when the riverbed and banks were free of snow and data was logged continuously every 15 minutes until 22 September when the diver was removed from the ice covered stream. Runoff peaked in June and again after the warm days (8-9 July). There was a small increase in late July after the rainy period which indicate that the flood observed in Zackenbergelven most likely must have been associated with drainage of a reservoir in the glaciated part of the basin, which again could be triggered by the rain water.

2.4 Precipitation and soil water chemistry

Precipitation

During the 2007 season, water from the open precipitation collector was sampled at six occasions. After rain events 30 June, 23 July, 26 July and 8 August and after snow events 28 September and 25 October.

Soil Moisture

Soil moisture at 10 cm and 30 cm below soil surface are measured year around at the micrometeorological stations M2 and M3 (Fig. 2.6). Since August 2005, soil moisture from 5, 10, 30 and 50 cm below the soil surface has also been logged continuously at M4 (Fig 2.1) In addition to these continuous measurements, soil moisture is being monitored manually twice a week throughout the summer season at 5, 10 and 30 cm depths at the soil water plots covered by different vegetation communities (see next section). All sensors at the

Table 2.12. Suspended sediment, conductivity, DOC, NH_4-N, DTN and NO_3 in water sampled from main tributaries to Zackenbergelven (streams from Store Sødal, Lindeman, PalnatokeNW, PalnatokeE, AucellaN, AucellaS and Rylekær). ND = No data. Dry = No water running. From StoreSødal and AucellaS, samples were not collected on 8 June, but on 13 and 17 June, respectively.

Suspended sediment (mg/l)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
8 Jun	101	ND	351	76	414	485	<2
22 Jun	78	483	418	26	493	786	<2
6 Jul	80	39	280	0	91	92	<2
20 Jul	110	138	1723	Dry	1169	516	Dry
26 Jul	106	103	341	Dry	2755	3698	Dry
11 Aug	264	15	230	Dry	141	5277	Dry
25 Aug	187	1	27	Dry	1272	1197	Dry
7 Sep	131	7	12	Dry	25	82	Dry
22 Sep	169	ND	Frozen	Dry	Frozen	Frozen	Dry

Conductivity (µS/cm)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
8 Jun	16	ND	29	33	39	ND	44
22 Jun	12	44	22	38	50	71	56
6 Jul	12	56	35	106	109	101	63
20 Jul	12	53	40	Dry	144	146	Dry
26 Jul	11	94	55	Dry	191	215	Dry
11 Aug	14	218	167	Dry	370	239	Dry
25 Aug	14	259	136	Dry	342	354	Dry
7 Sep	12	262	167	Dry	449	263	Dry
22 Sep	11	296	Frozen	Dry	Frozen	Frozen	Dry

DOC (mg/l)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
8 Jun	19.7	30.7	26.9	91.7	19.9	18.5	44.2
22 Jun	0.7	1.0	1.4	9.5	1.9	7.9	4.9
6 Jul	1.3	12.2	0.7	2.8	1.6	4.8	4.9
20 Jul	1.1	0.6	0.5	Dry	1.3	9.6	Dry
26 Jul	5.4	0.5	1.3	Dry	1.7	2.0	Dry
11 Aug	0.9	5.9	13.9	Dry	0.9	20.2	Dry
25 Aug	29.0	9.1	2.7	Dry	0.6	1.4	Dry
7 Sep	0.8	0.7	0.7	Dry	1.3	1.5	Dry
22 Sep	0.3	0.7	Frozen	Dry	Frozen	Frozen	Dry

NH_4-N (µg/l)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
8 Jun	23.9	14.6	14.6	22.3	17.2	31.2	16.3
22 Jun	20.6	17.0	19.6	16.2	16.0	16.5	10.4
6 Jul	31.9	18.3	28.2	20.8	22.1	21.1	17.1
20 Jul	28.6	21.0	45.9	Dry	33.4	29.2	Dry
26 Jul	14.9	16.6	21.7	Dry	33.2	30.1	Dry
11 Aug	18.4	15.0	12.9	Dry	17.0	23.9	Dry
25 Aug	36.7	21.6	13.0	Dry	21.3	20.3	Dry
7 Sep	20.6	18.7	16.8	Dry	19.0	23.9	Dry
22 Sep	17.6	19.8	Frozen	Dry	Frozen	Frozen	Dry

DTN (µg/l)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
8 Jun	393.0	321.3	603.0	278.9	467.4	285.7	343.5
22 Jun	158.3	296.1	115.3	239.5	122.2	194.4	93.4
6 Jul	219.3	128.2	273.1	132.6	87.5	54.3	184.5
20 Jul	115.4	84.3	148.2	Dry	190.0	376.9	Dry
26 Jul	71.6	92.5	90.2	Dry	281.0	229.3	Dry
11 Aug	179.8	123.2	200.9	Dry	300.7	496.4	Dry
25 Aug	190.2	113.0	101.8	Dry	260.7	243.2	Dry
7 Sep	254.2	185.6	230.1	Dry	316.6	229.8	Dry
22 Sep	140.7	99.3	Frozen	Dry	Frozen	Frozen	Dry

NO_3(µg/l)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
8 Jun	37.2	86.7	44.0	2.7	7.8	28.6	5.4
22 Jun	32.4	25.4	27.9	15.3	11.9	5.4	27.6
6 Jul	21.8	7.5	22.5	17.8	5.4	7.6	4.7
20 Jul	18.4	3.5	30.1	Dry	23.7	13.7	Dry
26 Jul	18.6	22.1	59.3	Dry	158.6	173.3	Dry
11 Aug	18.3	2.0	123.0	Dry	205.7	167.6	Dry
25 Aug	21.1	3.5	37.5	Dry	154.0	164.4	Dry
7 Sep	22.9	19.2	70.6	Dry	128.1	42.4	Dry
22 Sep	26.9	42.1	Frozen	Dry	Frozen	Frozen	Dry

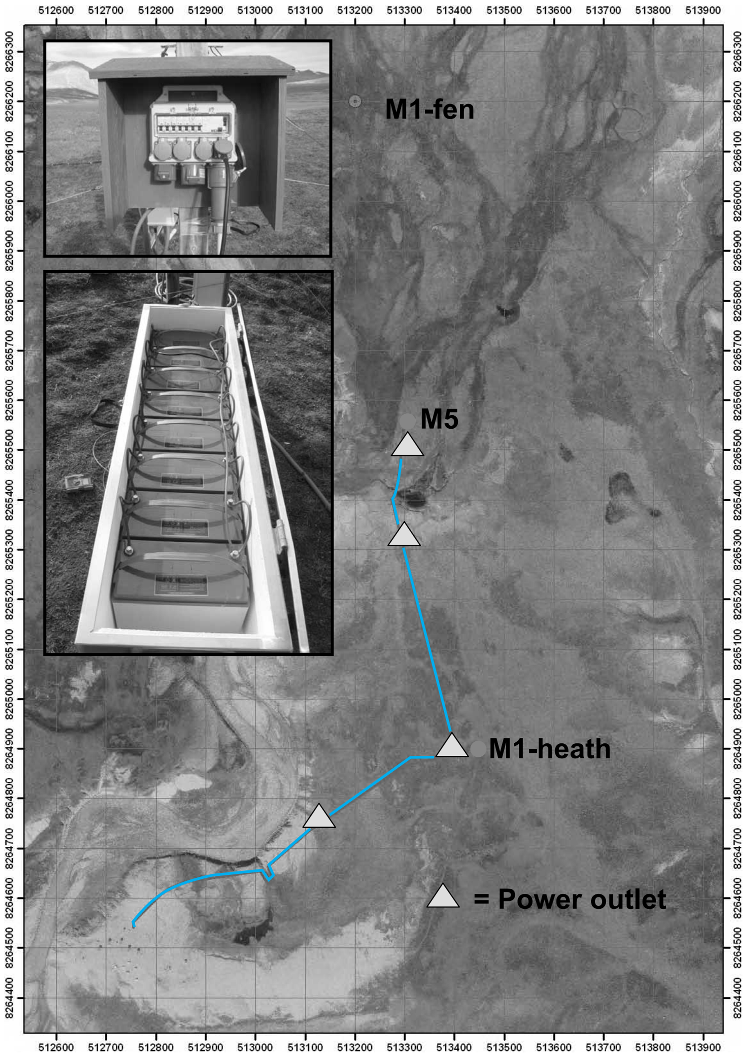


Fig. 2.12. The location of the new power cable and the four power outlets. The cable is armoured to prevent foxes from damaging the cable (and themselves) that is lying on the ground surface.

Sal1-site were lost during a storm. One sensor was installed at 10 cm depth (12 July) to replace the former ones in 5, 10 and 30 cm. At the Mix1-site, the sensor in 30 cm was broken and has not yet been replaced. Soil moisture is also being measured in the upper 5 cm along two transects in ZEROCALM-2, covering the variation from the very well drained barren ground in the upper end to the water soaked grassland in the lower end.

Soil water

Soil water is collected from various depths at five characteristic soil water regimes covered by the dominating plant communities in the valley. A well drained cassiope heath (K-site); a wet fen area (S-site); a dry heath site covered by *Dryas* (Dry1-site); a snowbed site covered mainly by *Salix* (Sal2-site) and finally a site covered by mixed heath vegetation (Mix1-site). A more detailed description of the sites are given in Caning and Rasch (2000) and Rasch and Caning (2004).

In 2007, soil water was collected four times during the season and the chemical composition of the soil water was analysed.

2.5 Gas fluxes

In order to secure enough power to run the flux measurements throughout September and October a permanent solution was established with a cable running from the generator at the research station through the northern part of Gadekæret and out to the micrometeorological station (M1) and further out through the valley to the methane site (M5) in the fen (Fig 2.12). From the end of August, these stations were powered through the new cable. When the generator at the research station is switched off at night, eight and three accumulators (12 V, 100 Ah) supply power to the M5 and M1, respectively.

Carbon dioxide flux

In order to describe the interannual variability of the seasonal carbon balance, exchange of CO_2 between a well drained heath ecosystem and the atmosphere has been measured since 2000 using eddy covariance technique. Details on the instrumentation are given in section 4.2 in Rasch and Caning (2003).

In 2007, measurements were initiated 27 May and continued until 28 October. The temporal variation in daily net exchange of CO_2 and mean daily air temperature for the first three months of continuous measurements are shown in Fig. 2.13. The sum of the two processes, i.e. uptake of CO_2 by plants from photosynthesis and loss due to microbial decomposition in the soil, is denoted Net Ecosystem Exchange (NEE). The uptake is controlled by the climatic conditions during the growing season with solar radiation and temperature being key controlling factors. The respiratory process is controlled by soil temperature in an exponential fashion, and also soil moisture has an effect on the respiration.

When measurements were initiated 27 May, the eddymast (3 m high) was placed on top of 40 cm snow and the snow cover in the fetch area was close to 100%. In the

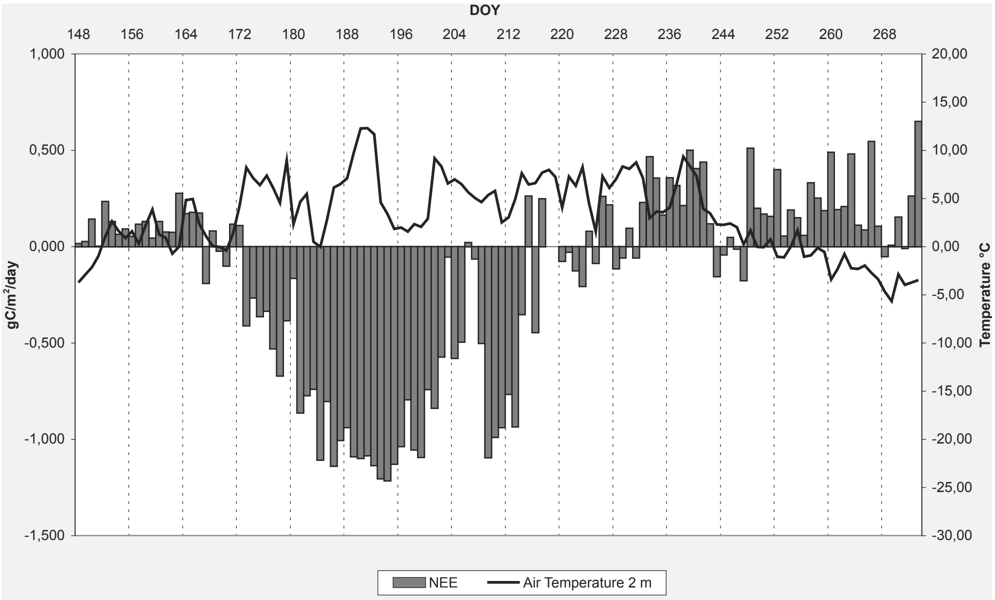


Fig. 2.13. Temporal variation in Net Ecosystem Exchange (NEE) and daily mean air temperature at the heath in 2007. The sign convention used is the standard for micrometeorological measurements; fluxes directed from the surface to the atmosphere are positive whereas fluxes directed from the atmosphere to the surface are negative.

first part of the season, the ecosystem was characterized by a small net emission of CO_2. During the first weeks of June, the snow cover gradually disappeared and the soil respiration increased resulting in a net emission of CO_2 from the soil to the atmosphere with a maximum NEE of 0.30 $gC/m^2/d$ captured on 13 June (Table 2.13). Note that the term "Net uptake period" has replaced the term "growing season" used in the annual reports prior to this one. The new term covers the same period as before but has been changed to avoid confusing with the growing season term used by the BioBasic programme. As the ground became free of snow, the vegetation developed and a photosynthetic uptake of CO_2 started. When photosynthetic uptake of CO_2 exceeded the respiration 22 June, the ecosystem switched from a source of CO_2 to a sink of CO_2. The period with a net uptake lasted 59 days and was only interrupted by a few days in early August where respiration exceeded the photosynthesis due to windy and cloudy weather and a low level of incoming solar radiation. Also in the end of July the uptake rates were reduced due to rainy and overcast conditions.

A maximum uptake of CO_2 was measured 13 July; immediately after the warmest period that summer (Table 2.13). By 18 August, the system returned to a source of CO_2 when respiration gradually had exceeded the fading photosynthesis.

Compared to previous years, the period with a net uptake was relatively long and only exceeded in 2005 where the onset of the period with a net uptake was a few days earlier due to an early snow melt (Table 2.13). The net uptake period ended up with a total of 31.4 g C/m^2, also only exceeded in 2005. For the measuring period in total, the ecosystem also acted as a sink of carbon with a total accumulation of 20.1 g C/m^2, but this value cannot be compared directly with the other years as the 2007 measuring period was two months longer than in previous years.

A new micro meterorological station using eddy covariance technique was installed at the heath site 4 September. The

Table 2.13. Summary of summer season environmental variables and CO_2 exchange 2000-2007. After a power failure 6 August, the CO_2/H_20 analyzer lost all settings. CO_2 values were being collected again the day after but there was no data for water vapour during the rest of the season. Therefore, the values after 6 August has been re-calculated using modelled water vapour. These data should for quantitative analyses be used with caution.

Year	2000	2001	2002	2003	2004	2005	2006	2007
Start of Net uptake period	25 June	6 July	2 July	28 June	23 June	17 June	10 July	22 June
End of Net uptake period	11 August	18 August	16 August	20 August	21 August	18 August	23 August	19 August
Length of Net uptake period	47 days	43 days	45 days	53 days	59 days	63 days	45 days	59 days
Beginning of measuring season	6 June	8 June	3 June	5 June	3 June	21 May	27 May	27 May
End of measuring season	25 August	27 August	27 August	30 August	28 August	25 August	27 August	28 Oct
Length of measuring season	80 days	81 days	86 days	86 days	86 days	97 days	93 days	153 days
NEE for Net uptake period ($gC\ m^{-2}$)	(-) 22.7	(-) 19.1	(-) 18.2	(-) 30.4	(-) 29.7	(-) 33.4	(-) 26.1	(-) 31.4
NEE for measuring season ($gC\ m^{-2}$)	(-) 19.1	(-) 8.7	(-) 9.5	(-) 23.0	(-) 22.4	(-) 29.6	(-) 21.6	(-) 20.1
Maximum daily accumulation ($gC\ m^{-2}\ d^{-1}$)	(-) 0.92	(-) 0.94	(-) 1.00	(-) 1.40	(-) 1.30	(-) 1.15	(-) 1.25	(-) 1.21

instrumentation consist of an Omnidirectional Research Ultrasonic anemometer (Solent 1210R3, Gill Instruments, Lymington, UK) for measuring wind speed and wind direction and an Infrared Gas Analyzer (Li-7000, LICOR, Nebraska, USA) for measuring water vapour and carbon dioxide concentrations. Data collecting and processing is based on the EdiSol software package (Moncrieff et al. 1997). In the period from 4 to 20 September a double set-up was running at the heath site with both the old and the new instruments.

The old instruments were moved to the fen site (20 September) at the same location as gasflux measurements were carried out in 1996-1999 (Nordstroem et al. 2001) (UTM: 8266136mN, 513186 mE -see Fig. 2.1). Solar panels powered the station (M1-fen) until 20 October 2007 when measurements at this site were stopped.

Methane flux

This year was the second full season for the automatic methane monitoring station (see section 2.5 in Klitgaard et al. 2007). The measurements were started 24 June, almost two weeks after snow melt at the site, so the very first part of the emission picture is missing. As in 2006, a fast increase in CH_4 emission was observed, coming to its maximum around 10 July (mean flux up to 7 mg $CH_4/m^2/h$) (Fig 2.14). After this clear peak the emission declined and reached the 2006 level of 3 mg $CH_4/m^2/h$ about 20 July. The gradual decrease continued until the end of growing season (coming to 1 mg $CH_4/m^2/h$ 30 August). Possible explanations of this flux pattern are given in the 2006 report.

Main differences between the 2007 and the 2006 growing season fluxes were:

- The season started a month earlier in 2007
- Higher and more "condensed" peak of emission
- Slightly lower fluxes at the end of the season.

Active layer depth development was more or less similar to 2006 (although we missed the first and most dynamic part of the season). The maximum registered active layer depth was 50.5 cm compared to 48 cm in 2006. The difference between 2006 and 2007 water table dynamics was however large. In 2006 water was standing above the surface for the whole season while it was below the surface from 7 July 2007 and stayed 11 to 16 cm below the surface throughout the rest of the 2007 season.

Surprisingly, this difference did not cause a dramatic difference in total methane fluxes. The emission values during peak season were higher in 2007 than in 2006 (about 7 mg $CH_4/m^2/h$ and 5 mg $CH_4/m^2/h$, respectively), but after the peak the emission values were slightly lower (about 1-2 and 2-3, respectively). It is hard to compare the total seasonal emissions, as the two seasons are different in timing and that both years contain data gaps. The reconstructed fluxes give about

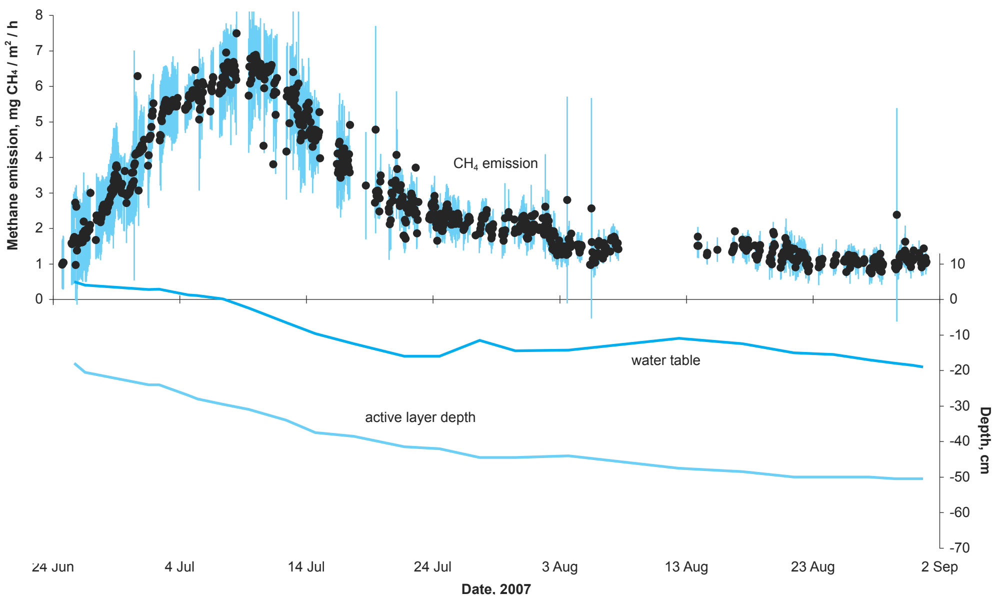


Fig. 2.14. Methane (CH_4) emission from the fen (Tørvekæret) during the summer 2007. Changes in water table and depth of active layer are given on the right axis. Missing data are mainly because of power failures but this problem should have been solved by the new set-up with a cable from the generator at the research station.

2.3 gC/m^2 per season in 2006 and 3.4 gC/m^2 per season in 2007 (note that "season" was 3 weeks longer in 2007).

2.6 Geomorphology

Landscape monitoring based on photos of different dynamic landforms such as talus slopes, rock glaciers, mud slides, frost boils, gullies, thermo karsts, beach ridges, coastal cliffs, snow patches and ice wedges are part of the GeoBasic monitoring.

	Recession (m)			
	Site 1	Site 2	Site 3	Site 4
1996-1997	0	0	0.3	1
1996-1998	0	0	0.3	1.3
1996-1999	0	0	0.3	1.3
1996-2000	0	0	0.5	1.4
1996-2001	0	0	0.5	1.4
1996-2002	0	0	0.7	2.8
1996-2003	0	0.4	1.6	3.2
1996-2004	0	0.5	1.7	3.2
1996-2005	0	0.7	1.7	3.2
1996-2006	0	0.9	1.8	3.2
1996-2007	0	0.9	1.8	3.7

Table 2.14. Coastal cliff reccesion at the southern coast of Zackenbergdalen 1996-2007.

Coastal geomorphology

Cliff recession along the southern coast of Zackenbergdalen is measured every year in August. From 2006 to 2007 approximately 0.5 m was lost at site 4 Table 2.14.

In the Zackenberg river delta rapid erosion is observed along the delta cliff on the western side of the river due to fluvial thermo erosion and subsequent block slumping. An automatic digital camera was placed on the eastern side of the delta looking towards the cliff in order to follow the changes (Position of camera: 8263392 mN, 511935 mE, 5 m a.s.l.). Photos have been taken on a daily basis since 23 June. Block slumping was observed several times during the summer and on 4 August the cliff was split in an outer and an inner part when the mid section collapsed.

3 ZACKENBERG BASIC
The BioBasic programme

Jannik Hansen, Lars Holst Hansen, Mikkel P. Tamstorf, Kirsten Christoffersen, Erik Jeppesen and Niels Martin Schmidt

The BioBasic programme at Zackenberg is carried out by the National Environmental Research Institute (NERI), Department of Arctic Environment, University of Aarhus, Denmark. It is funded by the Danish Environmental Protection Agency as part of the environmental support program Dancea – Danish Cooperation for Environment in the Arctic. The authors are solely responsible for all results and conclusions presented in the report, which do not necessarily reflect the position of the Danish Environmental Protection Agency.

Following the recommendations in the report from the International Evaluation Committee (Callaghan et al. 2006) and a workshop held at the National Environmental Research Institute, Aarhus University, in spring 2007, the BioBasic protocols were subjected to thorough revisions. Several changes were implemented and new monitoring initiatives incorporated into the programme during the 2007 field season. Among other things ITEX (International Tundra EXperiment) temperature chambers were established to evaluate the long-term effects of increased temperatures on the vegetation. Additionally, long-term UV-B effect monitoring was initiated. New advanced NDVI equipment was implemented in close collaboration with GeoBasic, and both plot and landscape NDVI measurements are now conducted as part of the BioBasic programme.

The major changes in the sampling protocol are mentioned in the individual sections below. Detailed information on the revised BioBasic methods and updated

Table 3.1. Inter- and extrapolated day of year of 50% snow-cover for white arctic bell-heather Cassiope tetragona, *mountain avens* Dryas integrifolia/octopetala, *arctic poppy* Papaver radicatum, *arctic willow* Salix arctica, *purple saxifrage* Saxifraga oppositifolia *and moss campion* Silene acaulis *plots 1996-2007. Brackets denote extrapolated dates.*

Plot	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Cassiope 1	166	160	164	178	154	158	164	157	<155	143	164	155
Cassiope 2	171	172	178	185	<156	172	171	164	168	158	183	167
Cassiope 3	167	172	171	184	165	171	171	158	159	148	179	158
Cassiope 4	172	166	171	185	165	172	168	158	159	158	174	164
Dryas 1	<155	<147	(143)	157	<156	<151	<150	(155)	<154	<140	(150)	<145
Dryas 2/Salix 7	178	178	185	193	173	184	179	173	173	168	192	170
Dryas 3	158	<147	158	170	<156	157	157	157	<155	<140	151	<145
Dryas 4	153	154	164	172	<156	158	157	(151)	<153	(118)	164	152
Dryas 5	158	151	155	165	<156	156	157	157	<153	<140	177	<145
Dryas 6/Papaver 4	173	185	186	192	172	179	181	170	173	165	191	164
Papaver 1	172	169	172	184	153	171	169	163	166	152	179	162
Papaver 2/Salix 5	172	171	172	185	166	172	171	172	163	158	183	161
Papaver 3	173	166	171	184	165	172	170	165	160	158	174	163
Salix 1	<155	<147	<147	<152	<155	<151	<150	(151)	<155	<140	(145)	<145
Salix 2	166	171	174	182	165	172	165	165	161	156	178	160
Salix 3	159	159	163	175	<155	158	158	(153)	<155	(138)	160	151
Salix 4	172	156	172	173	159	162	161	164	157	150	165	154
Salix 6									173	166	186	165
Saxifraga/Silene 1	<155	<147	<147	<152	<155	<151	<150	(152)	<154	<140	<146	<145
Saxifraga/Silene 2	<155	<147	<147	(147)	<155	<151	<150	(151)	<154	<140	<146	<145
Saxifraga/Silene 3	-	<147	147	157	<155	(147)	<150	(152)	<154	(128)	158	152
Silene 4	176	179	171	187	173	179	176	170	170	163	186	164

sampling protocols (Meltofte et al. 2008) are available at the home page of NERI (http://biobasis.dmu.dk).

3.1 Vegetation

The weekly records of snow-cover, plant flowering and reproduction were conducted by Lars Holst Hansen during 25 May-3 September. Niels Martin Schmidt, Jannik Hansen and Line Kyhn assisted at different times during the season.

In 2007, three new plant monitoring sites were established. Two sites consisting of 5 ITEX temperature chamber plots and 5 control plots each, and one site with a total of 15 plots with UV-B, filter controls and controls. The ITEX and UV sites were established by Anders Michelsen and Helge Ro-Poulsen. Also, new equipment for measuring plant greenness (NDVI) was implemented in close collaboration with GeoBasic, and new NDVI transects and more permanent NDVI plots were included in the programme.

Reproductive phenology and amounts of flowering

The field season began on 25 May. Compared to previous years, 2007 had an early snowmelt. Dates of 50% snow-cover in all of 22 plant plots were early when compared to previous years and only one plot had a later date in 2007 than in mean dates of all the previous 11 seasons (Table 3.1). Two plots had the earliest date recorded hitherto. The early snowmelt resulted in early flowering, and 8 of 28 plots had the earliest 50% flowering dates recorded hitherto, and a total of 26 of 28 plots had earlier flowering than the mean based on all previous 11 seasons (Table 3.2).

The dates of 50% open seed capsules are listed in Table 3.3. For the three species monitored, arctic poppy *Papaver radicatum*, arctic willow *Salix arctica* and purple saxifrage *Saxifraga oppositifolia*, dates were generally early with only one plot of *Salix* and one of *Saxifraga* being later than average based on the previous 12 seasons. However, no plot had a hitherto earliest date.

Table 3.2. Inter- and extrapolated day of year of 50% open flowers (50/50 ratio of buds/open flowers) for white arctic bell-heather Cassiope tetragona, *mountain avens* Dryas integrifolia/ octopetala, *arctic poppy* Papaver radicatum, *arctic willow* Salix arctica, *purple saxifrage* Saxifraga oppositifolia *and moss campion* Silene acaulis *1996-2007. Brackets denote interpolated dates based on less than 50 buds+flowers.*

Plot	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Cassiope 1	184	187	187	194	(180)	185	184	178	175	167	185	178
Cassiope 2	188	201	(202)	(207)	-	193	188	184	187	173	201	186
Cassiope 3	191	199	(200)	(207)	-	192	190	183	182	173	200	185
Cassiope 4	197	196	(202)	(207)	-	200	188	186	185	183	200	186
Dryas 1	171	173	177	184	178	173	176	181	173	164	177	173
Dryas 2	195	216	220	-	206	213	210	200	200	198	215	192
Dryas 3	184	177	187	194	179	187	179	180	175	164	180	177
Dryas 4	179	187	(190)	195	178	187	179	174	174	164	187	178
Dryas 5	182	186	182	188	174	186	179	179	172	164	172	171
Dryas 6	201	221	(219)	231	203	210	213	198	199	194	214	191
Papaver 1	196	201	205	214	186	193	193	186	193	185	206	(188)
Papaver 2	196	204	207	211	197	195	194	189	190	190	208	188
Papaver 3	196	200	207	213	192	198	194	192	187	187	201	(187)
Papaver 4	197	219	223	227	(202)	(208)	214	198	194	194	214	(192)
Salix 1	158	157	163	165	163	159	160	168	156	155	165	161
Salix 2	173	180	191	198	180	180	179	179	173	165	196	177
Salix 3	172	176	(179)	186	163	175	167	166	159	157	174	165
Salix 4	181	174	183	184	169	179	177	174	173	164	180	170
Salix 5	-	-	-	-	-	-	-	186	175	164	194	174
Salix 6	-	-	-	-	-	-	-	-	197	184	200	179
Salix 7	-	-	-	-	-	-	-	-	187	187	202	182
Saxifraga 1	-	151	156	158	158	159	154	165	157	144	(151)	(160)
Saxifraga 2	-	153	158	165	161	159	157	165	157	152	157	158
Saxifraga 3	157	152	160	167	159	160	158	165	<154	146	172	165
Silene 1	172	175	172	179	178	179	174	182	173	165	170	173
Silene 2	175	180	182	181	184	181	178	185	181	166	182	179
Silene 3	182	177	174	187	180	185	179	185	172	166	194	(179)
Silene 4	208	222	232	-	210	210	209	201	201	197	194	193

Plot	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Papaver 1	217	228	-	242	>238	222	228	232	213	219	212	232	223
Papaver 2	227	228	236	-	>238	(230)	228	229	215	219	215	234	221
Papaver 3	218	226	231	-	241	227	230	232	218	216	212	223	220
Papaver 4	232	-	>239	-	(>238)	(229)	236	(238)	222	227	220	(239)	(222)
Salix 1	220	221	220	217	225	225	214	210	214	208	201	219	218
Salix 2	224	222	231	242	237	233	230	223	215	218	215	231	220
Salix 3	214	221	228	(231)	228	225	226	217	209	209	206	223	215
Salix 4	224	230	226	233	228	226	225	224	215	219	210	223	219
Salix 5	-	-	-	-	-	-	-	-	216	220	219	>240	221
Salix 6	-	-	-	-	-	-	-	-	223	223	226	>240	222
Salix 7	-	-	-	-	-	-	-	-	225	223	226	>240	224
Saxifraga 1	-	202	222	223	225	222	220	216	219	205	203	(217)	218
Saxifraga 2	-	205	228	236	227	228	226	213	223	209	212	217	216
Saxifraga 3	-	220	221	235	228	220	225	224	221	205	212	225	221

Table 3.3. Inter- and extrapolated day of year of 50% open seed capsules for arctic poppy Papaver radicatum, *arctic willow* Salix arctica *and purple saxifrage* Saxifraga oppositifolia *1995-2007. Brackets denote interpolated dates based on less than 50 flowers+open capsules.*

The season of 2007 generally had very low numbers of flowers produced (Table 3.4). 39 of 43 plots produced fewer or the same number of flowers than the 1996-2006 average, and with new minima for one mountain avens *Dryas* sp., two arctic poppy *Papaver radicatum*, two *Salix* (male flowers), two moss campion *Silene acaulis*, two arctic cotton-grass *Eriophorum scheuchzeri* and one *E. triste* plot(s). More flowers than average were produced only in three *Dryas* plots and in one *Eriophorum scheuchzeri* plot. The two *Dryas* plots (Dry7 and Dry8) and the two *Cassiope* plots (Cas5 and Cas6) situated in the Aucellabjerg slopes were closed in 2007.

Two out of 7 *Salix* plots had catkins infested with fungi in 2007 (Table 3.5). This season the plots for monitoring the production of berries in alpine bearberry *Arctostaphylos alpina* and crow berry *Empetrum nigrum* and arctic blueberry *Vaccinium uliginosum* were closed, mainly due to an altered snow cover after the erection of the new housing facility, and low plot replication.

Vegetation greening

In close collaboration with GeoBasic (see section 2), new equipment for measuring NDVI (plant greenness) directly in the plant and most arthropod plots in the valley lowland was implemented in 2007. Also, NDVI is now being monitored along the three transect routes in the valley also covered by the GeoBasic snow monitoring programme (see section 2.2). Hence, the NDVI along the ZERO Line, NDVI in the valley lowland, and in the permafrost plot ZEROCALM-1 is now being estimated approximately every three weeks. Hereby, the vast majority of the vegetation types situated at various altitudes in the valley are being covered four times during the summer season.

In contrast to the previously used RVI meters, the new NDVI equipment measures actual NDVI. Therefore a series of calibration experiments were conducted to allow for the comparison of the two methodologies, and thus for the standardisation of all previously conducted and all future NDVI estimates.

The greening index data (NDVI) from an ASTER satellite image from 29 July 2007 are presented in Table 3.6. Means for 2007 are compared with data from previous years after extrapolation to simulate 31 July each year (Table 3.7). See Meltofte et al. (2008) for location of snow sections in Zackenbergdalen. Despite the early melting of the snow, landscape NDVI in all sections was around or below the average of the previous years (Table 3.7). The NDVI transects were walked four times during the summer season, and revealed a large altitudinal gradient in the seasonal greening pattern.

In the 26 plant plots, the greening of the vegetation (NDVI) culminated relatively early in the season when compared to the previous years. However, 6 plots had later than average peak NDVI (Table 3.8).

ITEX temperature chamber plots

Two sites with ITEX temperature chamber plots were established in July 2007. Each site holds 5 ITEX open top chambers (OTC; Fig. 3.1) and 5 controls. One site was established in a *Vaccinium-Salix-Dryas*

Plot	Area	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Mean	2007
Cassiope 1	2	1321	1386	1855	322	312	28	1711	1510	851	2080	1392	973	1160,7	435
Cassiope 2	3		1759	550	19	16	8	1353	952	1001	1745	1203	593	860,6	300
Cassiope 3	2	256	844	789	35	18	0	771	449	817	791	862	432	512,0	92
Cassiope 4	3	456	1789	391	24	6	3	578	164	1189	1274	1857	520	702,8	223
Cassiope 5	2.5	-	-	1224	455	474	50	3214	3208	2708	2006	2648	1238	1776,3	-
Cassiope 6	2	-	-	>350	16	3	1	544	736	134	2796	3938	610	1021,0	-
Dryas 1	4	(936)	(797)	138	223	852	607	1016	627	744	444	391	321	300,8	150
Dryas 2	60	534	1073	230	42	49	46	172	290	552	1174	519	521	425,5	577
Dryas 3	2	603	522	123	255	437	266	577	235	294	273	198	134	343,9	92
Dryas 4	6	(325)	(164)	155	69	356	55	301	187	224	218	143	168	110,8	191
Dryas 5	6	(654)	(504)	123	191	655	312	506	268	589	351	233	123	188,2	125
Dryas 6	91	809	1406	691	10	25	140	550	430	627	1854	878	1324	674,5	1144
Dryas 7	12	-	-	787	581	1355	574	1340	1483	1543	1026	599	363	1032,0	-
Dryas 8	12	-	-	391	240	798	170	403	486	545	229	243	119	389,4	-
Papaver 1	105	302	337	265	190	220	197	237	277	278	286	207	153	254,2	108
Papaver 2	150	814	545	848	316	315	236	466	456	564	402	682	416	513,1	334
Papaver 3	90	334	238	289	266	183	240	259	301	351	221	316	234	272,5	236
Papaver 4	91	196	169	192	80	30	35	65	59	56	37	68	71	89,7	29
Salix 1 mm.	60	-	807	959	63	954	681	536	1454	1931	1127	375	303	888,7	184
Salix 1 ff.	60	520	1096	1349	149	1207	900	1047	1498	2159	1606	386	223	1083,4	241
Salix 2 mm.	300	-	790	1082	132	416	55	803	1206	967	1276	737	654	746,4	317
Salix 2 ff.	300	617	1376	1909	455	418	95	1304	1816	1638	1862	1089	1076	1143,5	386
Salix 3 mm.	36	239	479	412	32	52	330	1196	344	621	693	285	204	425,7	169
Salix 3 ff.	36	253	268	237	38	68	137	1009	315	333	476	188	129	302,0	154
Salix 4 mm.	150	-	1314	831	509	718	965	680	1589	1751	1984	1317	1508	1165,8	1108
Salix 4 ff.	150	1073	1145	642	709	880	796	858	1308	1418	1755	1038	905	1056,5	827
Salix 5 mm.	150	-	-	-	-	-	-	-	-	494	844	945	1052	761,0	414
Salix 5 ff.	150	-	-	-	-	-	-	-	-	371	1314	1333	1365	1006,0	525
Salix 6 mm.	150	-	-	-	-	-	-	-	-	-	2162	2445	591	2303,5	525
Salix 6 ff.	150	-	-	-	-	-	-	-	-	1145	2736	2010	947	1963,7	1085
Salix 7 mm.	60	-	-	-	-	-	-	-	-	612	621	746	286	659,7	351
Salix 7 ff.	60	-	-	-	-	-	-	-	-	839	512	705	180	685,3	266
Saxifraga 1	7	-	(1010)	141	163	584	1552	558	542	1213	463	159	36	436,5	190
Saxifraga 2	6	-	513	387	432	158	387	515	617	561	584	522	167	467,6	313
Saxifraga 3	10	-	529	322	288	707	403	558	318	509	609	241	150	448,4	394
Silene 1	7	-	(251)	403	437	993	1327	674	766	1191	1187	312	430	754,1	94
Silene 2	6	-	493	524	440	400	692	568	1094	917	1406	740	540	727,4	285
Silene 3	10	-	348	211	127	313	274	348	480	1000	719	503	739	432,3	379
Silene 4	1	466	270	493	312	275	358	462	470	794	509	483	312	444,7	423
E. scheuz. 1	10	-	395	423	257	309	229	111	582	843	780	201	302	413,0	533
E. scheuz. 2	6	-	537	344	172	184	201	358	581	339	956	597	540	426,9	142
E. scheuz. 3	10	-	392	545	482	587	38	367	260	237	359	67	44	333,4	31
E. scheuz. 4	8	-	260	755	179	515	117	121	590	445	176	57	23	321,5	55
E. triste 1	10	-	0	3	1	1	1	0	3	11	12	0	0	3,2	1
E. triste 2	6	-	98	59	21	16	43	56	67	39	117	44	49	56,0	13
E. triste 3	10	-	0	0	0	0	0	0	0	0	0	0	0	0,0	0
E. triste 4	8	-	0	0	0	0	0	0	0	0	0	0	0	0,0	0

Table 3.4. Area size (m^2) and pooled numbers of flower buds, flowers and senescent flowers of white arctic bell-heather Cassiope tetragona, *mountain avens* Dryas integrifolia/octopetala, *arctic poppy* Papaver radicatum, *arctic willow* Salix arctica, *purple saxifrage* Saxifraga oppositifolia, *moss campion* Silene acaulis, *arctic cotton-grass* Eriophorum scheuzerii,*'dark cotton-grass'* Eriophorum triste *in 1995-2007. Numbers in brackets have been extrapolated from 1995 and 1996 data to adjust for enlargement of plots (see Meltofte and Rasch 1998).*

heath area, and one was established in a pure *Cassiope* heath area. Focal plant species in the first site is *Salix*, while in the latter it is *Cassiope*. Detailed pin-point analyses were carried out in all plots. Also, in all plots a metal frame base was mounted in order to allow for the measurements of carbon fluxes in 2008 and onwards. No monitoring was conducted in the plots during the 2007 season, except for the TinyTag temperature loggers, that revealed a clear heating effect of about 2°C

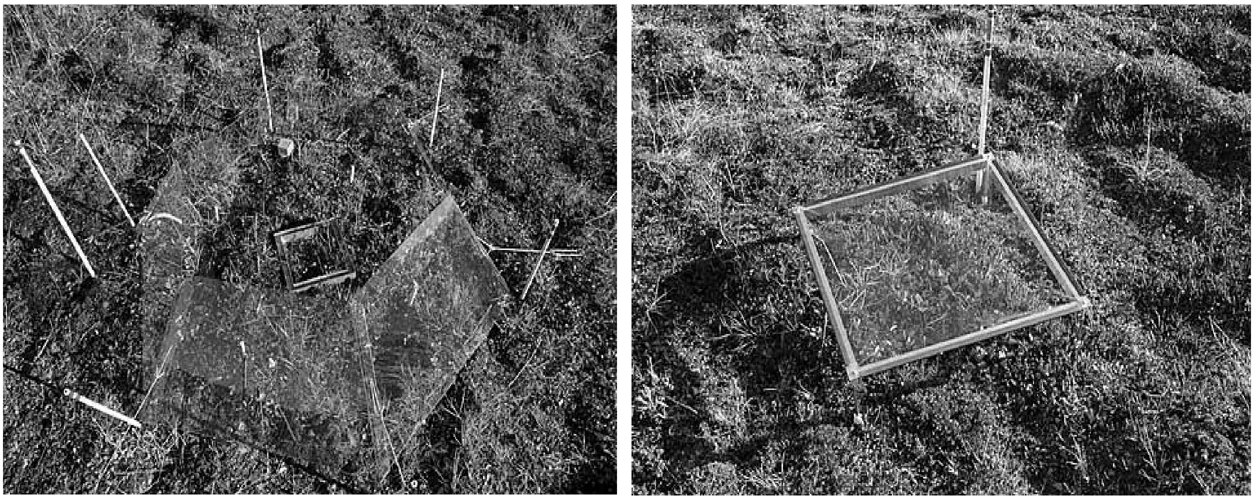


Fig. 3.1. ITEX open top chambers and UV-B exclusion plots

(Fig. 3.2). ITEX chambers were taken down in late August. One additional chamber was, however, left in the vicinity of the ITEX sites in order to examine the potential effects of the chamber on the snow accumulation and melt-off.

UV-B exclusion plots

In 2007, a new site was established to monitor the long-term effects of UV-B radiation on *Vaccinium uliginosum* and *Salix arctica* leaves (Fig. 3.1). The site is located next to the ITEX *Salix* site in a

Table 3.5. Peak ratio (%) of female Salix *pods infested by fungi in* Salix *plots in 1996-2007. '+' indicates non-quantified fungi infestation.*

Plot	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Salix 1	5	4	0	22	4	1	3	+	2	0	0	0
Salix 2	0	1	2	2	0	0	1	0	0	1	0	0
Salix 3	0	0	0	6	0	0	2	0	0	0	0	7
Salix 4	16	3	0	6	0	0	0	0	3	0	0	0
Salix 5	-	-	-	-	-	-	-	-	3	4	0	2
Salix 6	-	-	-	-	-	-	-	-	0	0	0	0
Salix 7	-	-	-	-	-	-	-	-	0	1	0	0

Section	Area	Min.	Max.	Mean	Std.Dev.
1 (0-50 m)	3.52	0.00	0.73	0.37	0.15
2 (0-50 m)	7.97	0.00	0.83	0.44	0.15
3 (50-150 m)	3.52	0.00	0.79	0.46	0.13
4 (150-300 m)	2.62	0.00	0.67	0.35	0.14
5 (300-600 m)	2.17	0.00	0.58	0.24	0.12
6 (50-150 m)	2.15	0.00	0.65	0.40	0.14
7 (150-300 m)	3.36	0.00	0.65	0.37	0.15
8 (300-600 m)	4.56	0.00	0.72	0.28	0.18
9 (0-50 m)	5.01	0.00	0.78	0.44	0.13
10 (50-150 m)	3.84	0.00	0.72	0.46	0.11
11 (150-300 m)	3.18	0.00	0.70	0.38	0.14
12 (300-600 m)	3.82	0.00	0.78	0.33	0.17
13 (Lemmings)	2.05	0.00	0.76	0.42	0.13
Total Area	**45.72**	**0.00**	**0.83**	**0.39**	**0.16**

Table 3.6. Area size (km^2) and Normalised Difference Vegetation Index (NDVI) values for 13 sections of the bird and musk ox monitoring areas in Zackenbergdalen together with the lemming monitoring area based on an ASTER satellite image from 29 July 2007 (see Meltofte et al. (2008) for position of the snow sections). The image has been corrected for atmospheric and terrain influence (humidity, aerosols, solar angle and terrain effects). All negative NDVI values, i.e. from water and snow-covered areas, have been replaced by zeros.

Section	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1 (0-50 m)	0.37	0.43	0.44	0.44	0.30	0.41	0.34	0.34	-	0.42	0.41	0.39	0.37
2 (0-50 m)	0.43	0.50	0.50	0.51	0.41	0.48	0.43	0.44	-	0.50	0.49	0.47	0.44
3 (50-150 m)	0.54	0.53	0.54	0.53	0.41	0.51	0.47	0.49	-	0.54	0.53	0.48	0.46
4 (150-300 m)	0.46	0.45	0.46	0.44	0.31	0.43	0.36	0.38	-	0.41	0.40	0.38	0.35
5 (300-600 m)	0.36	0.35	0.38	0.38	0.22	0.37	0.26	0.26	-	0.31	0.30	0.28	0.24
6 (50-150 m)	0.48	0.48	0.47	0.46	0.33	0.44	0.39	0.41	-	0.46	0.45	0.43	0.40
7 (150-300 m)	0.48	0.46	0.48	0.45	0.32	0.43	0.38	0.39	-	0.45	0.44	0.40	0.37
8 (300-600 m)	0.42	0.38	0.41	0.42	0.25	0.35	0.28	0.29	-	0.33	0.32	0.32	0.28
9 (0-50 m)	0.42	0.50	0.52	0.51	0.39	0.50	0.44	0.45	-	0.52	0.51	0.47	0.44
10 (50-150 m)	0.52	0.53	0.54	0.52	0.40	0.52	0.48	0.48	-	0.55	0.54	0.49	0.46
11 (150-300 m)	0.47	0.45	0.46	0.42	0.26	0.41	0.35	0.36	-	0.45	0.44	0.39	0.38
12 (300-600 m)	0.42	0.42	0.44	0.45	0.28	0.32	0.34	0.33	-	0.41	0.40	0.39	0.33
13 (Lemmings)	0.42	0.49	0.50	0.49	0.40	0.47	0.41	0.43	-	0.48	0.47	0.45	0.42
Total	**0.45**	**0.46**	**0.48**	**0.47**	**0.32**	**0.43**	**0.38**	**0.38**	**-**	**0.45**	**0.44**	**0.42**	**0.39**

Table 3.7. Mean NDVI values for 13 sections of the bird and musk ox monitoring areas in Zackenbergdalen together with the lemming monitoring area based on Landsat TM, ETM+ and SPOT 4 HRV and ASTER satellite images 1995-2007 (see Meltofte et. al (2008) for position of sections). The data have been corrected for differences in growth phenology between years to simulate the 31 July value, i.e. the approximate optimum date for the plant communities in most years. Data from 2003 are not available due to technical problems.

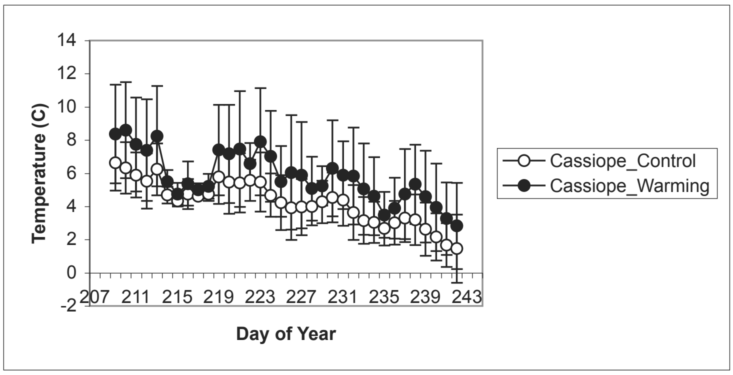
Vaccinium-Salix-Cassiope-Dryas heath area. The UV site consists of 5 plots with UV-B filters (Mylar), 5 filter controls (Teflon), and 5 control plots. Detailed pin-point analyses were carried out in all plots, but no monitoring was conducted here in 2007. In 2008 and onwards, the effects of UV-B will be examined in mid summer by means of leaf flourescens measurements in all plots. In 2008, a metal frame base will be mounted in all plots to allow for the measurements of carbon fluxes in 2009 and onwards.

3.2 Arthropods

To reduce the number of arthropod specimens collected annually, the number of pitfalls at each trap station was reduced. Each station now holds four pitfall traps (yellow cups) as opposed to the eight pitfall traps that previously operated within each station.

All five pitfall trap stations, each now with four subplots, and one window trap station, with four trap chambers, were open during the 2007 season. Sampling procedures were concurrent with previous seasons. Field work was carried out by Lars Holst Hansen, while Niels Martin Schmidt and Jannik Hansen contributed to the field collections.

Samples were sorted by personnel from the Department of Terrestrial Ecology (TERI) at the National Environmental Research Institute, Silkeborg, Denmark. The material is stored in 70% ethanol at the Museum of Natural History, Aarhus. In 2007, the entire collection of arthropods from Zackenberg 1996 onwards was moved to the Museum of Natural History, Aarhus, and is available for further study there. Please contact the BioBasic manager regarding access to the collection. Unfortunately, 16 arthropod samples were destroyed during the transportation from Zackenberg to Denmark, and numbers given below are thus minimum estimates.



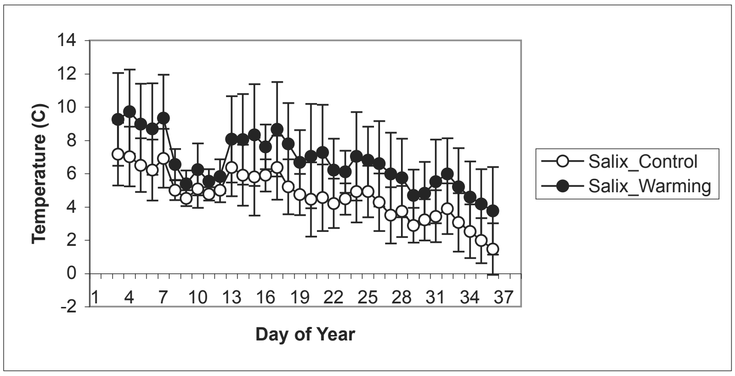


Fig. 3.2. Mean daily temperature in the ITEX open top chambers and their controls in the Salix plots and in the Cassiope plots. Bars indicate the standard deviation.

Plot	1999		2000		2001		2002		2003		2005 early		2005 late		2006		2007	
	NDVI	DOY	NDVI	DOY	NDVI	DOY	NDVI	DOY	NDVI	DOY	NDVI	DOY	NDVI	DOY	NDVI	DOY	NDVI	DOY
Cassiope 1	0.40	210	0.41	211	0.37	217	0.35	210	0.36	217	0.34	190	0.30	203	0.28	203	0.32	206
Cassiope 2	0.41	210	0.46	204	0.38	203	0.38	238	0.43	217	0.37	190	0.39	203	0.38	239	0.34	206
Cassiope 3	0.41	231	0.36	232	0.33	217	0.31	238	0.34	224	0.30	190	0.34	210	0.34	224	0.29	206
Cassiope 4	0.38	238	0.41	204	0.35	210	0.33	238	0.39	217	0.34	190	0.39	210	0.38	212	0.34	206
Mean	0.40		0.41		0.36		0.34		0.38		0.34		0.36		0.35		0.32	
Dryas 1	0.43	203	0.41	204	0.37	203	0.35	206	0.40	203	0.32	190	0.25	210	0.26	203	0.25	206
Dryas 2/Salix 7	0.39	231	0.42	204	0.39	210	0.43	217	0.42	217	0.36	190	0.37	203	0.36	239	0.37	206
Dryas 3	0.45	210	0.45	204	0.42	207	0.41	210	0.46	203	0.33	190	0.31	210	0.33	212	0.25	206
Dryas 4	0.34	231	0.32	204	0.33	203	0.28	210	0.29	203	0.25	190	0.29	210	0.30	212	0.29	206
Dryas 5	0.34	210	0.33	204	0.31	203	0.28	210	0.31	196	0.20	190	0.23	210	0.21	212	0.13	206
Dryas 6/Papaver 4	0.35	238	0.41	204	0.34	207	0.37	217	0.38	203	0.33	190	0.36	210	0.36	224	0.30	206
Mean	0.38		0.39		0.36		0.35		0.38		0.30		0.30		0.30		0.27	
Papaver 1	0.41	231	0.41	204	0.38	210	0.39	210	0.41	203	0.35	190	0.37	265	0.36	212	0.37	206
Papaver 2/Salix 5	0.44	231	0.45	204	0.41	210	0.40	217	0.42	210	0.37	190	0.43	210	0.40	212	0.39	206
Papaver 3	0.37	238	0.41	204	0.35	210	0.34	217	0.39	203	0.33	190	0.39	210	0.38	212	0.35	206
Mean	0.39		0.42		0.37		0.37		0.40		0.35		0.39		0.38		0.37	
Salix 1	0.57	210	0.59	204	0.54	189	0.54	203	0.60	196	0.51	190	0.43	210	0.48	203	0.48	206
Salix 2	0.52	210	0.52	204	0.49	210	0.51	203	0.50	203	0.46	190	0.42	210	0.46	220	0.42	190
Salix 3	0.41	210	0.44	204	0.39	210	0.38	210	0.38	203	0.34	190	0.31	203	0.32	203	0.35	206
Salix 4	0.46	210	0.47	204	0.43	214	0.45	210	0.47	196	0.40	190	0.38	210	0.42	212	0.37	206
Salix 6	-	-	-	-	-	-	-	-	0.39	212	0.33	190	0.43	210	0.45	212	0.39	206
Mean	0.46		0.48		0.44		0.45		0.46		0.40		0.40		0.43		0.40	
Saxifraga/Silene 1	0.28	210	0.34	220	0.27	189	0.19	203	0.27	196	0.19	190	0.15	210	0.19	212	0.11	206
Saxifraga/Silene 2	0.36	210	0.38	204	0.34	200	0.31	203	0.38	196	0.34	190	0.27	196	0.28	212	0.29	206
Saxifraga/Silene 3	0.23	210	0.26	204	0.27	196	0.20	210	0.24	203	0.17	190	0.15	210	0.20	212	0.13	190
Silene 4	0.32	238	0.36	204	0.27	210	0.26	217	0.28	210	0.26	190	0.30	210	0.28	224	0.24	206
Mean	0.30		0.34		0.29		0.24		0.29		0.24		0.22		0.24		0.19	
Eriophorum 1	0.57	217	0.60	196	0.60	210	0.57	210	0.61	196	-	-	0.54	196	0.55	220	0.50	190
Eriophorum 2	0.58	210	0.58	204	0.53	207	0.50	210	0.45	196	0.44	190	0.44	196	0.44	220	0.45	211
Eriophorum 3	0.54	231	0.56	204	0.47	210	0.47	210	0.48	203	0.37	190	0.35	203	0.39	224	0.35	211
Eriophorum 4	0.73	217	0.72	204	0.68	210	0.64	217	0.67	203	-	-	0.70	210	0.69	220	0.65	197
Mean	0.61		0.62		0.57		0.54		0.55		0.41		0.51		0.52		0.49	
Mean of all	0.43		0.44		0.40		0.39		0.41		0.33		0.36		0.37		0.34	

Table 3.8. Peak NDVI recorded in 26 plant plots 1999-2007 together with day of year of maximum values. NDVI values presented are transformed RVI averages of eight (four in very small plots) hand held measurements in each plot. Note that the greening measured accounts for the entire plant community, in which the taxon denoted may only make up a smaller part. Data from 2004 are not included due to instrumental error that season.

Station no.	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Art. 1	3.6	Dry	6.6	16.6	1.6	6.6	3.6	12.6	<1.6***	<20.5	5.6	27.5
Art. 2	<3.6*	28.5	29.5	8.6	<4.6*	<31.5*	<31.5*	1.6	<1.6*	<20.5*	<27.5	<26.5*
Art. 3	14.6	19.6	18.6	27.6	9.6	19.6	14.6	20.6	4.6	3.6	23.6	7.6
Art. 4	14.6	22.6	26.6	2.7	7.6	21.6	20.6	11.6	6.6	4.6	28.6	10.6
Art. 5	4.6	<29.5*	1.6	12.6	<4.6*	8.6	3.6	5.6	<1.6*	<20.5	3.6	<25.5**
Art. 7	-	-	-	<3.6	<4.6*	<30.5	<31.5*	2.6	<1.6*	<20.5	<27.5	<25.5**

* 0% snow ** <1% snow cover *** 7% ice cover

*Table 3.9 Date of 50% snow-cover (ice-cover on pond at Station 1) in the arthropod plots 1996-2007. * 0% snow, ** <1% snow, *** 7% ice cover.*

The total number of arthropods collected in 2007 was 27,089. Ice and snow at the arthropod trap stations generally melted early in 2007 (Table 3.9).

Window traps

This season window traps in Gadekæret was opened on 25 May, when the eastern and western ponds had ice covers of 25%

Date	3.6	10.6	17.6	24.6	1.7	8.7	15.7	22.7	29.7	6.8	12.8	19.8	26.8	2007	2006	2005	2004	2003	2002	2001
No. of trap days	14	14	14	14	14	14	14	14	14	16	12	14	16	**184**	178	195	172	168	168	168
COLLEMBOLA					3		6	11	12	1				**33**	35	112	175	31	191	119
COLEOPTERA																				
Latridius minutus														**0**	0	0	0	0	0	0
HEMIPTERA																				
Nysius groenlandicus								1						**1**	1	6	10	0	1	0
Aphidoidea														**0**	0	8	3	1	0	2
Coccoidea						1	8		11	1				**0**	0	0	0	0	0	0
THYSANOPTERA					1	1	1		1			1		**5**	7	7	11	0	3	1
LEPIDOPTERA																				
Colias hecla														**0**	0	1	9	2	6	0
Clossiana sp.							5	1	1		2			**9**	3	1	5	4	1	1
Lycaenidae							4	8		1				**13**	3	0	0	0	0	0
Geometridae								1						**0**	0	0	0	0	2	3
Noctuidae					1		2		1					**4**	4	7	1	1	0	0
DIPTERA																				
Nematocera larvae														**0**	0	0	0	0	2	0
Nematocera undet.														**0**	0	0	0	0	0	1418
Tipulidae							1	1						**0**	0	0	0	1	0	0
Trichoceridae														**0**	0	0	2	0	0	0
Culicidae					3	16	20	3	9	2				**53**	68	128	104	96	232	209
Chironomidae		402	4212	4729	1648	643	313	378	178	137	78	48	22	**12788**	9290	6470	5203	7792	6378	3876
Ceratopogonidae				4	15	16	8	34	2	2		2		**83**	32	9	21	66	1598	168
Mycetophiliidae								2	2	1	1	1		**7**	17	18	21	2	6	23
Sciaridae		1		81	53	30	5	4	2	3				**179**	125	749	53	12	56	33
Cecidomyiidae					1									**0**	0	0	0	0	3	4
Empididae				1	2	2	2		1					**8**	9	7	7	8	1	8
Phoridae									1					**1**	3	0	0	0	1	1
Syrphidae				2					1	1	3	2		**9**	8	10	12	6	10	4
Heleomyzidae														**0**	0	0	0	0	1	2
Piophilidae														**0**	0	0	3	0	0	0
Agromyzidae	1	1	1											**3**	17	99	34	2	3	0
Tachinidae									1					**1**	3	7	10	7	0	2
Calliphoridae	1							2			1		1	**5**	1	9	4	1	1	1
Scatophagidae						1		1	2	2	1	5	3	**15**	0	31	11	3	7	0
Anthomyidae		2	32	13	1	1			2	2	2	10		**65**	43	28	12	10	8	2
Muscidae			1	22	94	167	79	55	35	33	22	4	2	**514**	394	935	1423	866	554	1312
HYMENOPTERA																				
Bombus sp.									3					**3**	0	7	5	3	1	0
Ichneumonidae					4	10	3	2	2	3	2	1	2	**29**	33	68	47	70	24	34
Braconidae											1			**1**	0	0	1	0	0	0
Chalcidoidea								1		2				**3**	1	1	1	1	2	14
Ceraphronoidea												1		**0**	0	0	0	2	0	0
ARANEA																				
Lycosidae						2	6	7	2	1				**18**	31	10	1	1	1	0
Linyphiidae							1						1	**2**	8	12	4	8	8	15
ACARINA		6					1	3	8	1	4	4		**27**	80	704	524	54	347	358
Total	2	412	4246	4852	1826	890	465	515	277	193	117	79	31	**13879**	10216	9444	7717	9050	9448	7610

Table 3.10. Weekly totals of arthropods etc. caught in the window trap stations in 2007. The station holds two window traps situated perpendicular to each other. Each window measures 20x20 cm. Values from each date represents catches from the previous week. Totals from 2001-2006 are given for comparison.

and 5%, respectively. The traps worked continuously until 2 September. The total number of specimens caught this season in the window traps was 13,879 (Table 3.10). This number is the highest number caught at Zackenberg.

The gossamer-winged butterflies (Lycaenidae) were caught at the highest numbers yet, having previously only been caught in window traps in 2006 (Table 3.10). Mosquitos (Culicidae) on the other hand were caught at the lowest number

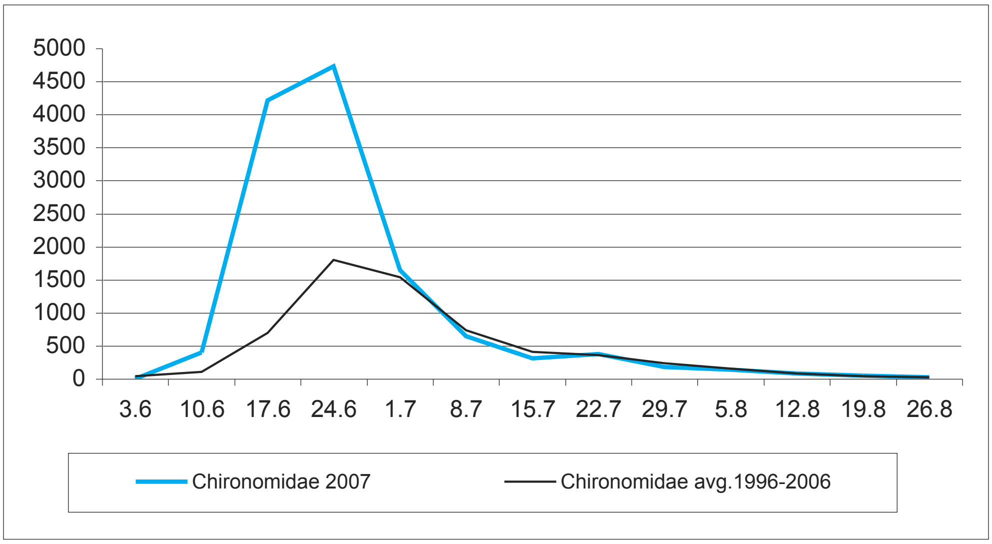


Fig. 3.3. Numbers of chironomid midges (Chironomidae) caught per trap day per week in the window traps 2007 compared with the mean for 1996-2006.

so far, about one third of the average numbers of 1996-2006. Like previous years, midges (Chironomidae) constituted the bulk of specimens caught. This year the midges had a very high and distinct peak, more than 2.5 times the average for the years 1996-2006 (Fig. 3.3). Early on, the curve is steeper than usual, but the peak is in the same week as the average of the previous ten years. Dark-winged fungus gnats (Sciaridae) were caught at numbers a little lower than average, whereas dung flies (Anthomyidae) continued to rise in numbers with new record numbers caught. Contrarily, only three leaf miner flies (Agromyzidae) were caught. This group was back to usual levels after the peak in 2004-2006 (Table 3.10). House flies (Muscidae) had higher numbers than the record low numbers of 2006, although still only at half the numbers of the 1996-2006 average. Mites (Acarina) were caught at low numbers (Table 3.10)

Pitfall traps

The first pitfall traps were established on 26 May, and all traps were in use from 12 June and until 2 September. The number of trapping days in 2007 was 1,709, which is high compared to previous season, considering that the number of traps was half of that previously used (Table 3.11). Weekly totals were pooled for all five stations and presented in Table 3.11 with totals from 2001-2006 for comparison. A total of 13,210 arthropods were collected from the pitfall traps in the 2007 season. This number is low compared to other years, even when taking the halved number of pitfall traps into account.

The seed bug (*Nysius groenlandicus*) was caught in relatively high numbers, just as scale insects Coccoidea were caught in high numbers (Fig. 3.4).

The hecla sulphur butterfly (*Colias hecla*) was missing from the samples, precedent only in 2006 and 2001. As in 2006, higher than usual numbers of the butterflies belonging to the Lycaenidae were caught again in 2007 (Table 3.11).

Midges (Chironomidae) were caught in high numbers; just over the average of 1996-2006 despite only having half the number of traps open. Scuttle flies (Phoridae) were caught in numbers above average. For house flies (Muscidae) numbers caught were near average out side of the two peak periods, in which there were very numerous. The usual double peaked abundances of Muscidae in the pitfall traps was still apparent, although the first peak was much higher and extended into the time of the average second peak. The second peak of the 2007 Muscidae catches was delayed one week compared to the average of previous years, and the second peak was very small, and delayed two weeks (Fig. 3.5).

The Ichneumon wasps (Ichneumonidae) were found at record low numbers, continuing a downward trend even considering the halved trap opening time. Chalcid wasp (Chalcidoidea) numbers were high compared to preceding seasons (Fig. 3.4). The sheetweb weavers (Linyphiidae) also appeared in the samples at the lowest numbers yet, also with the lower trap numbers taken into account (Table 3.11).

Date	3.6	10.6	17.6	24.6	1.7	8.7	15.7	22.7	29.7	6.8	12.8	19.8	26.8	2007	2006	2005	2004	2003	2002	2001
No. of active stations	3	5	5	5	5	5	5	5	5	5	5	5	5	**5**	5	5	5	5	5	5
No. of trap days	83	91	135	140	140	140	140	140	140	160	120	140	140	**1709**	2979	3686	3437	3101	3059	2954
COLLEMBOLA		21	95	68	362	119	37	204	177	122	54	11	22	**1292**	3003	9586	13277	17510	20312	17970
HETEROPTERA																				
Nysius groenlandicus							1				2	1		**4**	13	471	96	3	0	2
Aphidoidea	1			1	1		1		4	5	6	6	8	**33**	61	524	277	1624	157	359
Coccoidea	2		11	7	25	67	163	26	66	33	20	8	3	**431**	617	1092	1288	42	634	9
Unidentified Heteroptera														**0**	3					
THYSANOPTERA					1	2	1			2				**6**	2	19	4	0	5	0
LEPIDOPTERA																				
Lepidoptera larvae	1	3	2	2	3	5	3	2	2	4	4	1		**32**	116	82	280	37	63	16
Tortricidae														**0**	1	0	0	1	0	1
Colias hecla														**0**	0	15	38	156	29	0
Clossiana sp.						16	74	2	14	8	25	1		**140**	210	174	240	468	381	49
Lycaenidae						1	8		1		6			**16**	45	0	0	0	0	0
Plebeius franklinii														**0**	0	1	1	0	7	19
Geometridae														**0**	0	2	2	0	6	0
Noctuidae						2	2			6	6	2	1	**19**	19	183	14	110	1	15
DIPTERA																				
Nematocera larvae														**0**	21	10	18	29	46	15
Tipulidae larvae								1						**1**	2	1	6	3	3	3
Tipulidae				1	2									**3**	4	5	1	7	4	14
Trichoceridae														**0**	1	0	1	1	1	7
Culicidae														**0**	33	13	19	23	86	34
Chironomidae		3	25	2179	831	366	91	44	9	9	1		1	**3559**	4365	1492	1596	4768	5982	1958
Ceratopogonidae				56	23	5	8	4		1				**97**	92	6	16	107	102	7
Mycetophiliidae												1		**1**	74	104	63	70	48	181
Sciaridae			13	147	120	132	72	28	14	6			1	**533**	1256	819	912	1101	762	573
Cecidomyiidae														**0**	2	8	13	8	6	8
Brachycera larvae														**0**	0	0	0	3	0	0
Empididae										1	1			**2**	2	3	5	8	24	28
Cyclorrhapha larvae										1				**1**	1	77	60	23	22	0
Phoridae					3	8	106	21	295	48	73	57	9	**620**	461	386	461	665	489	445
Syrphidae		1	2		2	2	2		3	3	7	4	2	**28**	9	93	45	35	30	18
Heleomyzidae														**0**	1	0	1	1	5	6
Agromyzidae	1		1								1			**3**	29	151	60	10	6	4
Tachinidae					2	2	3				8		4	**19**	16	39	42	60	23	29
Calliphoridae	1	1	1							4	4	7	2	**20**	6	96	31	17	44	5
Scatophagidae									1	2	11		8	**22**	1	106	7	42	24	0
Fannidae														**0**	0	0	0	0	0	0
Anthomyiidae	16	23	83	15	2	1				13	22	23	12	**210**	183	535	124	108	238	57
Muscidae			8	105	356	541	227	61	49	60	81	28	9	**1525**	2313	5464	5623	8385	7499	6766
SIPHONAPTERA														**0**	0	0	0	0	0	0
HYMENOPTERA																				
Tenthredinidae														**0**	0	1				
Hymenoptera larvae														**0**	0	3	4	8	0	0
Bombus sp.		1		1		2			1	4	4	1		**14**	6	18	40	15	7	3
Ichneumonidae				2	7	12	29	9	11	10	11	11	13	**115**	269	717	720	974	436	442
Braconidae			2	3	3	3	4	1			1	1	2	**20**	42	80	61	52	11	11
Chalcidoidea			1	2	1	8	10	19	67	105	122	65	37	**437**	287	747	746	120	190	106
Scelionidae														**0**	4	0	0	310	5	3
Ceraphronoidea					1	1	1			2				**5**	8	17	13	3	8	3
Cynipoidae														**0**	0	24	3	0	0	1
ARANEA																				
Thomisidae	12	15	7	11	15	20	13	6	1	3	6	6	6	**121**	164	98	90	164	219	177
Lycosidae	18	20	60	185	411	363	282	152	254	365	164	112	64	**2450**	2869	3316	3428	3438	1760	2618
Lycosidae egg sac		1				8	2				2	2	3	**18**	56	45	69	85	12	85
Dictynidae	5	1		2	2			1						**11**	10	84	40	18	107	0
Linyphiidae	30	23	19	31	12	8	24	1	15	17	24	24	33	**261**	834	1411	1483	2526	1438	1833
ACARINA	11	44	64	130	108	109	129	61	75	101	108	138	63	**1141**	3505	10096	17616	18602	21282	9929
OSTRACODA														**0**	129	1	0	12	9	0
NEMATODA														**0**	233	1	1	4	0	0
ENCHYTRAEIDAE														**0**	20	1	0	0	1	0
Unidentified														**0**	89	0	0	0	0	0
Total	98	157	394	2948	2293	1803	1293	643	1059	935	774	510	303	**13210**	21487	38217	48935	61756	62523	43811

Table 3.11. Weekly totals of arthropods etc. caught at the five pitfall trap stations in 2007. Each station holds four yellow pitfall traps measuring 10 cm in diameter. Values from each date represent catches from the previous week. Totals from 2001-2006 are given for comparison.

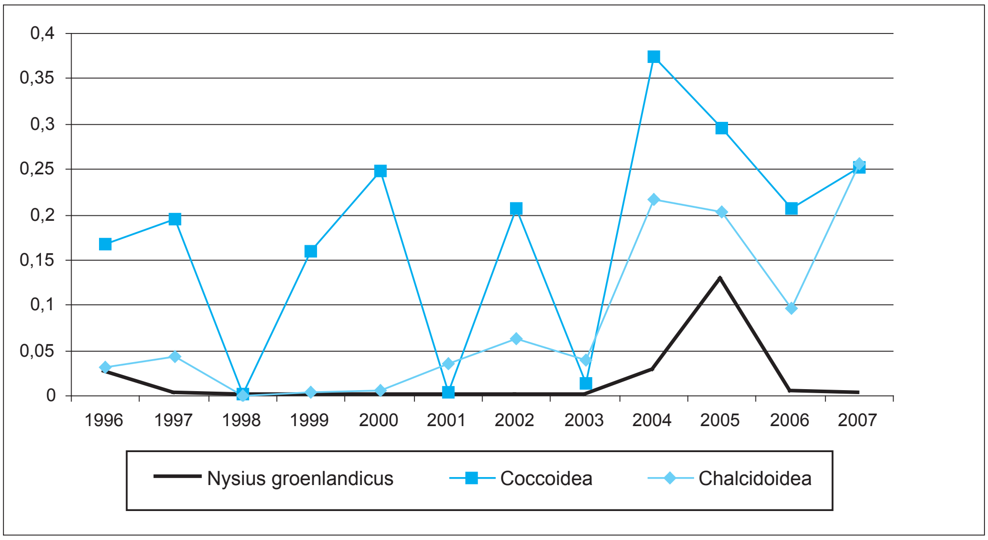


Fig. 3.4. Mean number of Nysius groenlandicus, *Coccoidea and Chalcidoidea individuals caught per trap day during 1996-2007.*

Insect predation on *Dryas* flowers and *Salix arctica*

There were three sawfly larvae *Symphyta* sp. feeding on catkins in the *Salix* study plots 2007 (Table 3.12). Black moth *Sympistis zetterstedtii* larvae were found eating *Dryas* flowers, but unfortunately the herbivory was not fully quantified in 2007 (Table 3.13). The numbers given in Table 3.13 for the 2007 season are thus minimum estimates.

3.3 Birds

In 2007, the breeding bird census area was reduced in size by excluding the area west of the Zackenberg river (see Meltofte and Berg 2006). Also, the estimation of wader fledging success in the delta was omitted in 2007 onwards. Finally, the transect routes Zackenberg – Store Sødal and Daneborg – Zackenberg were omitted from the monitoring programme in 2007.

Bird observations were made by Niels Martin Schmidt (25 May-5 June), Jannik Hansen (5 June-31 July), and Lars Holst Hansen (25 May-2 September). Other researchers and staff provided much valued information throughout the season. Local site names can be found in Meltofte et al. (2008). From 2007 onwards, the area west of the river, Zackenbergelven, has been omitted from the census area. Birds in the area is still followed unsystematically west of the river, but the main effort is kept to the 15.8 km^2 census area, sections 2-5 (see Meltofte et al. 2008).

Table 3.12. Peak ratio (percent) of female arctic willow Salix arctica *pods infested by sawfly larvae* Symphyta sp. *in 1996-2007. + indicates that numbers were not quantified.*

Plot	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Salix 1	+	0	0	43	2	0	0	0	0	0	0	1
Salix 2	3	0	0	6	0	0	0	0	0	0	0	0
Salix 3	9	0	0	3	5	0	0	2	0	0	6	2
Salix 4	0	0	0	1	7	0	0	0	0	0	0	0
Salix 5								0	0	0	0	0
Salix 6								0	0	0	0	0
Salix 7								0	0	0	0	0

Table 3.13. Peak ratio (percent) of mountain avens Dryas *sp.* integrifolia/octopetala *flowers depredated by larvae of "black moth"* Sympistris zetterstedtii *in mountain avens plots in 1996-2007. Note that the 2007 numbers are minimum estimates. ** Dryas *plots 7 and 8 were terminated after the 2006 season.*

Plot	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Dryas 1	2	6	3	0	0	0	15	2	15	1	27	0
Dryas 2	0	5	0	0	0	0	1	0	4	1	3	2
Dryas 3	11	18	3	0	0	0	7	1	33	10	6	8
Dryas 4	17	1	7	0	0	0	11	5	39	3	18	4
Dryas 5	2	8	2	0	0	0	9	2	3	0	2	0
Dryas 6	0	0	0	0	0	0	0	0	1	0	6	5
Dryas 7	-	-	0	26	0	0	2	3	0	3	0	*
Dryas 8	-	-	0	27	0	0	0	11	0	0	0	*

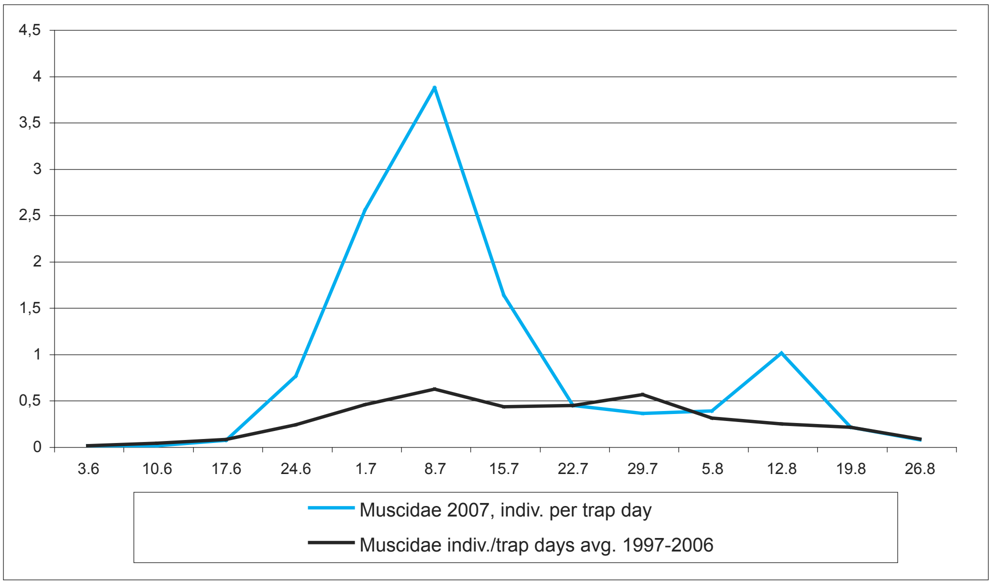


Fig. 3.5. Mean number of house flies Muscidae caught per trap day per week in the pitfall traps in 2007 compared with means for 1997-2006.

Breeding populations

A complete initial census was performed between 12 and 21 June, which is a normal start, but with a little later than usual ending. The weather prevented census work on several days in the period. The completion of the survey took 45 'man-hours', which is a little above average, considering that the census runs over one day less than usual. Most parts of the 15.8 km^2 census area were snow free, and the entire census was performed in good weather conditions.

In addition, large parts of the census area were covered regularly during June, July and most of August, exceptions being the closed goose moulting area along the coast and the Aucellabjerg slopes above 350 m a.s.l. The latter were covered on only six occasions.

The total effort in June and July 2007 (Table 3.14) was similar to recent years.

The results of the initial census, supplemented with records during the rest of the season (see Meltofte et al. 2008), are presented in Table 3.15, and in Table 3.16, these are compared with the estimates of previous seasons.

The first pair of red-throated divers *Gavia stellata* to settle was a pair in Sydkærene on 6 June, five days after the first red-throated divers were observed (Table 3.17). All in all, three to four pairs attempted to breed within the census area in 2007. No nests were found within the census area. In adjacent areas, red-throated diver pairs were recorded in four lakes and ponds. In Vesterport Sø a pair nested briefly. Most likely, the nest suffered predation. Red-throated divers started to form smaller flocks from 21 July, culminating in the largest number of birds, five on 18 August.

For the second year running, Sanderling *Calidris alba* territories were recorded at comparatively high numbers, comparable to the previous two peak years, 2003 and 2006 (Table 3.16). Since 2002, Dunlin *Calidris alpina* territories have appeared in high numbers and 2007 was no exception. Meltofte (2006a) suggests that the numbers were underestimated in early years – hence, the increase seen in numbers might be an artefact of this underestimation. Highly varying numbers of common ringed plover *Charadrius hiaticula* territories have occurred over the years, and it continues – this year with numbers near average. Ruddy turnstone *Arenaria interpres* territories were found in average numbers, following a two year peak with above average numbers. In some years, e.g. 2006, large proportions of the population did not seem to breed. In 2007, most – but not all – ruddy turnstone pairs bred. Red knot *Calidris canutus* territory numbers were a little above average in 2007 (Tables 3.15 and 3.16).

Long-tailed skua *Stercorarius longicaudus*

*Table 3.14. Number of trips and hours (trips; hours) allocated to bird censusing, breeding phenology and hatching success sampling west and east of Zackenbergelven during June and July 2007, respectively. * From 2007 onwards, the area west of the river, Zackenbergelven, is surveyed extensively only.*

Month	West of river*	East of river	Total
June	2; 6	25; 106	27; 112
July	6; 13	28; 106	34; 119
Total	8; 19	53; 212	61; 231

Table 3.15. Estimated numbers of pairs/territories in four sectors of the 15.8 km² census area in Zackenbergdalen, 2007.

Species	East of river <50 m a.s.l. 7.77 km²	East of river 50-150 m a.s.l. 3.33 km²	East of river 150-300 m a.s.l. 2.51 km²	East of river 300-600 m a.s.l. 2.24 km²	Total
Red-throated diver	3-4	0	0	0	3-4
King eider	1-2	0	0	0	1-2
Long-tailed duck	4-7	0	0	0	4-7
Rock ptarmigan	0	0	0	2	2
Common ringed plover	15-17	2	6-7	3	26-29
Red knot	3-6	12-15	11-12	1-2	27-35
Sanderling	26-32	3-4	12	21-22	62-70
Dunlin	74-93	12-14	1-2	2	89-111
Ruddy turnstone	12-15	26-32	3	1	42-51
Red-necked phalarope	1	0	0	0	0-1
Red phalarope	0	0	0	0	0
Long-tailed skua	9-11	5-7	2-5	1-2	17-25
Glaucous gull	1	0	0	0	1
Arctic redpoll	1-3	1	0	0	1-4
Snow bunting	19	19-22	9	4-5	51-55

Species	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Red-throated diver	1	2	3	2-3	2-3	2	0	2	2	4-5	3-4	3-4
Pink-footed goose	0	0	0	1	0	1	0	0	0	0	0	0
Common eider	2-3	0	0	0	1	1	0	0	1	0	0	0
King eider	0	2	1	1-2	2-4	2-4	4-6	1	1	1-2	1	1-2
Long-tailed duck	4-6	4-6	6-7	7-8	5-7	5-7	6-7	7-9	6	5-7	5-6	4-7
Rock ptarmigan	3	10-12	4-6	6-7	1-3	2-4	0	0	0	0	3-5	2
Common ringed plover	44-45	31-39	29-34	45-54	34	45-47	30-33	25	36	15-18	33-44	26-29
European golden plover	0	0	0	0	0	1	0	0	0	0	0	0
Red knot	30-39	31-39	24-29	24-30	23-25	25-28	21-23	22-23	19	28-33	27-40	27-35
Sanderling	41-52	45-61	51-57	48-54	44-51	48-57	40-46	54-59	54	33-43	65-76	62-70
Dunlin	45-55	54-65	55-69	55-67	72-76	76-81	89-98	80-88	91	73-82	83-101	89-111
Ruddy turnstone	36-45	43-49	50-54	39-44	45-47	39-44	28-33	31	47	60-67	56-69	42-51
Red-necked phalarope	0-1	0-2	1-2	1-2	1-2	1-3	1-2	1-2	1	1	2	0-1
Red phalarope	0	0	0-1	0	0	1	0	0	0	1	5-7	0
Long-tailed skua	20-23	19-22	19-20	18-21	17-24	19-21	19-22	22-25	16	20-25	16-23	17-25
Snowy owl	0	0	0	0	0	1	0	0	0	0	0	0
Arctic redpoll	0	0	0	0	0	0	0	0	1	0	0-2	1-4
Snow bunting	27-33	28-34	24-27	32-40	26-30	27-37	37-40	34-36	55-64	81-83	63-67	51-55

Table 3.16. Estimated numbers of pairs/territories in the 15.8 km² census area in Zackenbergdalen, 1996-2007. Please note, that numbers for 1996-2006 have been adjusted to the new bird census area. Numbers previously published included pairs breeding in the area west of river Zackenbergelven that is only monitored extensively from 2007 onwards.

territories were found in near-average numbers (Table 3.16). Fifteen pairs nested in the census area (see below).

A pair of Glaucous gulls *Larus hyperboreus* bred on an islet in the river, Zackenbergelven, as they have done since 2004. This year, no chicks were seen, and the fate of the nest is uncertain.

The number of rock ptarmigan territories *Lagopus mutus* was lower than 2006, but the population is still higher than the low period of 2002-2005. At the opening of the station, a few rock ptarmigan remains were found at the active Arctic fox *Alopex lagopus* dens and other parts of the valley. In much lower numbers than last year, however.

During the census, two pairs were registered. One brood was found in the census area. First, on 6 July the pair was seen with 10 pulli, and again on 11 July with 8 pulli, on the slopes of upper Aucellabjerg.

Fairly stable numbers of snow bunting *Plectrophenax nivlais* territories through the period 1996-2003, was followed by a rise in numbers that, so far, seem to have peaked in 2005. Numbers were lower in 2007, although still above average (Table 3.16).

Reproductive phenology in waders

Nest initiation in 2007 was fairly early for the waders in the area. Nearly 24% of the egg laying in all wader nests were initiated before 10 June, just under 57% before 16 June, and medians of the first egg dates

Species	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Red-throated diver	≤3.6	30.5	3.6	4.6	6.6	3.6	1.6	≤4.6	≤1.6	29.5	4.6	1.6
Pink-footed goose	≤3.6	≤28.5	27.5	3.6	4.6	3.6	1.6	≤3.6	≤1.6	≤19.5	≤26.5	≤25.5
Common eider	13.6	2.6	24.6	29.6	11.6	10.6	12.6	12.6	17.6	4.6	12.6	21.6
King eider	12.6	4.6	15.6	16.6	≤22.6	9.6	11.6	≤13.6	14.6	21.6	12.6	22.6
Long-tailed duck	≤1.6	30.5	2.6	6.6	6.6	7.6	3.6	7.6	2.6	1,6	7.6	5.6
Red-necked phalarope	5.6	30.5	5.6	10.6	7.6	4.6	5.6	11.6	≤1.6	27.5	6.6	28.5

Table 3.17. Dates of first observation of selected species at Zackenberg 1996-2007.

were before 16 June in all four species in which nests were found (Table 3.18). For ruddy turnstone, 2007 was the earliest year in terms of median first egg dates recorded so far.

The melting of the snow was early in 2007 and nest initiation was near or earlier than the average of previous seasons (Table 3.19).

Reproductive success in waders

The overall wader nest success was extremely low in 2007. Only in the 2005 season equally low nest success was recorded. 36 of 60 nests were predated. After the modified Mayfield method (Johnson 1979), 82% of the wader nests fell victim to predation. Dunlin suffered the lowest level of predation of the three main study species; 52.2% of the nests had full predation – somewhat higher than the average for 1996-2007. Sanderling and ruddy turnstone nests suffered extremely from predation, loosing more nests than previously recorded at Zackenberg (Table 3.20). A single sanderling nest was abandoned during laying and the fates of one dunlin (outside the census area) and one sanderling nests were unknown. Only four nests of red knot were found this season – all of which hatched successfully. No common ringed plover, red phalarope *Phalaropus fulicarius* or red-necked phalarope *Phalaropus lobatus* nests were found in 2007. However, a common ringed plover juvenile – with downy neck and still accompanied by two adults – was seen on 11 July. Circumstances suggest that the bird was approximately 20 days old, giving a first egg date around 23 May, which is the earliest estimated for Zackenberg.

The Arctic fox is the most likely predator of most nests, as only few nests were found with clear signs of avian predators. The number of fox encounters in the bird census area was also high (Table 3.20).

The mean clutch size was 3.9 in 2007 (Table 3.21). Nests containing fewer than 4 eggs were: Sanderling; two nests of three eggs, one nest of two eggs, and two nests of one egg – Dunlin: three nests of three eggs.

In July and early August alarming parents – and later juveniles – were found in the fens and marshes (dunlins), on the slopes of Aucellabjerg and in the dry lowlands (common ringed plovers, sanderlings and dunlins). Turnstone juveniles were only seen late in the season, most often in connection with low tide feeding.

Reproductive phenology and success in long-tailed skuas

Eight (40%) of the long-tailed skua nests were initiated prior to the census period. The season 2007 was average concerning timing of breeding (Table 3.22), and 11 of 15 nests (73%) were initiated prior to 20 June in the census area. (Counting nests

Species	Median date	Range	N
Common ringed plover	23 May	-	1
Red knot	6.5 June	2.6-21.6	10
Sanderling	15 June	5.6-4.7	48
Dunlin	15 June	6.6-2.7	17
Ruddy turnstone	7 June	5.6-21.6	13

Table 3.18. Median first egg dates for waders at Zackenberg 2007 as estimated from incomplete clutches, egg floating, hatching dates, as well as weights and observed sizes of pulli.

Species	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Snow cover on 10 June	84	82	76	80	91	53	84	79	83	48	28	na	na
Sanderling		(16 June)	18 June	18 June	23.5 June	16 June	22.5 June	17 June	13 June	8 June	(15 June)	30 June	15 June
Dunlin	(18 June)	11.5 June	13 June	16.5 June	22 June	11.5 June	25 June	8 June	12 June	12 June	12 June	27 June	15 June
Ruddy turnstone	(12 June)	18.5 June	13 June	12.5 June	24 June	11 June	23 June	9 June	8 June	8 June	11 June	(21 June)	7 June

Table 3.19. Snow cover on 10 June together with median first egg dates for waders at Zackenberg 1995-2007. Data based on less than 10 nests/broods are in brackets, less than five are omitted. The snow cover is pooled (weighted means) from snow sections 1, 2, 3 and 4 (see section 2.2), from where the vast majority of the egg laying phenology data originate. Snow cover data from 2006 and 2007 are currently not available.

Species	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	1996-2007
Common ringed plover				(60)		(38)				-	(100)	-	62-67
Red knot	-	-			-		-			-	-	(100)	(28)
Sanderling	(72)	(33-100)	(88)	40	(46)	19	(33)	45	71-85		(7.4)	3.4	27-29
Dunlin			28-47	65	68	(75)		63	93	(43)	47	48	60-65
Ruddy turnstone	21-68	67-100	16	23-28	29	(60)	52	21-27	83			36	58-64
Red-necked phalarope	-	-	-		-	-	-	-	-		-	-	
Red phalarope	-	-	-	-	-	-	-	-	-	-		-	
All waders	**33-63**	**52-100**	**32-37**	**42-44**	**44**	**43**	**43**	**42-44**	**87-90**	**22**	**37**	**18**	**41-45**
N nests	17	31	44	44	47	32	21	51	55	15	28	60	445
N nest days	163	274	334	521	375	328	179	552	700	104	332	533	4392,5
Fox encounters	14	5	7	13	11	14	21	11	16	18	22	23	
Fox dens with pups	2	0	1	0	2	2	0-1	2	3	0	2	3	

Table 3.20. Mean nest predation (%) 1996-2007 according to the modified Mayfield method (Johnson 1979). Poor data (below 125 nest days or five predations) are given in brackets. Data from species with less than 50 nest days have been omitted ('-' indicates no nests found). Nests with at least one pipped egg or one hatched young are considered successful. Also given are total numbers of adult foxes observed by the bird observer in the bird census area during June-July (away from the research station proper), along with the number of fox dens holding pups.

Species	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Mean
Common ringed plover	(4.00)	(4.00)	(3.50)	(4.00)	(3.50)	(4.00)	(3.50)	(4.00)	(4.00)	(4.00)		(3.75)		3.84
Red knot				(4.00)	(4.00)		(4.00)		(4.00)	(4.00)			(4.00)	4.00
Sanderling	(4.00)	4.00	3.86	4.00	3.67	4.00	3.43	3.83	4.00	4.00	3.75	3.63	3.73	3.84
Dunlin		(4.00)	(3.75)	3.90	3.70	3.93	3.63	(4.00)	4.00	3.92	4.00	3.13	3.79	3.81
Ruddy turnstone		3.71	3.79	3.82	3.58	3.80	3.75	4.00	3.77	3.92	3.86	(3.00)	(4.00)	3.75
Average	4.00	3.93	3.73	3.94	3.69	3.93	3.66	3.96	3.95	3.97	3.87	3.38	3.88	3.83

Table 3.21. Mean clutch sizes in waders at Zackenberg 1995-2007. Samples of fewer than five clutches are given in brackets.

Long-tailed skua breeding	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Median 1st egg date		7.6	12.6	17.6	18.6	15.6	9.6	15.6	8.6	8.6	19.6	12.6
No. of clutches found	8	17	23	8	5	21	14	7	21	8	2	15
No. of young hatched	1	25	16	2	2	18	14	5	36	6	1	11
Nest success % (Mayfield)		(80.6)	24.1	(18.1)	(17.5)	39.5	44.1	(76.2)	(100)	(51.8)	(100)	52.9
Estimated no. of young fledged	0	5	6	1	0	5	4	2	22	1	0	1
Lemming winter nests pr. km^2	224.5	247.2	467.0	227.4	136.8	208.5	178.3	66.0	238.7	170.8	189.6	236.8

Table 3.22. Egg-laying phenology, breeding effort and success in long-tailed skuas at Zackenberg 1996-2007. Median egg laying date is the date, when half the supposed first clutches were initiated. Number of clutches found includes replacement clutches. Mean hatching success according to the modified Mayfield method (Johnson 1979). Poor data (below 125 nest days or five predations) are given in brackets. Nests with at least one pipped egg or one hatched young are considered successful. Also given, are densities of lemming winter nests within the lemming monitoring area (see section 3.4). Please note that number for 1996-2006 are numbers breeding within the currently used census area.

found outside the census area, 18 of 22 (82%) nests were initiated prior to 20 June).

From 22 June, flocks of up to 34 long-tailed skuas roamed the lower slopes of Aucellabjerg and the lowlands.

A single lemming observation by the bird observer does not reflect the otherwise intermediate lemming season (Table 3.22). The average clutch size was 1.64 eggs per nest. 11 chicks hatched. Nest success for long-tailed skuas was just below average (average nest success 1996-2007: 55%) (Table 3.22). All but one of the eleven hatched chicks are thought to have suffered predation. This last young was last seen on 19 August, at an age of maximum 44 days – the only observation of a juvenile bird in 2007.

Four observations of one third calendar year bird were probably of the same individual; an unringed bird which must have hatched in the 2005 season, in which fledging success was low (Table 3.22).

Barnacle geese

Conditions did not allow a visit to a barnacle goose *Branta leucopsis* colony on the southern face of the mountain Zackenbergfjeld this season. Previous visits in 2005 and 2006 suggested that the colony is still in use (Hansen et al. *accepted*).

The first families with goslings were seen on 25 June. The number of broods was as high as 28 (Table 3.23), and the maximum number of goslings seen at one time, was 13.

The mean 2007 brood size was in the lower end of the scale until late July. 3.3 young per brood is the highest average brood size recorded in late July (Table 3.23).

Immature barnacle geese moulted in lower than average numbers in 2007 (Table 3.24). The coastal area west of the closed area has seen increasing numbers of moulting barnacle geese in recent year.

Common birds, not breeding in the census area

In 2007, immature pink-footed geese *Anser brachyrhynchus* migrated in lower than average numbers; 1,120 individuals passing over Zackenbergdalen northwards. Only two immature pink-footed geese were found moulting at Zackenberg this year (Table 3.24).

On 21 June, first common eiders *Somateria mollissima* was seen migrating along the coast and up along river Zackenbergelven. In the following month pairs and smaller flocks up to 14 individuals were seen regularly. A possibly nest was never confirmed, and no hatching took place. Seven young – most likely from the Daneborg or Sandøen colonies (c. 25-30 km east of Zackenberg) – were recorded with an adult female in the bay, Zackenberg Bugt, on 31 August. The last adult male was seen on 6 July. In late September, after the usual monitoring season, approximately 70 eiders assembled in a flock on Young Sund. At Daneborg, the common eider colony between the dog pens was once again censused by the Sirius Dog Sledge Patrol, and found to include 2,700 nests. Average nest number for the period 2002-2006 is 2,019. At Daneborg, the first eider ducklings were seen on 18 July.

Two female and one male king eider *Somateria spectabilis* arrived at Zackenberg on 22 June, which is later than usual (Tabel 3.17; 1996-2006 average arrival date: 13 June). A pair stayed in the area around the research station until 30 June, occasionally accompanied by an extra

Decade	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Primo July		(3.0)	3.1	(2.9)	1.9	(3.2)	(1.8)	2.4	(1.8)	2.6	(1.7)	(2.0)	1.3
Medio July		(2.3)	2.7	2.3	1.8	(3.1)	(1.7)	2.4	(1.2)	2.3	2.7	(1.5)	1.5
Ultimo July	(2.0)	(3.0)	2.6	2.2	1.7	3.1		2.3	(1.1)	2.3	(2.2)	(1.1)	(3.3)
Primo August	(2.3)	(2.3)	2.4		1.8		(2.0)	2.2	(1.2)	(1.9)		(1.5)	-
No. of broods	≥7	6-7	19-21	≥18	29	11	4	32	8	26	14	9	28
Scotland	2.00	2.30	1.95	2.28	1.92	2.20	1.94	2.23	1.59	2.35	1.67	1.15	-
Per cent juv.	7.2	10.3	6.1	10.5	8.1	10.8	7.1	12.5	6.4	15.9	6.3	3.23	-

Table 3.23. Average brood sizes of barnacle geese in Zackenbergdalen during July and early August, 1995-2007, together with the total number of broods brought to the valley. Samples of less than 10 broods are given in brackets. Brood size data from autumn on the Isle of Islay in Scotland are currently not available.

Study area	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Pink-footed Goose													
Closed moulting area and further east	310	246	247	5	127	35	0	30	41	11	17	27	0
Coast west of closed area	230	40	60?	0	29	0	0	0	0	10	0	3	2
Upper Zackenbergdalen	0	0	15	0	0	0	0	0	0	0	0	1	0
Pink-footed Goose total	540	286	322	5	156	35	0	30	41	21	17	31	2
Barnacle Goose													
Closed area at Lomsø and Kystkærene	21	0	29	21	60	84	137	86	120	81	87	148	66
Coast east of closed area	>120	150?	96	55	66	0	109	80	45	0	2	218	46
Coast west of closed area	0	0	0	0	0	30	0	0	0	0	29	29	106
Upper Zackenbergdalen	41	85	2	75	<57	27	60	0	14	0	25	30	6
Barnacle Goose total	>182	235	127	151	<183	141	306	166	179	81	143	425	224

Table 3.24. The number of immature pink-footed geese and barnacle geese moulting in the study area at Zackenberg 1995-2007. The close area is zone 1c (see http://www.zackenberg.dk/grafik/MapZoner.jpg). '?' indicates uncertain estimation of numbers.

female. No nesting attempts were recorded. A single female was seen west of the area on 6 July. The last record was a flock of 9 females and 3 males near the peninsula Halvøen, east of Zackenberg, on 15 July.

There was an estimated two pairs of common raven *Corvus corax* covering the valley, both assumed to nest in adjacent areas. A possible third pair would have been based in a third, neighbouring valley. The first six young birds were seen on 4 July near the research station.

During July, August and into September, this flock was seen regularly around the valley, with numbers varying from three to six.

Visitors and vagrants

A new species was added to the avifauna of Zackenberg in 2007, as a common snipe *Gallinago gallinago* was seen at the research station on 22 June. This is a very rare sighting in Northeast Greenland (cf. Boertmann 1994) (Table 3.25).

Table 3.25. Numbers of individuals and observations of avian visitors and vagrant at Zackenberg 2007, compared with the numbers of individuals observed in the preceding seasons, 1995-2006.

Visitors and vagrants														
	Previous records											2007		
Species	***1995***	***1996***	***1997***	***1998***	***1999***	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***	***No. of individuals***	***No. of observations***	
Great northern diver	0	0	0	0	0	0	1	0	0	0	0	0	2	1	
Wooper swan	0	0	0	0	0	4	0	0	0	0	0	0	0	0	
Snow goose	0	0	0	0	0	2	11	0	23	0	0	0	1	1	2
Canada goose	0	0	0	0	0	0	0	0	0	0	0	4	3	2	3
Merlin	0	0	0	0	0	1	0	0	0	0	0	0	0	0	
Gyr falcon	1	1	1	3	0	4	5	1	3	4	2	0	3	3	12
Pintail duck	0	0	0	1	0	0	0	0	0	0	0	0	1	1	7
Common teal	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
Eurasian golden plover	0	3	1	3	1	0	1[1]	1	0	1	1	1	1	3	
White-rumped sandpiper	0	0	0	0	0	0	1	0	0	0	1	0	0	0	
Pectoral sandpiper	0	0	0	1	0	0	0	1	0	0	0	1	1	2	
Purple sandpiper	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
Red phalarope	0	0	0	4-5[1]	0	0	4[1]	0	1	0	2[1]	11[1]	0	0	
Common snipe	0	0	0	0	0	0	0	0	0	0	0	0	1	1	4
Whimbrel	0	0	0	0	0	1	1	0	0	2	1	0	1	3	
Pomarine skua	0	0	0	0	0	0	2	0	0	0	0	0	0	0	
Arctic skua	0	0	11	6	0	2	7	4	3	2	0	1	0	0	
Great skua	0	0	0	4	0	0	0	1	0	0	0	0	0	0	
Lesser black-backed gull	0	0	0	0	0	0	1	0	1	2	1	4	0	0	5
Iceland gull	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
Great black-backed gull	0	0	0	0	0	1	3	0	0	0	0	0	0	0	
Black-legged kittiwake	0	0	0	0	0	0	0	0	14	0	0	0	0	0	6
Arctic tern	≈200	2	1	2	0	14	0	0	32	0	0	0	0	0	
Snowy owl	0	0	2	1	1	1-2	min. 4[1]	0	0	0	0	0	1	1	10
Meadow pipit	0	0	0	1	0	0	0	0	0	0	1	1	0	0	7
White wagtail	0	1	0	0	0	0	0	0	0	0	0	0	1	1	
Northern wheatear	4	8[1]	4	3[1]	1-2[1]	08	0	0	0	0	2	1	4[11]	1	
Arctic redpoll	7	9	16	23	8	5	3	6	31[9]	12	3[1]	2	8	7	13
Lapland longspur	0	0	0	0	1-2	0	1	0	0	0	1	0	0	0	

1 At least one territory, possible territory or breeding found, see table 1;
2 Circled over station with a snow goose/barnacle goose hybrid. The snow goose landed in camp and stayed for 3 days. Tame. See text.
3 Subspecies *interior*
4 2007: First record at Zackenberg
5 Increasing in East Greenland (Boertmann *in press*)
6 10 adults, 4 juveniles 28 August 2003.
7 Northernmost records in East Greenland (cf. Bortmann 1994)
8 One dead individual found
9 20 of these, a flock of juveniles in August
10 Additionally, one individual in neigbouring valley on 22 June and another one in Zackenbergelven 25 September 2007 (outside monitoring programme season).
11 Uncertain identification
12 Another 11 observations of 4 individuals in September 2007 (outside monitoring programme season).
13 A further four observerd on 25 September 2007 (outside monitoring programme season).

Two great northern divers *Gavia immer* were observed flying up along the river Zackenbergelven on 11 June. Great northern divers are seen occasionally around Zackenberg, but are known to breed in a neighbouring valley, Store Sødal (Meltofte 2006b).

On 27 June a snow goose *Anser caerulescens* and an apparent snow goose x barnacle goose hybrid *Anser caerulescens x Branta leucopsis* flew over the research station. After circling above the station, the hybrid bird continued eastwards, while the snow goose landed in the centre of the research station. The goose was apparently tame, and followed researchers around in the entire study area for three days.

Canada geese *Branta canadensis* were recorded for the second consecutive season at Zackenberg, with a single bird in a fen north of the research station on 13 June, and a pair at the coast on 26 June (Table 3.25).

On 26 May a female pintail duck *Anas acuta* was seen in Gadekæret where it stayed until 7 June. This is only the second record of pintail ducks at Zackenberg (cf. Rasch 1999).

Gyr falcons *Falco rusticolus* were spotted several times during the season. In June, single individuals were seen on the 8 and 19 June near the research station. One individual was seen on 31 August at the research station. After the normal monitoring season, gyr falcons were recorded on eleven occations, one time with three individuals at once (19 September, at the research station). The other ten observations are thought to be of one individual, most often seen at the research station.

Among waders, the Eurasian golden plover *Pluvialis apricaria* was once again recorded with a single individual, from the 1 to the 9 June, near the research station.

A pectoral sandpiper *Calidris melanotos* – presumably a male – was recorded on 12 and 19 June, in fens near the research station. On the 19 June, the pectoral sandpiper displayed behaviour (towards a dunlin), similar to courtship behaviour (H. Schekkerman, pers. comm.). At Zackenberg, this was only the third record of this rare visitor to Greenland.

For the fifth season in 12 years (Table 3.25), a whimbrel *Numenius phaeopus* was seen on 16th and 17th June, and heard again on 18 June, on the slopes of Aucelabjerg.

A great black-backed gull *Larus marinus* was observed 30 June at Lomsø, a lake south of the research station.

Twice during the normal opening of the research station snowy owls *Nyctea scandiaca* were seen. On 22 July, a single individual was seen in neighbouring valley, Cardiocerasdal, while the other bird was spotted on the slopes of Aucellabjerg on 22 August. After the usual monitoring period, a snowy owl was seen on the lower slopes of Aucellabjerg, 25 September.

A white wagtail *Motacilla alba* visited Zackenberg on 31 May. This is only the second record of a white wagtail in Zackenberg. The white wagtail is a rare visitor to Northeast Greenland, although it might have bred in Daneborg in 1996 (Meltofte and Thing 1997) – c. 25 km from Zackenberg.

Sandøen

In the period 12 July to 5 August 2007, fieldwork was conducted on Sandøen by researchers from Greenland Institute of Natural Resources and National Audubon Society – Alaska. For details, see section 5.6. Estimated breeding population size on Sandøen in 2007 are presented in Table 3.26, based on a combination of direct counts and number of nests found (Egevang and Stenhouse 2007). Arctic fox had depredated most common eider and long-tailed duck nests prior to the start of the fieldwork and breeding estimates of these species are based on the number of "in-active" nests found.

For other bird and mammal observations from Sandøen 2007, please consult Egevang and Stenhouse (2007).

Erratum:

In the 2006 report (Klitgaard et al. 2007), the date for the first juvenile dunlin was erroneously printed as 22 June, it should read 14 August. Also, in the same report, the date for the first fledged snow bunting was printed as 28 August, but should have

	Pairs	Nests found
Arctic Tern	700-1000	109
Sabine's gulls	60-65	56
Common eider	10-15	2
Long-tailed duck	1-2	-

Table 3.26. Estimated breeding population size and number of nests found of Arctic tern, Sabine's gull, common eider and long-tailed duck on Sandøen 2007.

read 10 July. Finally, the first juvenile common ravens were seen 30 June, not on 30 July, as printed in the 2006 report.

3.4 Mammals

The mammal monitoring programme was conducted by Lars Holst Hansen (25 May-3 September). Additional field work was conducted by Niels Martin Schmidt (25 May-19 June), Jannik Hansen (5 June-31 July) and Line Kyhn (3 July-31 July). The station personnel and visiting researchers supplied random observations during the entire field season.

The collared lemming *Dicrostonyx groenlandicus* census area was surveyed for winter nests during July. Throughout the entire season, when weather permitted a sufficient coverage, musk oxen *Ovibos moschatus* were counted every third day from a fixed elevated point of the research station. Counting took place between 19:00 and 23:00, and covered the coastal areas and mountain slopes from Zackenbergdalen in the west to Daneborg in the east. At the same time, numbers of seals on the ice in Young Sund and arctic hares *Lepus arcticus* on the south-east and east facing slopes of Zackenbergfjeld were censused during 26 May-17 July and 1 July-2 September, respectively.

The total numbers of musk oxen, including sex and age from as many individuals as possible, were censused weekly within the 40 km^2 census area during 3 July-29 August. The 15 known arctic fox *Alopex lagopus* dens (nos. 1-10 and 12-16) within the central part of the valley were checked weekly for occupancy and breeding. The only known den (no. 11) between Daneborg and Kuhnelv was checked on 2 and 11 July. The 29 fixed sampling sites for predator scats and casts were checked on 24 and 25 August (Table 3.27). Observations of other mammals than lemmings, foxes, musk oxen, and arctic hare are presented in the section "Other observations" below.

In 2007, the lemming census area was reduced in size (see below). Also, the frequency of the registrations of musk oxen, arctic hares and seals from the station was adjusted, and these registrations are now conducted every third day. Moreover, registrations of musk oxen and arctic hares were standardized and are now limited to well-defined census areas (see Meltofte et al. 2008). Finally, the transect routes into Store Sødal and to Daneborg previously covered were omitted, and are no longer part of the monitoring program.

Year	Skua casts	Owl casts	Fox scats	Stoat scats
1997	44	0	10	1
1998	69	9	46	3
1999	31	3	22	6
2000	33	2	31	0
2001	39	2	38	3
2002	32	6	67	16
2003	16	0	20	1
2004	27	0	16	3
2005	7	6	24	0
2006	15	4	29	0
2007	13	3	54	4

Table 3.27. Numbers of casts and scats from predators collected from 29 permanent sites in Zackenbergdalen. The samples represent the period from mid/late August the previous year to August in the year denoted.

Collared lemming

The reduced lemming census area is a sub-area of the original lemming census area (see Meltofte and Berg 2006; Meltofte et al. 2008), and was carefully selected to reflect the habitat composition and the lemming winter nest distribution (including the distribution of stoat predated nests) of the original lemming area. The lemming census area now covers 1.06 km^2.

In 2007, a total of 251 collared lemming *Dicrostonyx groenlandicus* nests from the previous winter were recorded within the reduced census area (Table 3.28). This is the second highest number ever registered (Fig. 3.6 and Table 3.28).

In the years 1996-2005, between 0.0% and 4.7% of the lemming winter nests have been depredated by stoats (Fig. 3.6). As in the three previous seasons of 2004-2006, not a single nest was found depredated by stoat in the 2007 season.

Musk ox

The pattern of musk oxen *Ovibos moschatus* occurrence within the musk ox census area in Zackenbergdalen was in general accordance with the patterns observed in the previous years, i.e. low numbers during late May and June, and increasing numbers throughout July and August (Fig. 3.7). There was a small decline in numbers in late July/early August. Mean group size started off rather high in late May, then declined in June only to increase again in early July. Mean number of musk oxen per observation day were the highest hitherto, with a maximum of 189 on 15 August and a minimum of 44 on 1 June (Fig. 3.8).

Based on the weekly field censuses, Table 3.29 lists the sex and age distribution. In 2007, 3 year old females (F3) represented the highest proportion registered so far (Table 3.29). The increase in overall proportion of younger animals, which have been ongoing since 2003, seem to have slowed down. Animals younger than 4 years constituted 53.3% in 2007 compared to 53.4% in 2006 (Table 3.29).

Fig. 3.9 illustrates how the proportion of the different sex and age classes changed from week to week in 2007. The decrease in the proportion of M4+ is a combined result of a numerical decrease and an increase of the remaining classes.

Twelve fresh musk ox carcasses were registered during the 2007 season (Table 3.30). This is the second highest number observed and only superseded by one in 1996. Additionally, DNA samples from a total of five lemmings, one Arctic fox and one long-tailed skua were collected.

Year	Winter nests category 1	Winter nests category 2	Animals seen
1996	84	154	0
1997	202	60	1
1998	428	67	43
1999	205	36	9
2000	107	38	1
2001	208	13	11
2002	169	20	4
2003	51	19	1
2004	238	15	23
2005	98	83	1
2006	161	40	3
2007	251	21	1

Table 3.28. Annual numbers of lemming winter nests recorded within the 1.06 km² census area in Zackenbergdalen 1996-2007 together with the numbers of animals encountered by one person with comparable effort each year within the 15.8 km² bird census area during June-July. Numbers from previous years are from the new, reduced lemming census area only. Category 1 denotes nests from the previous winter, category 2 nests from earlier winters that were not recorded previously.

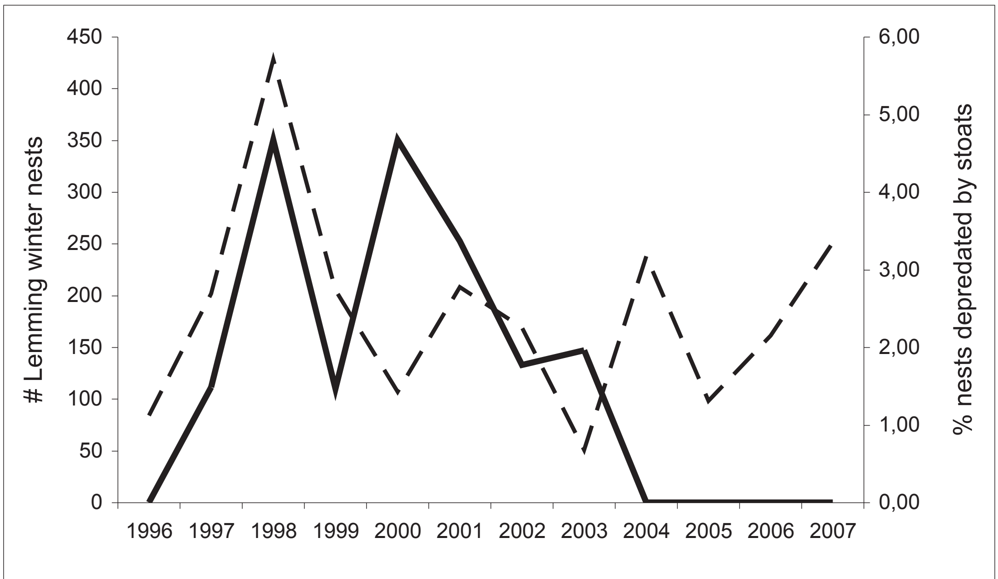


Fig. 3.6. The number of collared lemming winter nests registered within the lemming census area (dashed line), along with the percentage of winter nests taken over by stoats 1996-2007 (full line). Winter nest recordings from previous have been adjusted to reflect the number within the new 1.06 ha census area.

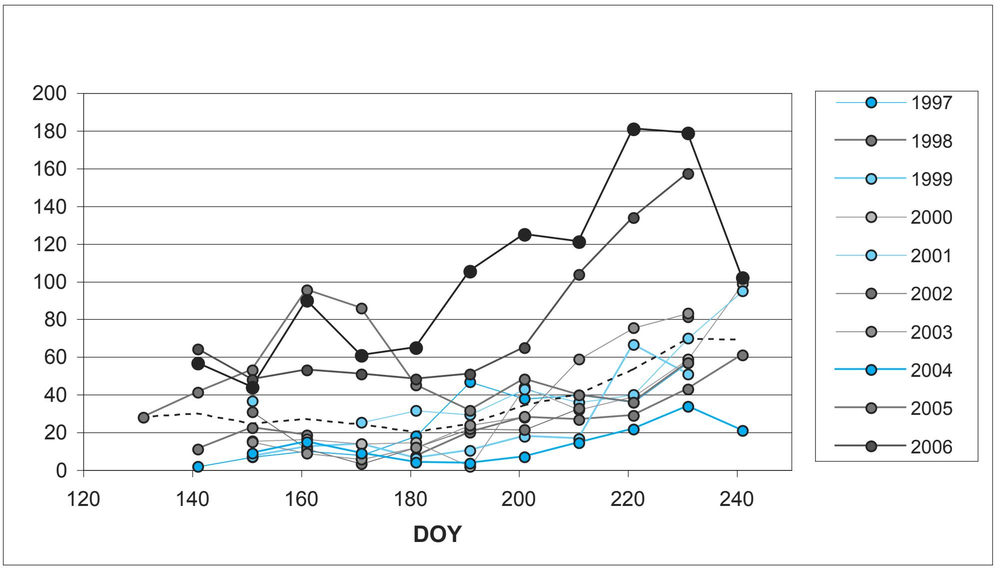


Fig. 3.7. Number of musk oxen (solid circles) and group size (open circles) recorded from a fixed elevated point at the research station from late May to early September 2007. ‡ Argo activity in Rylekærene may have frightened musk oxen.

Year	M4+		M3		M2		F4+		F3		F2		M1 + F1		Calf		Not determined		No. of
	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	weekly counts
1996	98	14.5	7	1.0	54	8.0	184	27.2	31	4.6	17	2.5	146	21.6	124	18.3	15	2.2	9
1997	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1998	97	29.5	22	6.7	30	9.1	97	29.5	19	5.8	27	8.2	14	4.3	22	6.7	1	0.3	8
1999	144	37.9	21	5.5	9	2.4	106	27.9	21	5.5	12	3.2	5	1.3	30	7.9	32	8.4	8
2000	109	29.5	11	3.0	2	0.5	118	32.0	15	4.1	7	1.9	31	8.4	73	19.8	3	0.8	8
2001	127	30.2	8	1.9	26	6.2	120	28.5	19	4.5	19	4.5	43	10.2	55	13.1	4	1.0	7
2002	114	19.9	20	3.5	38	6.6	205	35.8	24	4.2	43	7.5	51	8.9	77	13.5	0	0.0	8
2003	123	23.3	24	4.5	16	3.0	208	39.3	23	4.3	19	3.6	44	8.3	72	13.6	0	0.0	8
2004	122	22.2	13	2.4	5	0.9	98	17.9	28	5.1	8	1.5	32	5.8	124	22.6	119	21.7	7
2005	212	23.2	11	1.2	43	4.7	260	28.4	46	5.0	21	2.3	116	12.7	200	21.9	6	0.7	9
2006	205	29.1	29	4.1	62	8.8	123	17.5	55	7.8	34	4.8	102	14.5	94	13.4	0	0.0	7
2007	391	24.8	73	4.6	80	5.1	341	21.6	152	9.6	83	5.3	202	12.8	246	15.6	8	0.5	9

Table 3.29. Sex and age distribution of Musk Oxen based on weekly counts within the 40 km^2 census area in Zackenbergdalen from July-August, 1996-2007.

Year	Total carcasses	4+ yrs F / M	3 yrs F / M	2 yrs F / M	1 yr F / M	Calf
1995	2	0 / 1				1
1996	13	7 / 1	0 / 1	0 / 2	1 / 1	
1997	5	0 / 2		1 / 0	1 / 0	1
1998	2	0 / 2				
1999	1	0 / 1				
2000	8	0 / 6	1 / 0			1
2001	4	0 / 4				
2002	5	1 / 2	1 / 0			1
2003	3	0 / 2				1
2004	2	1 / 1				
2005	6	2 / 3				1
2006	5	0 / 2			0 / 1	2
2007	12	3 / 4	1 / 0		1 / 0	3

Table 3.30. Fresh Musk ox carcasses found during the field seasons of 1995-2007. F = female, M = male.

Year	No. of known dens inside/outside	No. of dens in use inside/outside	No. of breed. dens inside/outside	Total no. of pups recorded
1995	2 / 0	0 / 0	0 / 0	0
1996	5 / 0	4 / 0	2 / 0	5W + 4D
1997	5 / 0	1 / 0	0 / 0	0
1998	5 / 0	2 / 0	1 / 0	8W
1999	7 / 0	3 / 0	0 / 0	0
2000	8 / 0	4 / 0	3 / 0	7W
2001	10 / 2	6 / 1	3 / 1	12W + 1D
2002	10 / 2	5 / 1	0-1 / 0	0
2003	11 / 2	8 / 1	3 / 0	17W
2004	12 / 2	12 / 2	4 / 1	18+W
2005	14 / 2	6 / 0	0 / 0	0
2006	15 / 1	6 / 1	3 / 0	17W
2007	15 / 1	12 / 1	3 / 1	23W

Table 3.31. Numbers of known dens in use, numbers with pups and the total number of pups recorded at their maternal dens within and outside the 50 km^2 census area in Zackenbergdalen 1995-2007. W=white phase, D=dark phase.

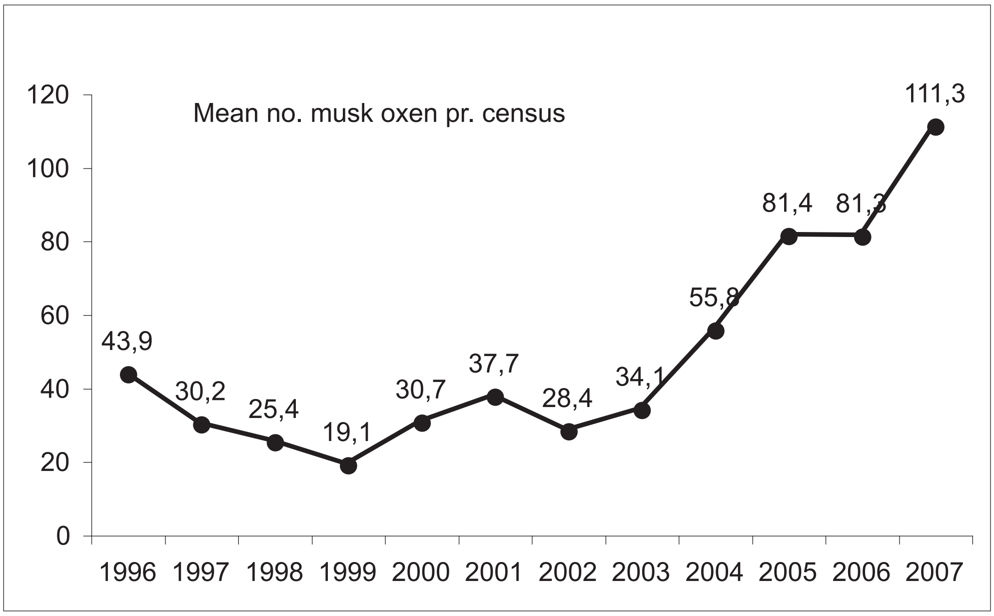


Fig. 3.8. Mean annual number per observation day of musk oxen observed from a fixed elevated point at the research station 1996-2007 within the 40 km² census area.

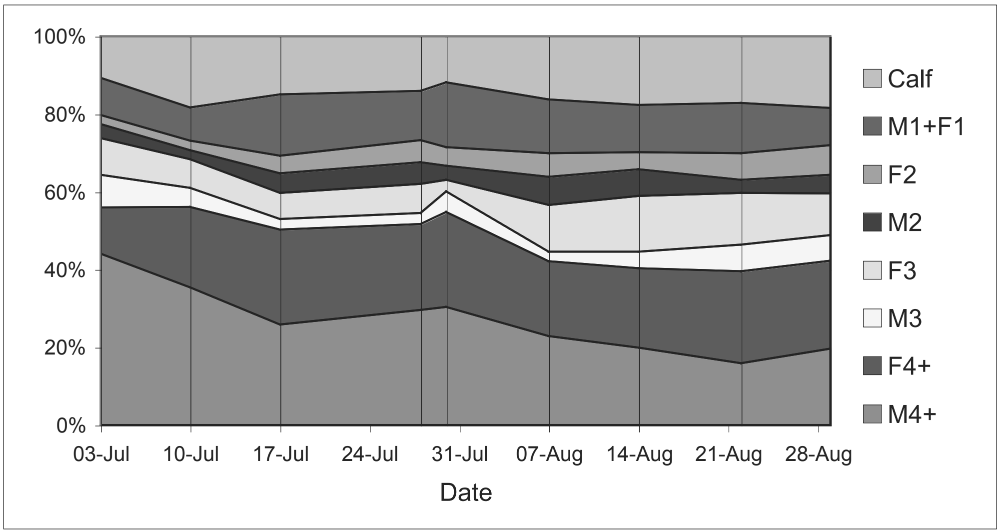


Fig. 3.9. The sex and age composition of musk oxen registered during the weekly censuses within the 40 km² census area during July and late August 2007 (7 August census only considered musk oxen south of Aucellaelv).

Arctic fox

In 2007 a minimum of 23 arctic fox *Alopex lagopus* pups (all white colour phase) were observed in the known dens. This is the highest minimum number recorded so far (Table 3.31). Also, the number of fox records in the field was very much higher than generally recorded previously, and only slightly lower than the record number in 2004 (Table 3.32). Pups were recorded in 5 dens. However, only 4 of these were actual breeding dens, since one family probably moved between den no. 1 and no. 8 and back again. The carcass of one Arctic fox was found in 2007 (Table 3.32).

Year	Total number of records	Total number colour phase	Number of fox carcasses
1996	34	31W + 3D	
1997	22	17W + 5D	1W + 1D
1998	24	21W + 3D	1W
1999	19	18W + 1D	2W
2000	28	28W	2W
2001	55	54W +1D	1W
2002	23	23W	0
2003	50	50W	0
2004	90	90W	0
2005	58	58W	0
2006	74	74W	1W
2007	84	84W	1W

Table 3.32. Total numbers of encounters with arctic fox in the field away from their dens during June-August 1996-2007.

Arctic hare

In 2007, a designated hare census area was defined on the south-east and east facing slopes of Zackenbergfjeld. The new census area is a fraction of the old census area, and covers 3.13 km^2. The census area was scanned with a 30× spotting scope every third day from 1 July to 30 August, and the number of arctic hares *Lepus arcticus* was recorded. Hare numbers from previous years within the new census area are given in Table 3.33. In 2007, 18 counts with good visibility were made with a mean of 4.8 hares, a maximum of 11 on 28 July and a minimum of 0 arctic hares per census. The mean of 2007 is a little lower than 2005 and 2006 but higher than the years 2001-2004. The number of arctic hares observed at other sites than Zackenbergfjeld was 46, which is lower than the 2001-2006 mean of 73.5 (Table 3.33)

Other observations

Polar bear *Ursus maritimus*

No animals or tracks were observed.

Arctic wolf *Canis lupus*

Tracks were seen on two occasions and a scat was found at fox den no. 9. An adult arctic wolf was observed on three occasions.

Stoat *Mustela erminea*

Stoats were observed on two occasions, and tracks were seen on two occasions. None of the 251 lemming winter nests found in the census area were depredated by stoats. During the standardised collection of scats and casts, 4 stoat scats were found (Table 3.27).

Walrus *Odobenus rosmarus*

Between 50 and 100 walruses generally use Sandøen as haul out site and feed in Young Sund. In 2007 a maximum of 45 were observed (Egevang and Stenhouse, 2007). Although, walruses are only rarely seen in the shallow waters along the coast of Zackenbergdalen, two walruses were observed there on 4 August 2007.

Table 3.33. The number of arctic hares per observation day counted during July and August. Counts from the previous years have been recalculated to reflect the new hare census area.

Year	Sum	Average ± SD	Range	Counts	Other obs.
2001	27	1.2 ± 1.3	0-5	22	72
2002	7	0.4 ± 0.6	0-2	16	10
2003	47	2.4 ± 1.8	0-6	20	42
2004	21	0.9 ± 1.1	0-3	23	135
2005	264	5.5 ± 5.1	0-26	48	150
2006	231	5.9 ± 3.7	1-19	39	32
2007	94	4.8 ± 3.0	0-11	18	46

Year	Average ± SD	Range	Counts
1997	8.5 ± 5.0	3 - 21	23
1998	7.4 ± 4.5	0 - 18	18
1999	25.1 ± 12.3	2 - 61	22
2000	14.4 ± 7.0	2 - 28	16
2001	22.1 ± 14.2	3 - 57	16
2002	28.7 ± 3.8	9 - 48	13
2003	63.6 ± 32.1	14 - 126	12
2004	19.0 ± 6.4	9 - 30	13
2005	13.4 ± 12.8	2 - 48	15
2006	14.1 ± 4.5	6 - 22	21
2007	6.2 ± 4.6	0 - 16	13

Table 3.34. The number of seals counted per observation day during the period from 1 June until the fjord ice became too fragmented in early/mid July 1997-2007. Only counts conducted with good visibility are included.

Seals *Phoca sp.*

Different seal species haul out on the ice of Young Sund but the specific species can only rarely be identified during the censuses from the research station. Seals were recorded from 29 May until 17 July when the ice broke up. A total of 13 counts were made with an all time low average of 6.2 seals per census and a maximum of 16 on 10 June (Table 3.34).

Narwhal *Monodon monoceros*

No Narwhales were observed in 2007.

3.5 Lakes

Sommerfuglesø and Langemandssø in Morænebakkerne were sampled during the period 20 July to 23 August following the standard BioBasic monitoring program for lake surveys. It has been decided to increase the sampling intensity from three to four times per season due to the warmer conditions and thus longer ice-free periods that has been prevailing in the area during the last 10 years (Christoffersen et al. 2008). Concomitant to the early snowmelt, both lakes were ice free very early in the season. Dates of 50% ice coverage for Sommerfuglesø and Langemandssø were 15 June (DOY 166) and 16 June (DOY 167), respectively, which is the earliest recorded so far (Table 3.35 and Table 3.36).

Lake	SS	SS	SS	SS	LS	LS	LS	LS
Date	**20.7**	**1.8**	**11.8**	**23.8**	**20.7**	**1.8**	**11.8**	**23.8**
Ice cover (%)	0	0	0	0	0	0	0	0
Temperature (°C)	11.0	11.8	10.8	6.4	11.8	12.0	10.6	7.8
pH	6.7	6.8	6.6	6.3	5.4	6.1	6.3	6.1
Conductivity (µS/cm)	8	9	10	12	7	7	6	8
Chlorophyll a (µg/l)	0.80	1.14	2.45	1.57	0.89	1.57	1.83	1.88
Total nitrogen (µg/l)	260	310	330	390	290	300	200	280
Total phosphorous (µg/l)	2	15	15	6	5	8	9	11

Table 3.35. Physico-chemical variables and chlorophyll a concentrations in Sommerfuglesø (SS) and Langemandssø (LS) during July and August 2007.

Lake	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
DOY of 50% ice cover	ND	192	199	177	183	184	175	176	169	186	166	ND	204	202	182	189	187	183	178	173	191	167
Temperature (°C)	6.3	6.5	6.1	10.1	8.4	8.3	11.0	8.7	9.8	10.1	10.0	6.8	6.4	4.0	9.5	8.4	8.1	11.1	9.1	10.5	9.8	10.6
pH	6.5	7.4	6.7	5.8	6.6	6.0	6.5	6.3	6.0	6.2	6.6	6.5	7.0	6.3	5.5	6.4	5.5	6.1	6.1	6	6.3	6.0
Conductivity (µS/cm)	15	13	10	18	18	8	12	15	22	11	10	8	9	7	9	8	6	6	8	14	5	7
Chlorophyll a (µg/l)	0.84	0.24	0.41	0.76	0.67	1.27	1.84	1.62	1.59	0.65	1.49	1.04	0.32	0.38	0.90	1.46	2.72	3.14	0.98	1.62	0.56	1.54
Total nitrogen (µg/l)	ND	130	210	510	350	338	277	267	263	293	323	ND	80	120	290	340	387	237	230	247	203	268
Total phosphorous (µg/l)	4	9	11	10	19	11	11	7	9	8	10	8	7	7	11	20	13	10	11	11	6	8

Table 3.36. Average physico-chemical variables in Sommerfuglesø (SS) and Langemandssø (LS) in 1999-2007 (July-August) compared to single values from mid-August 1997 and 1998. ND = no data.

Water temperatures varied between 6.4ºC and 12.0ºC, with mean temperatures of 10.0ºC and 10.6ºC in Sommerfuglesø and Langemandssø, respectively. This means that 2007 as an average follows the general trend of warming (Tables 3.35 and 3.36). The variations in water temperature are related to hydrological conditions (depth, residence time and inflowing melt-water) as well as to snow cover and snow depth of the entire area, but are also influenced by the actual weather conditions. However, the water chemistry, i.e. concentrations of total nitrogen and total phosphorus as well as the value for conductivity, remained within the average values that have been recorded for the lakes since 1997 (Table 3.36).

The chlorophyll *a* concentrations which are a measure of the phytoplankton biomass were likewise comparable to the concentration found for the previous

Lake	SS	SS	SS	SS	LS	LS	LS	LS
Date	20.7	1.8	11.8	23.8	20.7	1.8	11.8	23.8
Nostocophyceae	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dinophyceae	0.005	0.067	0.152	0.226	0.039	0.080	0.057	0.025
Chrysophyceae	0.101	0.310	0.640	0.491	0.110	0.078	0.278	0.303
Diatomophyceae	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Chlorophyceae	0.000	0.002	0.001	0.001	0.020	0.012	0.025	0.009
Others	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.106**	**0.379**	**0.793**	**0.718**	**0.169**	**0.170**	**0.360**	**0.337**

Table 3.37. Biovolume (mm³/l) of phytoplankton species in Sommerfuglesø and Langemandssø during July-August 2007.

	SS	SS	SS	SS	SS	SS	SS	SS	LS	LS	LS	LS	LS	LS	LS	LS	LS
Year	1998	1999	2001	2002	2003	2005	2006	2007	1997	1998	1999	2001	2002	2003	2005	2006	2007
Nostocophyceae	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Dinophyceae	0.034	0.044	0.015	0.006	0.027	0.185	0.068	0.113	0.291	0.185	0.305	0.040	0.156	0.123	0.030	0.068	0.050
Chrysophyceae	0.022	0.096	0.358	0.066	0.237	0.554	0.145	0.386	0.066	0.187	0.048	0.592	0.377	0.358	0.296	0.318	0.192
Diatomophyceae	0.002	0.000	0.001	0.000	0.000	0.000	0.007	0.000	0.002	0.000	0.000	0.002	0.000	0.000	0.000	0.009	0.000
Chlorophyceae	0.005	0.002	0.000	0.000	0.002	0.009	0.004	0.001	0.016	0.000	0.002	0.002	0.000	0.003	0.019	0.008	0.017
Others	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.063**	**0.147**	**0.377**	**0.073**	**0.266**	**0.749**	**0.223**	**0.499**	**0.375**	**0.372**	**0.354**	**0.637**	**0.533**	**0.484**	**0.345**	**0.404**	**0.259**

Table 3.38. Average biovolume (mm³/l) of phytoplankton species in Sommerfuglesø and Langemandssø from 1997 to 2007 (except for 2000 and 2004).

Lake	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS	LS
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Cladocera																						
Daphnia pulex	0.3	10.5	0.3	6.7	8.2	6.8	7.7	0.7	6.4	7.07	3.8	0	0	0	0	0	0	0.1	0	0	0	0
Macrothrix hirsuiticornis	0.1	0	0	0	0	0	0	0	0.07	0	0	0	0	0.2	0	0	0	0	0	0	0	0
Chydorus sphaericus	0.05	0	0	0	0.06	0	0	0	0.13	0	0	0	0.1	0	0.5	0.1	0.07	0	0	0.13	0.07	0.07
Copepoda																						
Cyclops abyssorum alpinus (adult+ copepodites)	0.8	0.5	0.5	0.3	0.5	0.2	0.9	0.3	0.07	0.27	2	3.3	2.9	4.1	22.0	13.4	6.8	8.6	4.9	5.8	11.74	8.93
Nauplii	5.7	1.3	6.5	1.1	1.4	2.3	0.3	0.3	0.2	1.67	0.13	5.2	3.8	6.4	3.1	4.5	4.5	4.2	0	2.20	5.13	1.07
Rotifera																						
Polyarthra dolicopthera	171	90	185	97	74	11	0.5	1.87	7.67	42.2	108	316	330	274	168	248	22	78	71	99	181.33	40
Keratella quadrata group	4.5	3.0	17	0	0	0.4	0.1	0	0	0.33	0	4.5	28	34	0	0	0.3	0	1.3	0	41.33	0
Conochilus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euchlanis sp.	0	0	0	0	0	0	0	0	0.33	0.07	0	0	0	0	0	0	0	0	0	0	0	0

Table 3.39. Density (no/l) of zooplankton in Sommerfuglesø (SS) and Langemandssø (LS) in mid-August 1997-2007.

years. The average concentrations for the ice free period in 2007 were 1.5 µg/l in both lakes, but varied between 0.8-2.5 µg/l and 0.9-1.9 µg/l in Sommerfuglesø and Langemandssø, respectively (Tables 3.35). The phytoplankton communities were dominated by chrysophytes (Table 3.37 and 3.38), with averages of 79% and 74% of the total biovolume in Sommerfuglesø and Langemandssø, respectively. Dinophytes constituted the majority of the remaining biomass with 13 and 19%, respectively. However, chlorophytes constituted on average 7% of the phytoplankton biovolumen in Langmandssø. The most conspicuous genera were *Gymnodium* spp., *Uroglena* spp., *Ochromonas* spp. and *Chromulina* spp.

The composition of the zooplankton communities were analysed from samples taken in mid-August (Table 3.39). *Daphnia pulex* was recorded in Sommerfuglesø, which has no fish population, and was absent in Langemandssø, that holds a population of dwarf-sized Arctic charr. Both lakes have populations of cyclopoide copepods (*Cyclops abyssorum alpininus*), and in Langemandssø *Chydorus sphaericus* is furthermore present. The recorded densities were similar to previous years (Table 3.39).

4 ZACKENBERG BASIC
The MarineBasic programme

Mikael K. Sejr, Søren Rysgaard, Ditte Mikkelsen, Morten Frederiksen, Egon R. Frandsen, Kunuk Lennert and Thomas Juul-Pedersen

This report presents results from the 5th year of the Marinebasic programme. The aim of the programme is to provide long time data series of physical, chemical and biological parameters in the Tyrolerfjord – Young Sund system. The intention is to detect changes in the physical environment and how changes in the physical environment affect selected compartments of the marine ecosystem. This is accomplished by sampling during a three week field campaign in the summer combined with autonomous sampling by moored instruments during the rest of the year. Physical, chemical and biological data are predominantly collected in the outer part of Young Sund but supplemented with data from Tyrolerfjord and the Greenland Sea.

The sampling strategy during the summer field campaign is to describe the geographic variation in the entire study area including Tyrolerfjord and the Greenland Sea by visiting a number of stations once (Fig. 4.1) but also to describe the short term temporal variability by sampling a single station on daily basis if the weather allows it ("water column station", Fig. 4.2). The parameters selected for the programme were selected based on broad scale ecological research efforts during the 1990s of most of the compartments of the ecosystem. The findings of the research projects were synthesized by Rysgaard and Glud (eds.) 2007. In 2007 measurements of $p\mathrm{CO_2}$ levels of the surface water in the entire study area was included as a new permanent parameter. Measurements of sea surface and atmospheric $p\mathrm{CO_2}$ are now done once along the section from Tyrolerfjord to the Greenland Sea and approximately every other day at the main hydrographic station in the outer Young Sund.

During the summer field campaign the physical and chemical part of the sam-

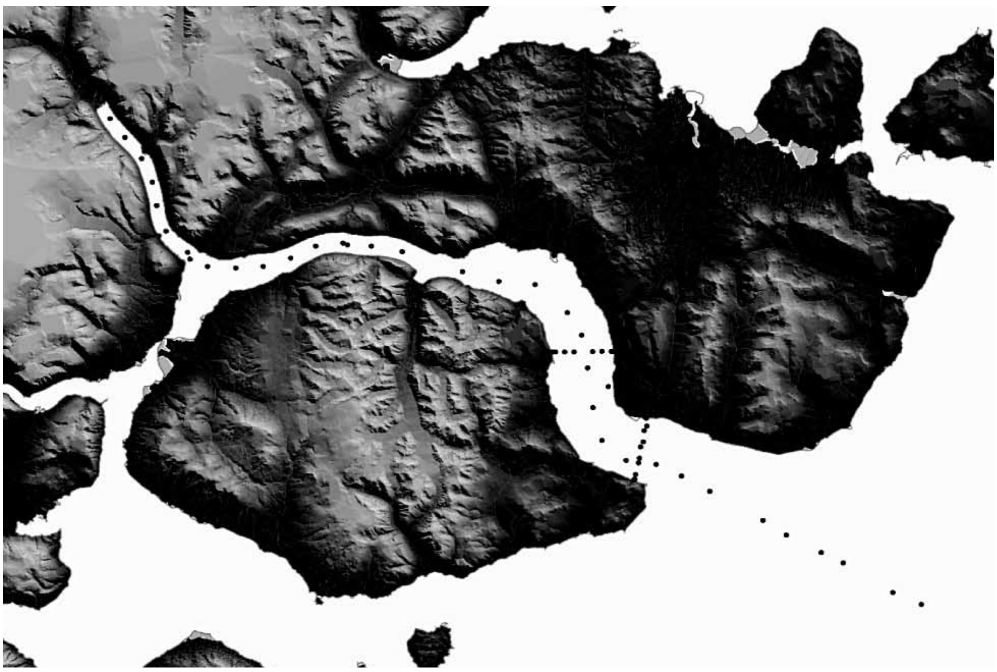


Fig. 4.1. Map of the sampling area. The dots represent the hydrographic sampling stations from the innermost Tyrolerfjord on the left to the East Greenland Shelf on the right.

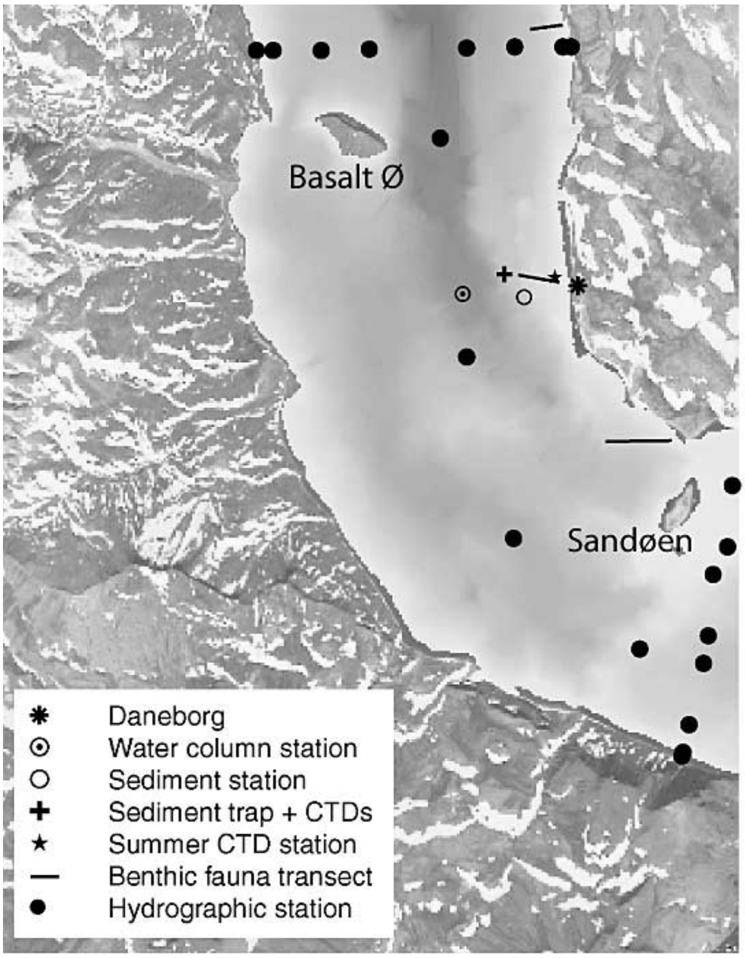


Fig. 4.2. Map showing the sampling stations in the outer part of the Young Sund in more detail.

pling programme consists of hydrographic measurements (salinity, temperature, pressure, oxygen, fluorescence, turbidity) combined with measurement of nutrient concentrations ($NO_3^- + NO_2^{2-}$, PO_4^{3-}, SiO_4), dissolved inorganic carbon (DIC), total alkalinity (TA), surface pCO_2 together with estimation of attenuation coefficients of light (PAR) and UV-B. The biological part of the summer field campaign includes sampling and identification of pelagic phyto- and zooplankton, density of selected benthic epifauna, estimation of sediment-water fluxes of nutrients, oxygen and DIC and sulphate reduction. In the sediment, vertical profiles of oxygen were also measured. Annual growth of the macroalgae *Laminaria saccharina* is estimated and abundance of walruses is recorded and specimens of arctic charr are collected and stored for future analysis of contamination levels and isotopic composition.

To supplement data collected during the summer campaign a permanent mooring is established in the outer Young Sund. Here continuous measurement of salinity, pressure and temperature are conducted at approximately 40 and 55 m depth. Sedimentation of particles is also estimated throughout the year using a sediment trap at approximately 60 m.

In addition to the monitoring activities logistical support was provided with the research ship Aage V. Jensen. Assistance was provided to GeoArk, NANOK and to Carsten Egevang studying Arctic terns and Sabine's gulls on Sandøen.

4.1 Sea ice

The autonomous camera system provided daily images of the ice formation and melting of sea ice in the outer part of Young Sund (Fig. 4.3). The photos were used to estimate when fast ice was established in autumn 2006 and when it broke up in the summer thaw of 2007. The dates of ice formation and ice melt were confirmed by SIRIUS. During the open-water period in 2007 sea ice from the Greenland Sea occasionally entered the fjord and circulated for a few days before being exported again. Personnel from SIRIUS continued their measurements of sea ice and snow thickness at 74°18.59'N, 20°15.04'W during 2006-2007. Compared to previous years (2003-2006) a thicker sea ice cover was recorded in 2007 whereas snow cover was thinner (Fig. 4.4, Table 4.1).

4.2 Water column

Annual data from mooring

Continuous data of temperature, salinity and density were obtained at two depths at the same position as that of the sediment trap (74°18.930'N, 20°16.697'W). The equipment was deployed on August 16, 2006 and retrieved after one year. Data are presented in Fig. 4.5 and Fig. 4.6. The instrument at 56 m displayed salinity variability in the range 32.2 to 32.8 and at 40 m the variability was 31.4 to 32.6. The annual temperature variation at 56 m was in the range of -1.27°C to -1.74°C and at 40 m it was -0.85°C to -1.74°C. The freshwater from the summer thaw was gradually mixed deeper in the water column during autumn and winter. Detailed investigation of the first 5 years of oceanographic monitoring data has been initiated and will be presented elsewhere.

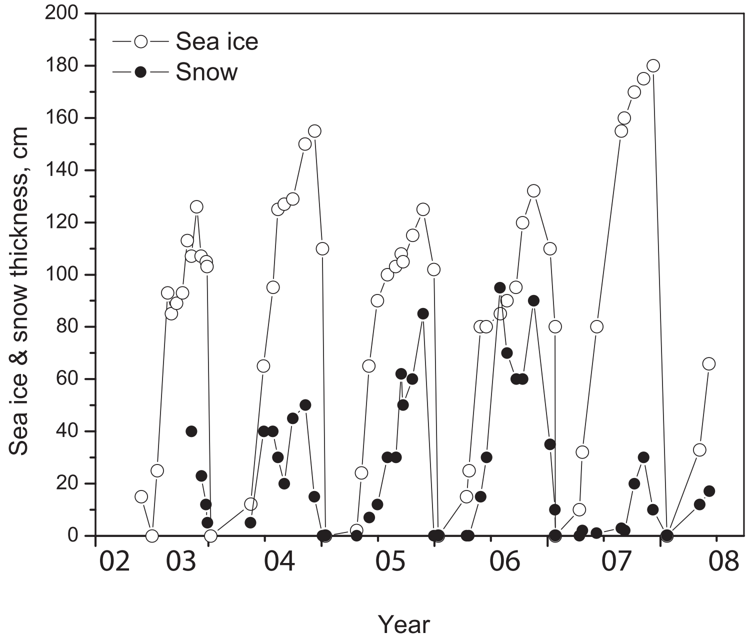


Fig. 4.4. Snow and sea ice thickness in the outer part of Young Sund.

	2003	2004	2005	2006	2007
Ice thickness (cm)	120	150	125	132	180
Snow thickness (cm)	20	32	85	95	30
Days with open water	128	116	98	75	*

* will be provided in next report when the autonomous camera system has been collected.

Table 4.1. Summary of sea ice and snow conditions in Young Sund

The sediment trap was retrieved on August 6, 2007. Highest vertical sinking flux of total matter and carbon occurred during ice free conditions from July to September (Fig. 4.7). Consistently low sedimentation was observed throughout the rest of the year, i.e. from October to June. The peak in vertical sinking flux of total matter and carbon in mid-July (1.2 g m^{-2} d^{-1} and 21.0 mg m^{-2} d^{-1}, respectively) was likely due to an input of terrestrial material, as indicated by the low $\delta^{13}C$ value (-27.4 ‰) and high C:N ratio (10.5 mol: mol). The annual sedimentation of total matter and carbon in 2006-07 (114 and 1.4 g m^{-2} yr^{-1}, respectively) were markedly lower than values recorded during previous years (e.g. 1600 and 19.1 g m^{-2} yr^{-1}, respectively, in 2002-03).

Fig. 4.3. Examples of daily images used to monitor ice conditions in 2006-2007 in Young Sound.

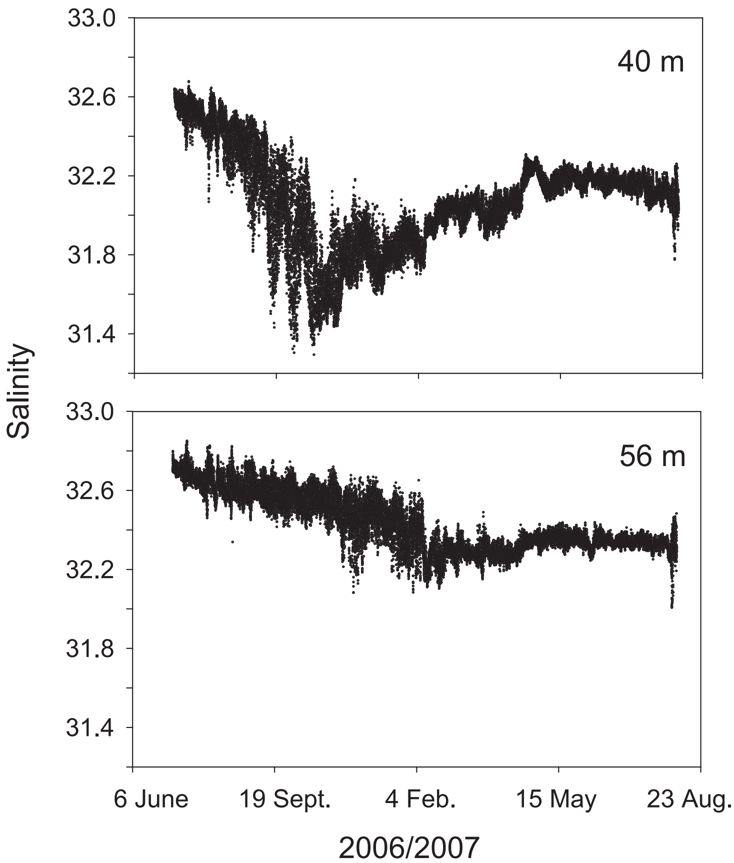


Fig. 4.5. Time series of salinity from 40 and 56 m in Young Sund. The mooring was deployed on 17 August, 2006 and retrieved on 6 August 2007.

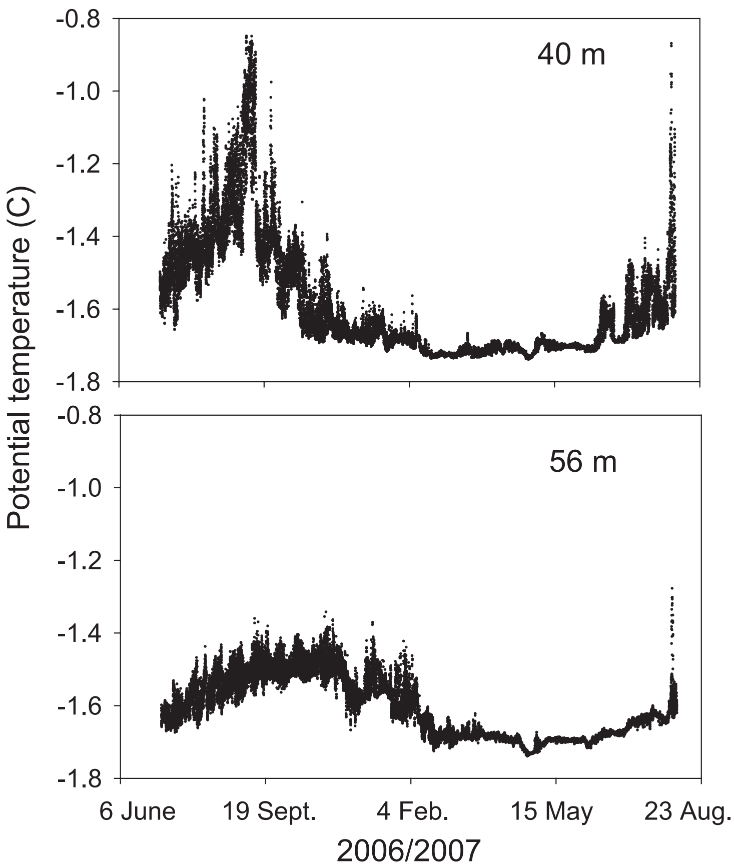


Fig. 4.6. Time series of potential temperature at two depths in Young Sund. Continuous data were collected from 17 August, 2006 until 6 August 2007.

Summer distribution of temperature, salinity, density, oxygen and chlorophyll

Vertical distribution of temperature, salinity, density, oxygen and chlorophyll was obtained along the hydrographic transect from Tyrolerfjord to the Greenland Sea on August 7 (Fig. 4.8). Fluorescence was converted to chlorophyll concentrations based on water samples collected at the standard hydrographic station (see below). Due to ice conditions measurements were not conducted at all the stations in the Greenland Sea as access was prevented by drift ice. As observed in previous years maximum chlorophyll values are found outside the fjord. However, a relative large area in the central part of the fjord was supersaturated with oxygen which could be an indication of active primary production despite relatively low chlorophyll concentrations. Another distinct feature related to the oxygen concentration in the fjord is the lower saturation observed in the inner part of Tyrolerfjord. Below 100 m depth saturation drops below 75% which is lower compared to the rest of the fjord. This indicates that the inner basin in Tyrolerfjord is partly isolated from the rest of the fjord most likely due to the shallow sill which reduces circulation.

The input of freshwater into the fjord forms a low saline surface layer which is relatively warm. Cross sections at Sandøen and at Basalt Ø confirm previous observations that the freshwater predominantly exits the fjord along Clavering Island which creates a low saline surface layer that is slightly thicker compared to the opposite side of the fjord (Fig. 4.9) However, due to strong wind on 2-3 August this stratification was partly broken down. The wind induced mixing of the surface water is visible in Fig. 4.10 which shows vertical profiles of temperature and salinity from 2003-2007 at a station in outer Young Sund. The temporal variability (Fig. 4.11) was studied in detail at the standard hydrographic station (74°18.58'N, 20°18.11'W) throughout the field campaign. Prior to the storm a distinct subsurface peak in chlorophyll is observed as well as a low saline surface layer with temperatures just above 4 °C. After the storm the subsurface peak in chlorophyll has disappeared and the temperature of the surface water dropped to less than 1 °C.

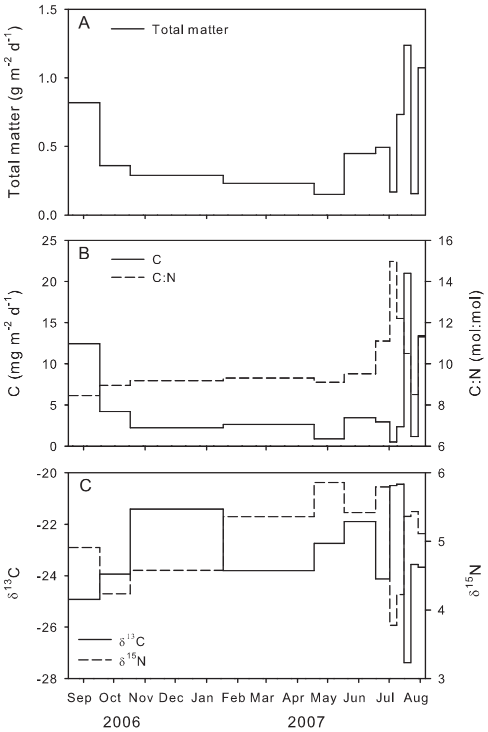


Fig. 4.7. Time series of the vertical sinking flux during 2006-07 in the outer part of Young Sund. A) Total flux of organic and inorganic matter. B) Flux of organic carbon and C/N values of organic matter. C) Isotopic composition of carbon and nitrogen in sedimented matter.

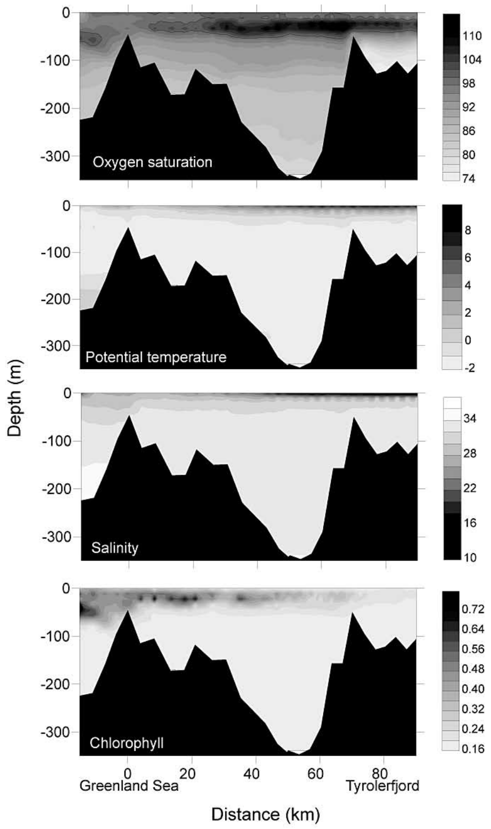


Fig. 4.8. Oxygen concentration (% atmospheric saturation), potential temperature (°C), salinity and chlorophyll (µg/L) in the Young Sund – Tyrolerfjord system on 9 August, 2007. Due to ice condition it was not possible to reach the 4 hydrographical stations furthest from the coast.

Nutrients, dissolved inorganic carbon (DIC) and total alkalinity (TA)

Vertical profiles of nutrients, DIC and TA were measured at the standard hydrographic station (74°18.58'N, 20°18.11'W) on three occasions in the summer 2007 (27 July, 4 August and 12 August). Profiles of nutrients are shown in Fig. 4.12. Nitrate (NO_3^-) concentrations were very low in the surface due to phytoplankton uptake. From about 30 m depth the concentration in nitrate shows a steady increase in concentration with a maximum of 5 µM at 150 m depth. Profiles of nitrate concentration showed little variation on the three sampling dates. Phosphate (PO_4^{3-}) profiles showed a minimum concentration of 0.3 µM at the surface which increase to about 0.5 µM near the bottom. Silicate (SiO_4) concentrations show some temporal variation during the sampling period but follow the general pattern with lowest concentrations at the surface and maximum near the bottom.

Profiles of TA and DIC were also measured at the standard hydrographic station (Fig. 4.13). Low concentrations of both TA and DIC were found at the surface due to dilution from freshwater. On 4 August surface concentrations show an increase due to mixing induced by two days with strong winds. About a week later on 10 August the surface layer is reestablished and surface concentrations of TA and DIC approach values recorded on 27 July.

Mean concentrations of nutrients, DIC and TA for different depth intervals for

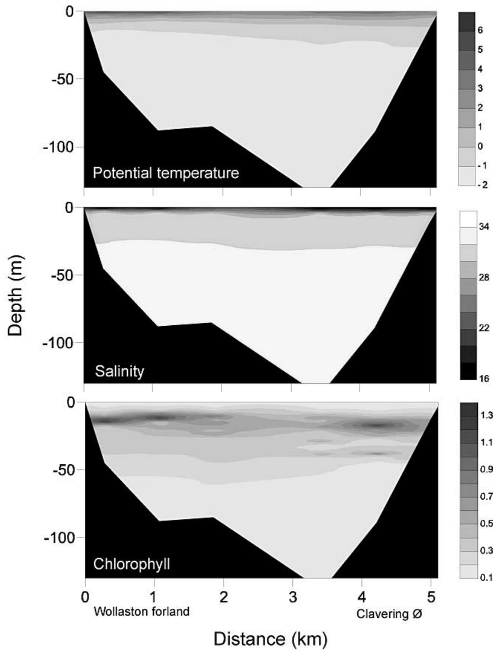


Fig. 4.9. Potential temperature (°C), salinity and chlorophyll (µg/L) across Young Sund, near Basalt Ø in August 2007.

Table 4.2. Summary of hydrographic conditions in Young Sund. Mean values of depth profiles sampled throughout August. ± represents Standard Error (SE) of the mean.

0-5 m depth	**2003**	**2004**	**2005**	**2006**	**2007**
Potential temp. (°C)	5.570 ± 0.175	5.515 ± 0.158	4.612 ± 0.077	3.59 ± 0.46	2.066 ± 0.207
Salinity	28.10 ± 0.230	26.02 ± 0.247	27.42 ± 0.089	27.63 ± 0.77	24.86 ± 0.714
Chlorophyll (μg L^{-1})	0.727 ± 0.069	0.060 ± 0.004	0.945 ± 0.239	0.29 ± 0.08	0.20 ± 0.04
DIC (μM)	1806.2 ± 60.4	1769.0 ± 46.5	1829.5 ± 11.5	1763 ± 58.8	1716.8 ± 92.0
TA (μM)	1929.5 ± 65.8	1867.5 ± 52.5	2066.6 ± 11.1	2002 ± 67.3	1812 ± 101.8
pCO_2 (μatm)*	302.2 ± 32.6	197.1 ± 10.1	154.8 ± 9.0	122.1 ± 4.5	239.9 ± 5.0
NO_3^- (μM)	0.00 ± 0.04	0.16 ± 0.05	0.04 ± 0.08	0.12 ± 0.07	0.03 ± 0.03
PO_4^{3-} (μM)	0.25 ± 0.01	0.58 ± 0.17	0.20 ± 0.01	0.56 ± 0.20	0.27 ± 0.02
SiO_4 (μM)	2.41 ± 0.30	2.51 ± 0.59	1.85 ± 0.11	1.17 ± 0.85	3.31 ± 0.42

0-45 m depth	**2003**	**2004**	**2005**	**2006**	**2007**
Potential temp. (°C)	2.564 ± 0.203	0.708 ± 0.095	0.998 ± 0.109	-0.32 ± 0.15	-0.532 ± 0.062
Salinity	30.44 ± 0.168	31.16 ± 0.104	31.02 ± 0.105	31.58 ± 0.15	30.72 ± 0.139
Chlorophyll (μg L^{-1})	0.498 ± 0.032	0.407 ± 0.021	1.465 ± 0.292	1.14 ± 0.22	0.69 ± 0.14
DIC (μM)	2000.6 ± 40.4	1986.3 ± 3.6	2001.6 ± 17.6	2007.5 ± 26.3	1949.8 ± 50.6
TA (μM)	2146.0 ± 44.9	2175.5 ± 31.2	2263.8 ± 19.5	2274.3 ± 29.0	2063.0 ± 55.2
NO_3^- (μM)	0.83 ± 0.27	0.46 ± 0.15	0.08 ± 0.04	0.27 ± 0.14	0.07 ± 0.21
PO_4^{3-} (μM)	0.34 ± 0.03	0.62 ± 0.08	0.24 ± 0.01	0.34 ± 0.04	0.36 ± 0.02
SiO_4 (μM)	2.20 ± 0.2	1.45 ± 0.27	1.25 ± 0.09	0.05 ± 0.03	6.43 ± 0.22

45-150 m depth	**2003**	**2004**	**2005**	**2006**	**2007**
Potential temp. (°C)	-1.65 ± 0.004	-1.65 ± 0.001	-1.72 ± 0.002	-1.68 ± 0.01	-1.628 ± 0.001
Salinity	32.93 ± 0.002	33.09 ± 0.001	33.21 ± 0.001	32.97 ± 0.01	32.67 ± 0.010
Chlorophyll (μg L^{-1})	0.257 ± 0.011	0.117 ± 0.004	1.040 ± 0.257	0.33 ± 0.14	0.10 ± 0.02
DIC (μM)	2181.1 ± 7.9	2172.4 ± 0.40	2188.9 ± 3.2	2190.9 ± 3.2	2203.2 ± 10.4
TA (μM)	2318.8 ± 1.7	2347.6 ± 5.0	2450.5 ± 4.7	2440.9 ± 3.5	2307 ± 21.9
NO_3^- (μM)	3.95 ± 0.15	4.64 ± 0.14	3.15 ± 0.18	3.91 ± 0.35	3.88 ± 0.36
PO_4^{3-} (μM)	0.58 ± 0.01	0.88 ± 0.11	0.50 ± 0.01	0.47 ± 0.06	0.48 ± 0.01
SiO_4 (μM)	4.22 ± 0.27	4.48 ± 0.11	3.99 ± 0.26	4.63 ± 1.23	5.66 ± 0.41

*Mean of surface layer (0-1 m)

each summer from 2003-2007 are compiled in Table 4.2. Compared to previous years, 2007 was characterized by high concentration of nutrients and DIC at the 45-150 m layer. In the surface layer (0-5m and 0-45m) concentrations of DIC and TA were the lowest observed since 2003.

Surface pCO_2

In 2007 a new sampling routine for CO_2 partial pressure in the sea surface was implemented. The partial pressure is now measured within minutes using an infra red gas analyzer (EGM-4 by PP Systems) coupled to a lap top computer on board

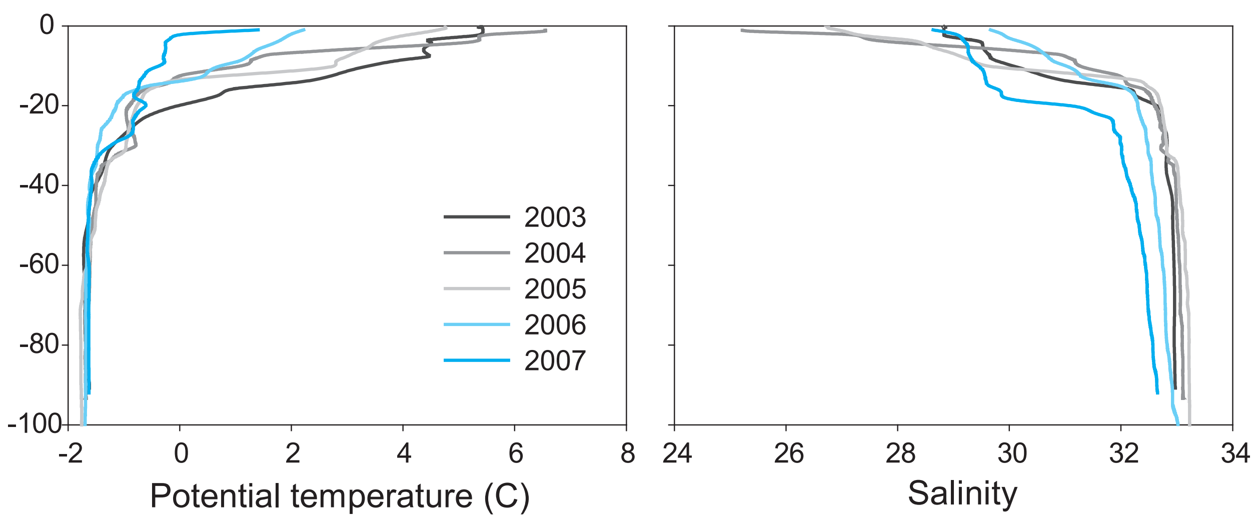


Fig. 4.10. Vertical profiles of temperature (left panel) and salinity (right panel) at station 3.06 in Young Sund from 2003 to 2007.

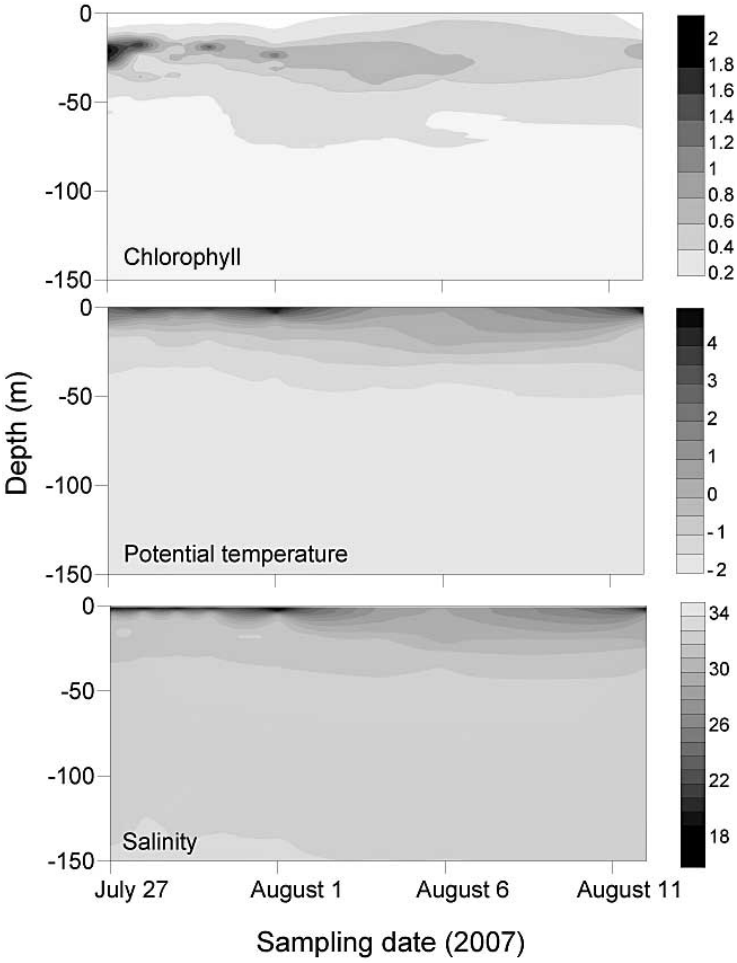


Fig. 4.11. Chlorophyll (µg/L), potential temperature (°C) and salinity during August 2007 at the standard hydrographic station in Young Sund.

the ship. Sea water is pumped from the sea surface and through a gas equilibrator (MiniModule by Luqui-Cel) and into the CO_2 analyzer. The partial pressure of CO_2 in the surface water is then compared with measurements of partial pressure of CO_2 in the atmosphere. The spatial variation in the entire study area is studied by measuring pCO_2 levels along the transect from Tyrolerfjord and into the Greenland Sea (Fig. 4.14a). Considerable variation was found in 2007 along the transect. In general, pCO_2 levels in the sea surface were below atmospheric levels indicating than the fjord acted as a sink for atmospheric CO_2 (negative ΔpCO_2). The highest difference between air and sea content of CO_2 was found in the Greenland Sea. The measurements were conducted in the middle of a large belt of heavy drift ice that prevented sampling along the entire transect. In 2006 a similar study was conducted as part of a research project. Here the fjord was generally less under saturated with CO_2 compared to 2007. Also in 2006 the most under saturated area was in Tyrolerfjord with only a marginal decrease in ΔpCO_2 in the Greenland Sea.

The temporal variation during the field campaign was investigated by measurement at the main hydrographic station (Fig. 4.14b). In 2007 the sea surface was more undersaturated compared to 2006. The mean ΔpCO_2 was -134 ± 5.0 ppm (mean ± SE) in 2007 compared to -95 ± 3.0 ppm in 2006. In 2007 ΔpCO_2 became less negative after 3 days with strong wind around August 4. The wind increased mixing and most likely brought deeper water with higher CO_2 content to the surface which decreased the difference between the air and sea content of CO_2.

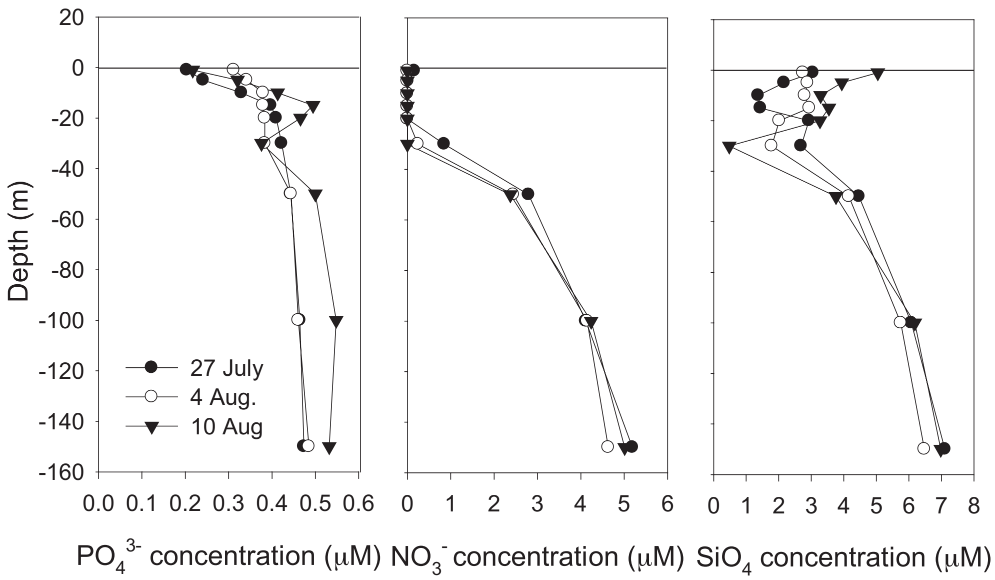


Fig. 4.12. Profiles of the concentrations of nutrients in the water column at the hydrographic station in outer Young Sund in August 2007.

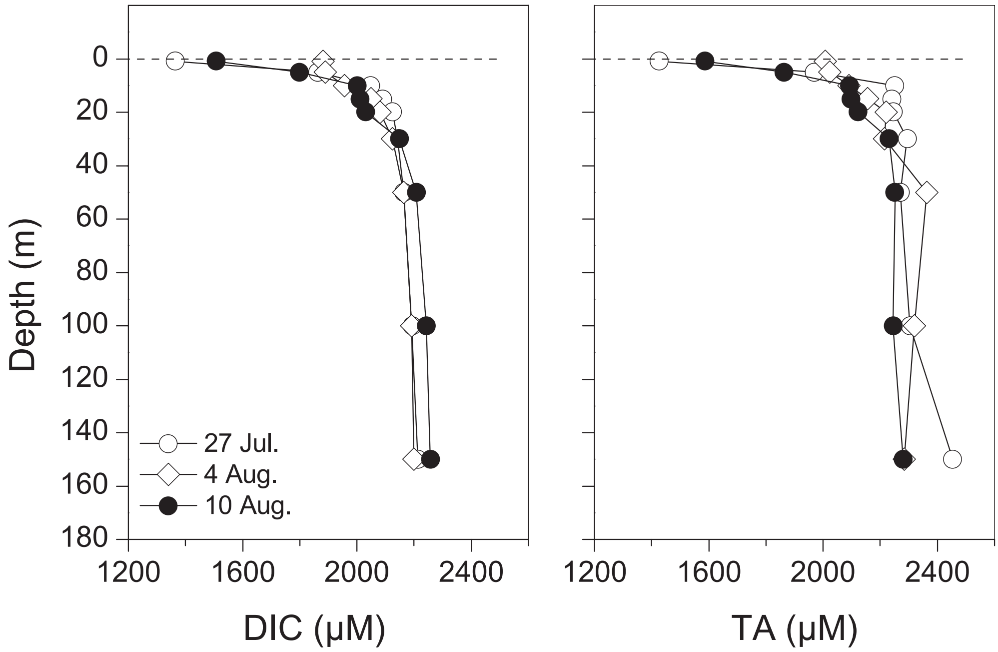


Fig. 4.13. Concentration of dissolved inorganic carbon (DIC) and total alkalinity (TA) in the water column at the standard hydrographic station in the outer part of Young Sund, August 2007.

Light and UV-B attenuation

On eight occasions during the summer field campaign the attenuation coefficients of photosynthetically available radiation (PAR) was determined at the hydrographic station. The average attenuation coefficient (Table 4.3) was the highest recorded during the monitoring program. Water samples were collected three times during the study period for estimation of the attenuation of UV-B (280-315 nm). Like the attenuation of PAR the average value for 2007 was the highest recorded since 2003. Part of the reason for the high attenuation for both PAR and UV-B is the increased mixing of the water column during the storm on 2-3 August. Prior to the storm vertical profiles of fluorescence showed very low densities of phytoplankton at the surface but a distinct subsurface peak at 20-25 m depth. After the storm both the fluorescence and turbidity was uniformly distributed in the water column which increased the surface level compared to prior the storm. Both active phytoplankton and inorganic particles

Fig. 4.14. Difference in partial pressure of CO_2 between atmosphere and sea surface in 2006 and 2007 in Young Sound. A) Depicts changes along a transect from Tyrolerfjord to the Greenland Sea. B) Shows temporal changes and the standard hydrographic station in Young Sound.

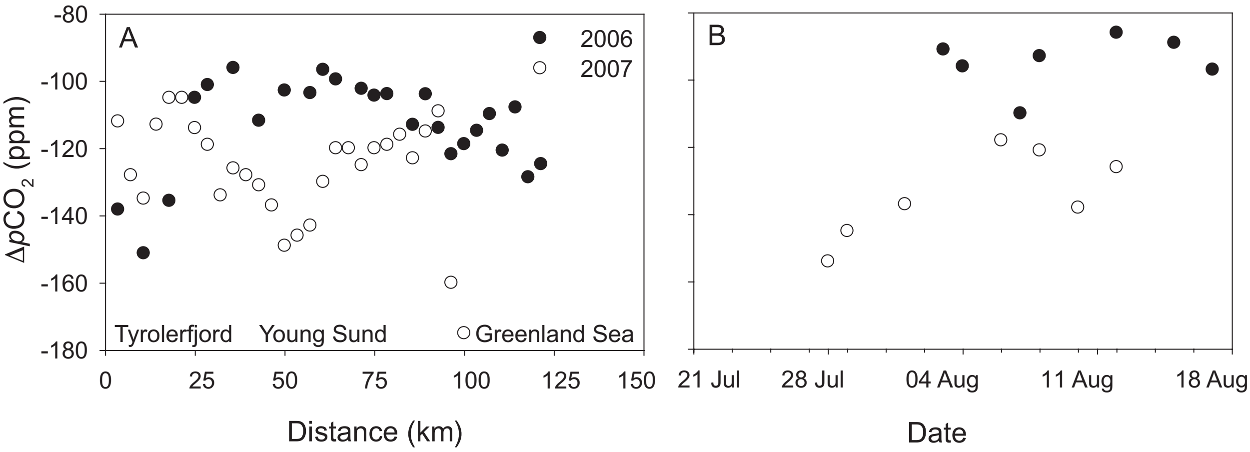


Table 4.3. Attenuation coefficients in the water column of photosynthetically available radiation (PAR) and UV-B (280-315 nm) in Young Sund. Mean ± SE (n).

	2003	2004	2005	2006	2007
PAR attenuation coeff. (m^{-1})	0.117 ± 0.007 (8)	0.136 ± 0.004 (8)	0.110 ± 0.009 (4)	0.173 ± 0.004 (7)	0.177 ± 0.010 (8)
UV-B attenuation coeff. (m^{-1})	1.27 ± 0.05 (8)	1.43 ± 0.23 (8)	1.32 ± 0.12 (4)	1.62 ± 0.22 (4)	1.98 ± 0.20 (6)

	27 July 2007		4 August 2007		10 August 2007	
No. species	19.0 ± 0.58		17.7 ± 2.40		15.3 ± 0.33	
Diversity	1.91 ± 0.02		1.84 ± 0.13		2.19 ± 0.13	
Equitability	0.65 ± 0.01		0.64 ± 0.01		0.80 ± 0.04	
Dom. species	*Fragilariopsis cylindrus*	33	*Fragilariopsis cylindrus*	34	*Chaetoceros wighamii*	27
	Chaetoceros wighamii	55	*Attheya septentrionalis*	47	*Fragilariopsis cylindrus*	40
	Fragilariopsis pseudonana	64	*Fragilariopsis oceanica*	58	*Attheya septentrionalis*	52
	Attheya septentrionalis	71	*Chaetoceros wighamii*	69	*Pseudonitzschia delicatissima*	65
	Achnanthes taeniata	79	*Achnanthes taeniata*	77	*Fragilariopsis pseudonana*	69
	Pseudonitzschia seriata	84	*Pseudonitzschia delicatissima*	83	*Navicula septentrionalis*	74
	Eucampia groenlandica	86	*Dinobrion balticum*	87	*Chaetoceros eibenii*	79
	Bacteriosira sp.	89	*Fragilariopsis pseudonana*	91	*Eucampia groenlandica*	83
	Navicula septentrionalis	91	*Pseudonitzschia seriata*	93	*Fragilariopsis oceanica*	87
	Chaetoceros eibenii	93	*Navicula septentrionalis*	94	*Dinobrion balticum*	90

Table 4.4. Phytoplankton diversity in Young Sund at 0-50 m depth during August 2007. The ten most abundant species are listed together with the relative accumulated proportion (%) of total cell count.

increase the attenuation of PAR and UV-B in the water column and the increased coefficients observed in 2007 is more likely a result of the storm event rather that part of a long term trend.

Phytoplankton and zooplankton

To determine the species composition of the phytoplankton vertical net hauls were performed using 20 µm plankton net at 0-50 m depth on three occasions on the hydrographic station in the outer Young Sund. The composition of the phytoplankton community did not change much during the field campaign as shown by the ten most abundant species present at each sampling date (Table 4.4). Diatoms are the most abundant group of phytoplankton and the psyocrophilic species *Fragilariopsis cylindrus* often dominate together with the species belonging to the genus *Chaetoceros*. The number of identified species and the species diversity estimated using the Shannon diversity index and Simpson equitability index is very similar to values from previous years and do not change much during the sampling period.

The zooplankton was also sampled at the hydrographic station using a 50 µm net hauled from the bottom (app. 170 m) to the surface (Table 4.5). As observed in previous years the abundance of the different copepodite stages increase during the sampling period. Most abundant are the copepodites belonging to the species *Oithona spp.*, *Pseudocalanus spp.* and *Calanus finmarchicus*. One interesting trend in the data on copepod composition in the summer in Young Sund is the change in relative abundance between the arctic copepod *Calanus hyperboreus* and the Atlantic species *C. finmarchicus*. In 2003 the ratio of copepodite abundance of *C. hyperboreus* to *C. finmarchicus* was 56:1. This ratio has shown a steady decrease with 11:1 in 2004, 3:1 in 2005 and 0.8:1 in 2006 and 2007. This could be an indication of increasing input of Atlantic water onto the east Greenland shelf which influences the copepod composition in the fjord.

4.3 Sediment

Sediment-water exchange rates of oxygen, DIC and nutrients, oxygen conditions and sulphate reduction

The organic matter reaching the sediment from the water column undergoes degradation within the sediment, a process also known as mineralization. This occurs via a number of steps involving several different electron acceptors, or oxidants. In the surface layer, O_2 serves as electron acceptor and below the oxic zone SO_4^{2-} is the dominant electron acceptor. In the anoxic zone, oxidised Fe and Mn and NO_3^- may act as electron acceptors as well. When either oxidised metals or SO_4^{2-} oxidise the organic matter, reduced species are formed and subsequent re-oxidation of these species leads to oxygen consumption. The nutrients incorporated in the organic matter undergoing degradation are released and may bind to the sediment particles, participate in reactions in the sediment or be released to the overlying water. The sediment processes were measured in intact sediment cores sampled at a water depth of 60 m (74°18.58′N, 20°15.74′W) on 8 August 2007.

Of the organic carbon reaching the sediment surface 1.544 mmol C m^{-2} d^{-1} was returned to the water column as dissolved inorganic carbon (DIC) in 2007 (Table 4.6).

Table 4.5. Composition of the copepod fauna in August 2007 in Young Sund at 0-150 m depth.

Species	Stage/sex	27 July Mean (No. m^{-3})	27 July SE (n=3)	4 August Mean (No. m^{-3})	4 August SE (n=3)	10 August Mean (No. m^{-3})	10 August SE (n=3)
Calanus hyperboreus	Adult ♀	20.0	3.3	20.0	6.1	46.7	8.1
	Adult ♂	0.0	0.0	0.0	0.0	0.0	0.0
	C V	25.3	13.9	61.3	7.1	54.7	10.4
	C IV	64.0	0.0	1280.0	73.9	1280.0	64.0
	C III	106.7	42.7	2282.7	170.7	2154.7	129.8
	C II	128.0	0.0	2581.3	129.8	1621.3	112.9
	C I	21.3	21.3	746.7	93.0	832.0	73.9
Calanus glacialis	Adult ♀	14.7	8.1	42.7	9.6	6.7	4.8
	Adult ♂	0.0	0.0	0.0	0.0	0.0	0.0
	C V	28.0	18.3	704.0	128.0	85.3	21.3
	C IV	5.3	5.3	0.0	0.0	0.0	0.0
	C III	1.3	1.3	0.0	0.0	0.0	0.0
	C II	0.0	0.0	0.0	0.0	0.0	0.0
	C I	0.0	0.0	0.0	0.0	0.0	0.0
Calanus finmarchicus	Adult ♀	106.7	21.3	213.3	21.3	106.7	21.3
	Adult ♂	0.0	0.0	0.0	0.0	0.0	0.0
	C V	192.0	37.0	960.0	97.8	853.3	56.4
	C IV	128.0	37.0	896.0	64.0	362.7	56.4
	C III	85.3	21.3	917.3	76.9	682.7	76.9
	C II	128.0	37.0	2602.7	395.1	2858.7	118.8
	C I	128.0	37.0	1130.7	388.1	2410.7	203.5
Pseudocalanus spp.	Adult ♀	170.7	56.4	384.0	37.0	85.3	21.3
	Adult ♂	0.0	0.0	20.0	2.3	0.0	0.0
	C V	61.3	2.7	853.3	93.0	618.7	42.7
	C IV	64.0	0.0	789.3	21.3	917.3	76.9
	C III	64.0	37.0	960.0	133.2	896.0	97.8
	C II	256.0	37.0	1109.3	118.8	2069.3	76.9
	C I	64.0	0.0	938.7	93.0	1301.3	93.0
Oithona spp.	Adult ♀	1472.0	110.9	1216.0	133.2	1216.0	133.2
	Adult ♂	85.3	21.3	362.7	56.4	16.0	4.6
	C I-CV	2154.7	246.0	3818.7	240.4	5696.0	426.1
Oncea	Adult ♀	320.0	73.9	170.7	21.3	64.0	37.0
	Adult ♂	42.7	21.3	0.0	0.0	64.0	37.0
	C I-CV	341.3	56.4	874.7	76.9	341.3	42.7
Microcalanus	Adult ♀	149.3	76.9	64.0	37.0	21.3	21.3
	Adult ♂	85.3	56.4	5.3	3.5	6.7	3.5
	C I-CV	1749.3	379.2	2240.0	315.7	384.0	37.0
Metridia longa	Adult ♀	16.0	9.2	298.7	42.7	106.7	21.3
	Adult ♂	5.3	1.3	256.0	64.0	36.0	15.1
	C V	213.3	21.3	256.0	0.0	85.3	21.3
	C IV	128.0	37.0	106.7	56.4	21.3	21.3
	C III	42.7	21.3	21.3	21.3	21.3	21.3
	C II	42.7	42.7	0.0	0.0	21.3	21.3
	C I	21.3	21.3	0.0	0.0	21.3	21.3

Table 4.6. Sediment-water exchange rates of O_2 (TOU, total oxygen uptake), DIC (dissolved inorganic carbon), NO_3^- + NO_2^-, NH_4^+, SiO_4 and PO_4^{3-} measured in intact sediment cores, sulphate reduction rates (SRR) in the sediment integrated to a depth of 12 cm, diffusive oxygen uptake by the sediment (DOU) and the ratios of DOU to TOU and SRR to DIC flux. SRR/DIC flux is calculated in carbon-equivalents. n denotes the number of sediment cores. Positive values indicate a release from the sediment to the water column. All rates are in mmol m^{-2} d^{-1}. SE denotes the standard error of the mean.

Parameter	Average	±SE	n
TOU	-2.834	0.841	10
DIC	1.544	0.275	10
NO_3^- + NO_2^-	0.052	0.022	10
NH_4^+	-0.019	0.011	10
PO_4^{3-}	-0.118	0.240	10
SiO_4	0.214	0.035	10
SRR	0.590	0.101	3
DOU	-1.841		10
TOU/DOU	1.539		
SRR/DIC	0.764		

The O_2 consumption by the sediment of 2.834 mmol m^{-2} d^{-1} was higher than the DIC efflux primarily due to reduced substances diffusing up from deeper sediment layers and reacting with oxygen. Thus, the specific O_2 consumption was also high in the lower part of the sediment (Fig. 4.15). The DIC flux was significantly lower than previous years showing that the input of organic matter to the sediment during 2007 was significantly lower (compare with previous ZERO reports).

	2003	2004	2005	2006	2007
Length of new leaf blades (cm yr^{-1})	108.6 ± 7.6 (14)	105.7 ± 6.2 (16)	118 ± 5.5 (20)	77 ± 6.6 (20)	84.6 ± 5.7 (22)
Production of new leaf blades (g C yr^{-1})	15.1 ± 1.3 (14)	5.8 ± 0.8 (16)	11.0 ± 0.9 (20)	2.0 ± 0.5 (17)	5.9 ± 1.0 (22)

Table 4.7. Annual growth (mean ± SE) of Laminaria saccharina *at 10 m depth in Young Sound. Number of specimens measured are given in parenthesis.*

This agrees well with the heavier ice conditions and hence lower phytoplankton productivity during 2007 as compared with the previous years.

Sulphate reduction was responsible for 76% of the mineralization of organic matter in summer 2007 (Table 4.6) which is the highest recorded in the monitoring program. Sulphate reduction was low in the upper layers of the sediment, where other mineralization processes dominated, and increased significantly with depth (Fig. 4.16). The ratio between diffusive and whole-core O_2 uptake of 1.539 indicated an active bioturbation this year.

Benthic macrofauna

The abundance of dominant epifauna was estimated from 150 photos of the sea floor covering a total area of 40 m^2. Photos were taken along three transects (see Fig. 4.2). At each transect 10 photos were taken at each of the following depths: 20, 30, 40, 50 and 60 m. Compared to previous years large amounts of drift ice was found in the Young Sund during the field campaign. For the first time visible signs of ice scour on the sea floor was observed in four photographs out of ten at transect H2, 30m (Fig. 4.17). The ice scours appeared to have been made during the summer of 2007 since scour ridges were very clear cut. However, a layer of benthic micro algae was visible in most photos indicating that the scours were at least 1-2 weeks old. The effect was a significant reduction in abundance of brittle stars and bivalves (t-test, P<0.01) in the four photos impacted by ice scour compared to the six photos not impacted with ice from the same site (Fig. 4.18). Although the effect of scouring ice clearly reduced abundance of macrofauna the frequency of ice scour is relatively low. From the 5 years of data at three transects in Young Sound at depths from 20 to 60 m the total area affected by ice scour is 1.6 m^2 out of a total of 231.5 m^2 or 0.7% of the area studied.

In general, data on abundance of macrofauna show large variation from year to year. A part of this variation is certainly due to small scale geographical variation. Data of abundance for the most abundant species are presented in Fig. 4.19. The most characteristic feature of the

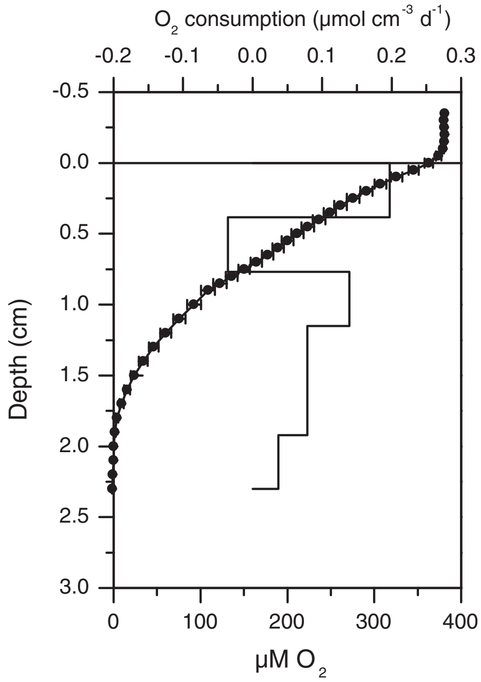


Fig. 4.15. Vertical concentration profiles of oxygen (dots) and modeled consumption rates (line) in the sediment at 60 m depth in Young Sound, August 2007.

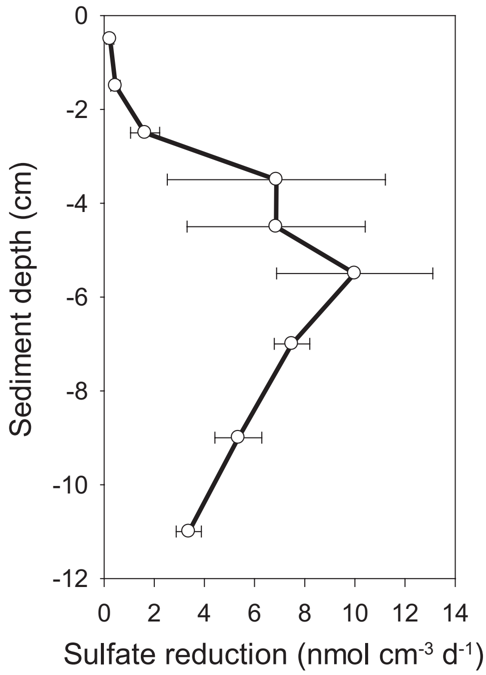


Fig. 4.16. Sulfate reduction rates in the sediment at 60 m depth in Young Sund during August 2007.

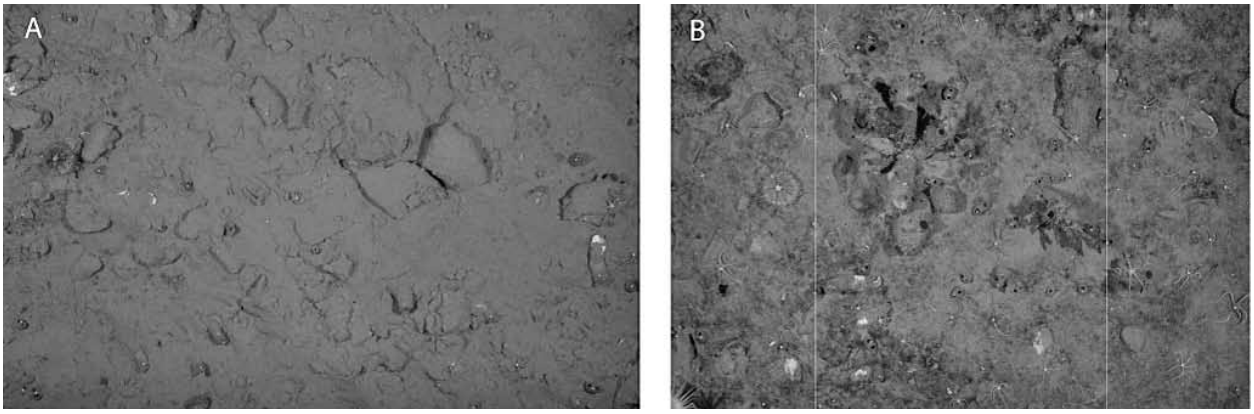
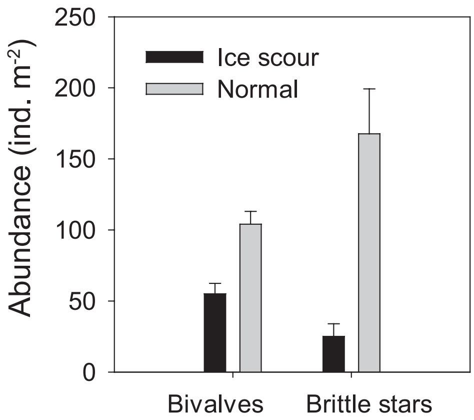


Fig. 4.17. Photos showing the impact of scouring ice on the sea floor (A) at 30 m depth compared to normal conditions (B).

Fig. 4.18. Abundance of bivalves and brittle stars estimated from photos at sites impacted by ice scour and normal sites at transect H2 at 30 m depth.



2007 data is the very high abundance of brittle stars found at several sites (Fig. 4.20).

Underwater plants

The annual growth of individual specimens of the brown macroalgae *Laminaria saccharina* can be estimated by measuring the length of the new leaf produced. In addition to measuring the length of the new leaf the wet and dry weight is recorded and the carbon content mea-

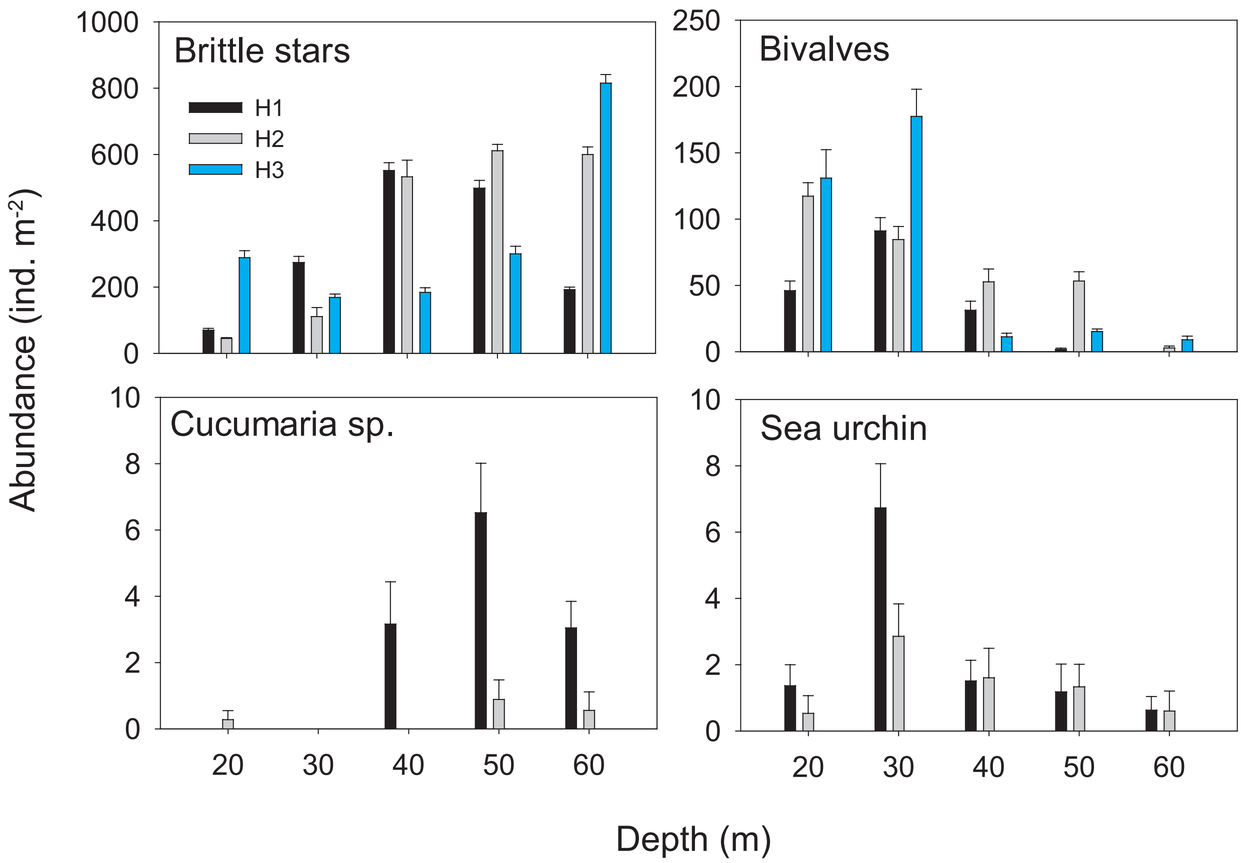


Fig. 4.19. Abundance of dominant benthic fauna in Young Sund estimated from photos of the sea floor taken in August 2007. Mean ± SE, n=10.

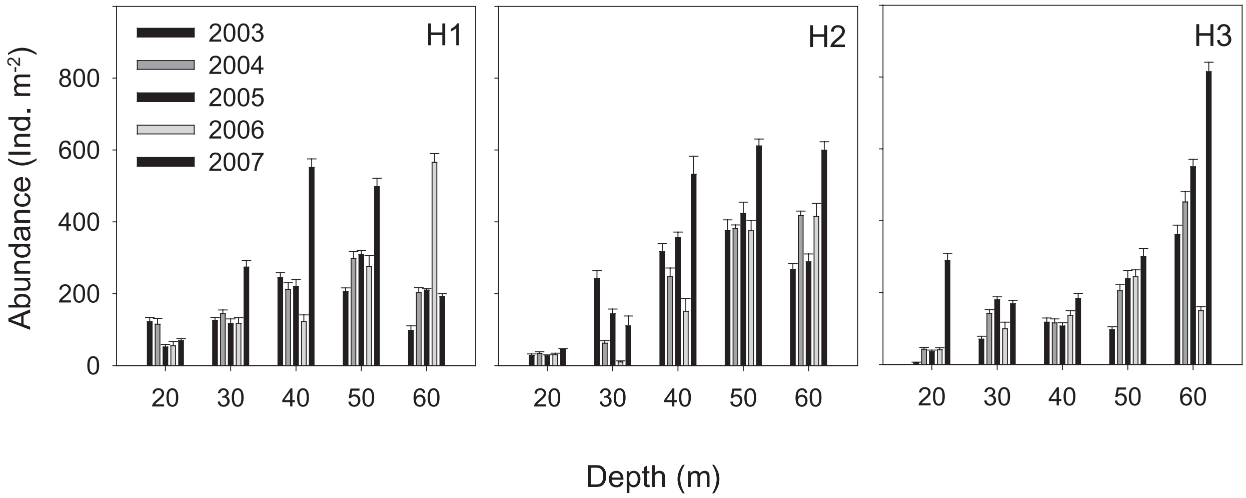


Fig. 4.20. Abundance of brittle stars estimated from photos (mean ± SE) from 2003 to 2007 at transects H1, H2 and H3 in outer Young Sund.

sured. The growth in cm and g C during the 2007 growth season is given in Table 4.7 together with data for 2003-2006. The growth recorded in 2007 was comparable to 2006 and most likely represent the "normal" annual growth rate after increased growth in 2003-2005 which was probably induced by an increased period of open water. Previous studies in the area have indicated that annual growth in this species is limited by light due to the very short open water period in summer (Borum et al. 2002).

4.4 Walrus and arctic char

The abundance of walruses at their haul-out location Sandøen was determined on 10 occasions from 25 July to 12 August. On average 16.6 ± 5.1 animals were observed with a range in observation from 0-41 animals. MarineBasic also collected specimens of arctic char. The specimens are kept frozen and will in time be used for analysis in long term changes in contamination level and isotopic composition.

5 Research projects

5.1 PolarVision – a pilot-study for an Austrian ecosystem research initiative in arctic Greenland

Wolfgang Schöner, Michaela Panzenböck, Karl Reiter, Bernhard Hynek, Andreas Fritz and Andreas Richter

The Austrian pilot study at Zackenberg was organised in three parts.

The first part was performed by members of the ZAMG (Central Institute for Meteorology and Geodynamics) in cooperation with University of Innsbruck (Institute of Meteorology and Geophysics) and Technical University Vienna (Institute of Geodesy and Geophysics), who started measurements of mass balance at Fröyaglacier (Clavering Island) aiming at estimating the contribution of glaciers to the freshwater supply to streams of the Zackenberg region. The activities were coordinated with the GlacioBasic monitoring programme at Zackenberg. Local climate measurements and available data from previous studies (e.g. measurements from a Swedish expedition in the 1930's) will be used to investigate the glacier-climate relationship. To quantify the spatial distribution of precipitation during winter a detailed GPR (ground penetrating radar) campaign is planned for the spring of 2008.

In addition to the glaciological investigation, sampling for estimation of the microbial activity on glaciers was performed at Fröyaglacier in 2007. Within the frame of a PhD study, data from Greenland will be compared (diversity, activity, abundance) to other sites in the arctic and antarctic regions. Sampling at Fröyaglacier includes one transect with shallow ice coring and surface near air sampling.

The second set of activities concentrated on the vegetation. The VEGMON working-group (University of Vienna) explored the different vegetation-types in the area, focusing on the usability of the summits around the station for monitoring activities in the frame of the international GLORIA project (Global Observation Research Initiative in Alpine Environments, www.gloria.ac.at). The aim of GLORIA is to establish and maintain a long-term observation network to obtain standardised data of biodiversity and vegetation patterns on mountain biota at a global scale. Its purpose is to assess risks of biodiversity losses and the vulnerability of high mountain ecosystems under climate change pressures.

Finally, the third part of the pilot study was carried out by members of the University of Vienna and focused on dissolved organic carbon (DOC) quantity and quality in streams and lakes in the area. As expected, glacier creeks exhibited the lowest DOC concentrations (0.28-0.78 mg C l^{-1}), while tundra creeks and small streams (1.63-1.88 mg C l^{-1}) and small lakes (1.97 to 2.46 mg C l^{-1}) had higher C concentrations. The fluorescence indices (FI 450/500) clearly showed a decreasing amount of terrestrial carbon (humins and humic acids) from lakes (1.62 ± 0.01) to glacier creeks (2.32 ± 0.13). Several experiments were conducted to study the degradability of various organic carbon sources (soil waters of different origins and to plant leachates) at different temperatures and nutrient additions, as well as after UV exposure.

5.2 Effects of manipulations of local climate on carbon dioxide exchange and plant performance in two high arctic heaths

Anders Michelsen, Kristine Boesgaard, Marie Arndal, Mikkel P. Tamstorf, Niels Martin Schmidt, Kristian Albert and Helge Ro-Poulsen

In order to clarify the effects of climate on carbon balance and plant performance in widespread high arctic vegetation types, effects of ecosystem manipulations have been investigated from 2004 to 2007 in two heath types at Zackenberg, a *Salix arctica* and a *Cassiope tetragona* dominated heath.

In each of the two heath types, plant cover development, phenology and gas exchange has been followed through the growing season in 25 plots of 1 m^2. The treatments consist of plastic tents which increase the soil temperature by 1.0 ºC in order to simulate slightly increased summer temperature, snow removal and addition treatments which prolong and reduce the growing season length by 3-8 days and 1-4 days, respectively, a 50% shading treatment which simulates denser cloud cover and reduces soil temperature by 2.0 ºC, and non-manipulated control plots.

Through the growing season of 2007, normalized differential vegetation index (NDVI, a measure of plant cover), plant phenology, soil moisture and temperature and CO_2 exchange between the ecosystem and the atmosphere was measured in all plots. As plant cover is sparse and variable in the two heath types, NDVI did not differ consistently between treatments, although it demonstrated the increase in plant cover at the onset of the growing season. Also soil moisture content measured in the entire 0-7 cm top soil generally did not show clear responses to treatment, although effects such as drying of the soil surface may take place without detection by the method used in the study. As detailed data on plant responses such as flowering and leaf nitrogen content in earlier years were presented in the annual report of 2006, we focus here on some of the effects on gas exchange.

The preliminary results from the *Cassiope* heath in the growing season of 2007 show that the manipulations tended to affect both plant photosynthesis and respiration from plants and soil, measured in transparent and dark plexiglass chambers respectively, installed on permanent bases in each plot. The gross ecosystem production was increased by 28% in warmed plots compared to un-manipulated control plots, across the growing season. Hence, the plants are able to benefit from the higher temperature, and will increase their cover and biomass with time if summer warming persists, leading to denser vegetation and higher above ground carbon storage. However, the increased carbon gain by plants in warmed plots was partly counteracted by a 18% increased carbon loss from the ecosystem across the growing season, due to increased plant and soil respiration.

The net ecosystem production (NEP), presented in Fig. 5.1, represents the net amount of carbon stored by the ecosystem, i.e. the difference between gross ecosystem production and ecosystem respiration.

During the growing season, the *Cassiope* heath is a net sink of carbon, with higher sink strength in late July and in August (Fig. 5.1). Warming and shading increased mean growing season NEP by 76% and 139% respectively, compared to control, while changed length of growing season had less impact. Hence, warming occasionally led to higher ecosystem carbon gain in the growing season because photosynthesis increased more than ecosystem respiration. Shading had an even more pronounced effect on NEP, but this was because ecosystem respiration was reduced while photosynthesis was unaffected. These results demonstrate a tight temperature control of carbon dioxide exchange in two high arctic heath types. Future analyses of gas exchange at leaf level will show how changes in growing season length, summer temperature and incoming light affect plant performance in more detail.

5.3 The effect of species composition on below ground carbon turnover and greenhouse gas exchanges in a continuous fen

Lena Ström and Torbern Tagesson

Changes in vegetation composition and carbon balance such as increased emissions of CH_4 and CO_2 have been reported from sub-arctic and arctic areas (Oechel et al., 1993; Svensson et al., 1999; Christensen

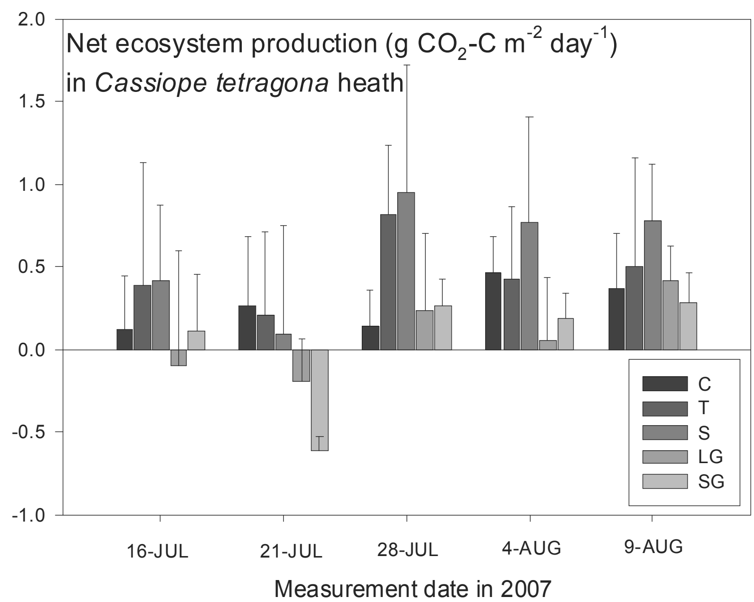


Fig. 5.1 Net ecosystem production (in g CO_2-C m^{-2} day^{-1}) in Cassiope tetragona *heath during the growing season of 2007. The heath has been subjected to five experimental treatments simulating climate change since 2004. Treatments were C: Control, T: Increased temperature, S: Shading, LG: Prolonged growing season and SG: Shortened growing season. Means ± standard error, n=5. By convention, net C uptake by the ecosystem is positive while net C fluxes out of the ecosystem are negative.*

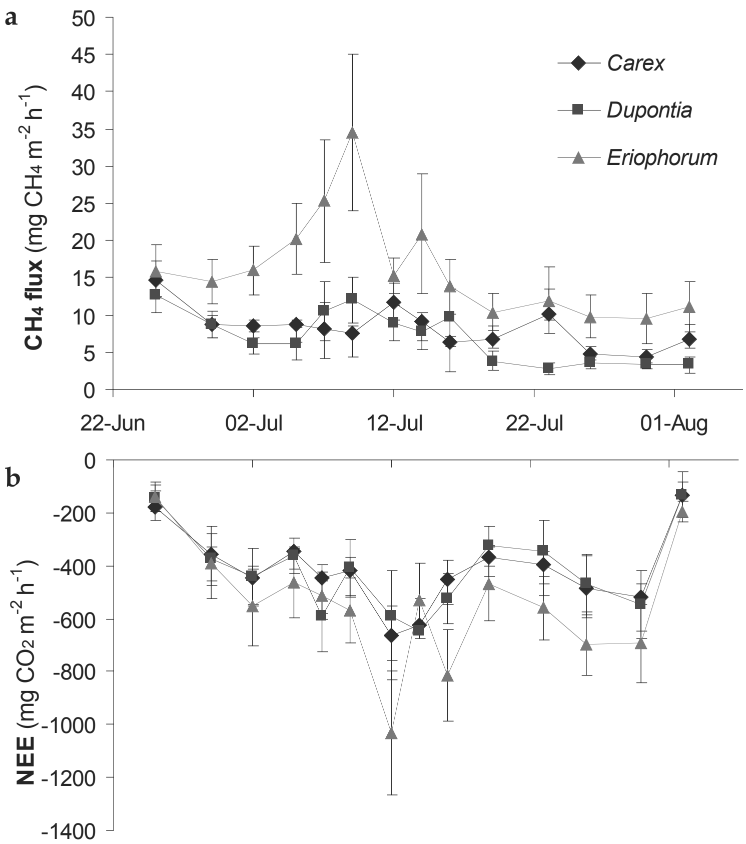
et al., 2004; Malmer et al., 2005, Johansson et al., 2006). These changes are believed to be a consequence of climatic warming resulting in permafrost degradation, a deepening of the active layer and often in a shift in plant composition or productivity (Christensen et al., 2004). In wetlands plant composition and productivity have a direct and often species-specific effect on CO_2 dynamics through photosynthesis and respiration (Ström and Christensen 2007). In addition presence and species composition of vascular plants can affect CH_4 exchange between wetland ecosystems and the atmosphere, because plants affect important aspects of CH_4 dynamics, e.g., production, consumption and transport (Joabsson et al., 1999; Ström et al., 2003, 2005, Ström and Christensen 2007). Furthermore, several environmental variables, with a presumably high dependence on permafrost depth, such as soil temperature and depth of water table have been identified as controls of methane production and ultimately of net CH_4 emission (e.g. Torn and Chapin 1993; Waddington et al., 1996, Ström and Christensen 2007).

It is of vital importance to understand how the fluxes of CH_4 and CO_2 in arctic areas respond to environmental variables and how individual vascular plant species affects components of the carbon cycling in wetland ecosystems. This will in future promote an increased understanding of the possible feedback mechanisms that vegetation responses or changes in species composition might impose on the global climate and future climatic change. Thus, the main objective of this study was to investigate the species-specific effects of frequently occurring sedges (*Eriophorum scheuchzeri*, *Carex subspathacea* and *Dupontia psilosantha*) on the fluxes of CO_2 and CH_4 and the substrate availability for methane producing bacteria. To pinpoint the effect of vascular plant composition the experiments where carried out in a continuous fen part of Rylekærene, situated within the Zackenberg valley, with little variation in environmental conditions, e.g. water table and active layer depth and soil temperature.

Simultaneous measurements of the fluxes of CO_2 (SBA-4, PP Systems, UK) and CH_4 (Fast Methane Analyzer, Los Gatos Research, USA) were performed at 3 to 4 day intervals using a closed chamber technique on plots dominated by *Eriophorum*, *Carex* or *Dupontia*. Net Ecosystem Exchange (NEE) was defined as ecosystem exchange of CO_2 under light conditions, respiration as exchange of CO_2 after darkening of the chamber and photosynthesis was calculated as the difference between NEE and dark respiration. The pore water concentration of labile substrate (e.g., organic acids such as acetate) for CH_4 production was analysed using LC-MS.

The results that are currently in the process of being analysed show clear species-specific effects on primarily CH_4 emissions, with higher emissions from *Eriophorum* dominated plots throughout the season (Fig. 5.2a). NEE measurements indicate that plots dominated by the three species acts as sinks for atmospheric CO_2 throughout the measurement period. *Eriophorum* dominated plots tend to have both higher rates of photosynthesis and respiration, however still resulting in an NEE that indicates a higher CO_2 uptake in these plots that in plots dominated by the two other species (Fig. 5.2b). The analysis of organic acids in pore water shows a much higher concentration of acetate (has previously been shown to be a substrate of major importance to CH_4 producing

Fig 5.2. The flux of CH_4 (panel a) and the Net Ecosystem Exchange (NEE, panel b) of CO_2 measured on plots dominated by Eriophorum scheuchzeri, Carex subspathacea *or* Dupontia psilosantha *in a continuous fen part of Rylekærene.*



bacteria in Rylekærene, Ström et al. 2003) in *Eriophorum* dominated plots, indicating that one of the drivers of the higher CH_4 emissions is increased substrate availability for methane producing bacteria in these plots. Presumably *Eriophorum* has a higher rate of root exudation of labile carbon compounds that can be fermented into acetate than the two other studied species. The collected data and materials will be further analysed and processed and additional results and conclusions will most likely follow.

In conclusion, species composition has a major impact on the fluxes of both CH_4 and CO_2 in the continuous fen area. Recent years has indicated a progressive drying of the entire fen area that may ultimately result in a species shift. As indicated by the results presented above the outcome of this species shift can have major implications for the greenhouse gas budget of the fen ecosystem.

5.4 The influence of snow and ice on the winter functioning and annual carbon balance of a high-arctic ecosystem (ISICaB)

Niels Martin Schmidt and Mikkel P. Tamstorf

During the period 28 August to 30 October 2007, the Zackenberg research facility was extraordinarily manned with personnel from the IPY project ISICaB. The project is funded by the Commission for Scientific Research in Greenland (KVUG) and by the Danish Environmental Protection Agency. The main objective of ISICaB is to examine the influences of ice and snow on the functioning of the terrestrial, limnic and marine compartments of a high-arctic ecosystem. Specifically, ISICaB focuses on two overall perspectives, namely (i) How does snow and ice cover impact the spatio-temporal distribution and functioning of selected faunal and floral components from the terrestrial, limnic and marine environments during winter?, and (ii) How does the winter season affect the annual carbon budget and net feedback of carbon gas fluxes to/from the atmosphere?

During the autumn season 2007, ISICaB focused on the terrestrial and limnic compartments. Hence, besides prolonging the ordinary Zackenberg Basic monitoring season, new methodologies and equipment were implemented and additional measurements conducted until late October.

ISICaB will resume its activities at Zackenberg in March 2008 with initiatives within the fields of terrestrial, limnic and marine ecology. The project will be fully reported in the ZERO Annual Report 2008.

5.5 Effects of climate change on soil microarthropod diversity and ecological function

Heidi Sjursen Konestabo and Anders Michelsen

The aim of this study is to investigate environmental change responses of soil microarthropods and the impact on their community structure. The rate of litter decomposition is influenced by temperature and moisture, as well as by biotic factors such as the composition of the soil fauna. Soil fauna can both directly and indirectly influence the rate of litter decomposition and mineralisation by fragmentation and dispersal of detritus particles, and by grazing on microbial biomass. The soil fauna generally consists of microarthropods, insects and annelids. Soil microarthropods are dominated by mites (Acari) and springtails (Collembola), which account for about 90% of the microarthropods in most soil systems. Together with protozoans, nematodes and other small soil fauna, the microarthropods make up a food web of several trophic levels, and are especially important in the Arctic, where there are few or no earthworms.

In 1996, an experiment with water application to the soil weekly during the growing season, as well as two years of N or P addition, was established in a semi desert on a dry gravel terrace adjacent to the river delta banks of the Zackenberg River. Another experiment was started in 2004 in a *Cassiope tetragona* and a *Salix arctica* heath with treatments of warming (plastic greenhouses), increased cloud cover (shading nets) and changed growing season length (snow cover removal or addition). In 2007, plant and soil samples were taken from these three experiment sites for soil fauna quantification and identification, and for measurements of nutrient content and microbial biomass. Also, 10 samples measuring 6 cm Ø, to a depth of 3 cm, were extracted from an area dominated by *Dryas* sp. adjacent to the *Cassiope tetragona* heath, for extraction of live Collembola to be used in laboratory experiments.

All soil fauna samples were brought to the University of Oslo, where living soil fauna was extracted using a temperature gradient controlled funnel system. Specimens for quantification and identification were extracted into a mixture of ethanol and benzoic acid, and stored for further analysis. Specimens for use in laboratory experiments were extracted onto moist plaster of Paris and hand sorted. Plant and soil samples for measurements of nutrient content and microbial biomass were prepared in the Zackenberg field laboratory. Plant material was sorted and dried, and nutrients from the soil were extracted with and without preliminary fumigation with chloroform to dissolve microbes. All soil extracts and dried plant material was brought to the University of Copenhagen for analysis of N, P and C contents. The effects of the different treatments on the microarthropod community and the nutrient status of the soil and plants will be examined.

5.6 Mapping long-distance migration in two Arctic seabird species

Carsten Egevang and Iain J. Stenhouse

The main aim of this study is to track the long-distance migration of two high-arctic breeding seabird species, the Arctic Tern *Sterna paradisaea* (ARTE) and the Sabine's Gull *Larus sabini* (SAGU) (Fig. 5.3). By attaching small data loggers (which record ambient light level and thereby archive daily geographical position) to breeding birds in 2007, and retrieving these in 2008, a full year of migration can be tracked from the breeding colony in Northeast Greenland to the presumed wintering areas between South Africa and Antarctica.

Fig. 5.3. A Sabine's Gull in one of the breeding habitats on Sandøen 2007. Photo: Carsten Egevang/ ARC-PIC.COM.

Fieldwork was conducted over the period of 12 July to 5 August, 2007, at Sandøen at the mouth of Young Sund approximately 30 km southeast of Zackenberg Research Station. Sandøen is approximately 1 km long by 0.3 km at the widest point, and peaks at only 2.5 meters above sea level at high tide. The habitat consists mostly of fine sand and gravel, but a raised section in the centre of the island has sparse vegetation, mostly willow (*Salix* sp.).

Fifty geo-locator data loggers were attached to adult ARTEs and 30 to adult SAGUs, between 16 and 27 July 2007, during their incubation period. Each logger (1.4 g) was attached to a darvic ring on the leg of the bird. Total mass of the logger, darvic ring, tape, and cable tie equaled 2.0 g – approximately 2% of adult body weight in ARTEs and 1% in SAGUs. Birds were caught at the nest using "Kieler traps" and further handling of the birds was conducted in a large tent. In addition to the attachment of data loggers, the biometrics of each bird were recorded (Table 5.1), as well as blood samples (for later genetic sexing of the birds).

ARTEs were found breeding over the entire area of the island, except within low lying patches with a potential risk of flooding. Breeding habitats included areas of pure sand, gravel, and the more vegetated parts of the island. A breeding population of 700-1000 pairs was estimated in 2007, based on counts of 1150 to 1500 individuals in six sub-sections across the island. A total of 109 nests were included in study plots.

Most SAGU nests (approx. 90%) were located among ARTE nests on the raised, central part of the island, where there was little risk of flooding. A breeding population of 60-65 pairs of Sabine's Gulls was estimated in 2007, with 56 nests actually found. Based on 60 pairs, the overall breeding density of SAGUs on Sandøen (0.272 km^2) was 220 pairs per km^2. Within the central, raised part of the island (0.068 km^2), however, where most SAGU nests were located, breeding density reached 780 pairs per km^2.

The average clutch size of ARTEs in 2007 was 1.4, with no 3-egg clutches observed (Table 5.2). The first ARTE eggs hatched on 31 July. In contrast, SAGU nests contained 1-3 eggs, with an average clutch size of 1.9 (Table 5.2). The first SAGU eggs were observed hatching on 25 July, but this was several days ahead of all other SAGU nests.

The median hatching date for both species was around 3-5 August. Unfortunately, this coincided with a series of severe weather systems (including gale force winds and torrential rains) which prevented us from checking nests daily, and resulted in both flooding of nests and high egg and chick mortality. Of 84 ARTE eggs, 45 did not hatch due to predation or weather conditions (Table 5.3), while 24 of 102 SAGU eggs failed to hatch (Table 5.3). Only eggs from nests with a negligible level of disturbance (from researchers) were included in this estimate of egg survival.

Of 59 ARTE nests (in plots with negligible disturbance), 21 (35%) were presumed to be still active at the last nest check on 4 August. Of the known 56 SAGU nests, 25 (45%) appeared to be still active on 4 August. Continued severe weather conditions between 4 and 6 August, however, caused further extensive flooding across much of the island and no doubt increased egg and chick mortality considerably in both species.

Over the course of the fieldwork, ARTEs were observed to display several different food items, mainly small fish (likely polar cod) of approx. 8-10 cm, but also large crustaceans was observed on a few occasions. ARTEs were also observed plunge diving in open water close to the island, especially in the area immediately to the south of the island, which appeared to have the strongest ocean currents.

SAGUs were also observed plunge diving in open water close to the island, either together with ARTEs or in (almost) exclusive flocks of SAGUs. During capture in early to mid-incubation, one SAGU regurgitated a single food load, which included approx. 150 food items, all small (0.5 cm) amphipods. Another captured SAGU regurgitated a partly digested fish of unknown species, estimated to be of a size of 10-15 cm. During our entire time on the island, SAGU faeces had a distinctly fishy odour, suggesting that they are reliant on marine resources throughout the breeding season. In late incubation and around hatching, SAGUs were observed foraging in shallow water, particularly along the eastern shore of the island. In this area, birds (possibly in pairs) focused their attention on a specific stretch of shoreline (approx. 20-25 m) from which they drove off other intruding SAGUs.

While predation risk to adult individuals of the two focal species was restricted to the occasional visit by a Gyrfalcon, egg loss to predation was common and involved several predatory species. At least one Arctic fox had access to the island when the fjord was ice-covered and even after sea ice break-up, when loosely packed ice floes formed enough of a bridge for foxes to reach the island. We observed predation by an Arctic fox on several occasions. The fox appeared to focus its search on Common Eider nests, but paused to take ARTE and SAGU eggs from nests that it found along the way. Eggs were either eaten at the nest location or buried nearby. The fox exhibited what appeared to be an extremely high rate of

	Arctic Tern (SD)	Sabine's Gull (SD)
Tarsus (mm)	16.31 (0.702)	33.57 (1.653)
Head & bill (mm)	71.64 (2.634)	66.82 (2.484)
Culmen (mm)	31.59 (1.577)	26.01 (1.339)
Mass (g)	105.4 (6.50)	181.7 (13.27)
Wing (mm)	280.4 (5.38)	278.4 (7.76)
Bill depth (mm)	8.2 (0.42)	8.07 (0.47)

Table 5.1. Mean adult biometrics for Arctic Terns (n = 50) and Sabine's Gulls (n = 31) on Sandøen, 2007.

	Arctic Tern (SD)	*n*	Sabine's Gull (SD)	*n*
Clutch size	1.44 (0.50)	109	1.91 (0.68)	54
Length (L) all eggs (mm)	40.18 (1.78)	134	42.60 (1.87)	92
Width (W) all eggs (mm)	29.03 (0.75)	134	31.08 (1.10)	92
IEV all eggs (ml)	16.27 (1.24)	134	19.80 (1.99)	92
IEV A-egg (ml)	16.48 (1.30)	90	20.16 (1.84)	48
IEV B-egg (ml)	15.86 (1.00)	42	19.40 (2.05)	35
IEV C-egg (ml)	-	-	19.41 (2.39)	9

IEV: Internal Egg Volume=0.00048 L W^2

Table 5.2. Mean clutch size, egg size, and calculated egg volume for Arctic Terns and Sabine's Gulls on Sandøen, 2007.

	Arctic Tern	Sabine's Gull
Egg hatched	20 (24%)	37 (36%)
Did not hatch	45 (54%)	24 (24%)
Unknown fate	19 (23%)	41 (40%)
Total	84	102

Table 5.3. Apparent (until 4 August) hatching success of Arctic Terns and Sabine's Gulls on Sandøen, 2007. Number in parenthesis lists the percentage of total eggs included in the study.

nest detection in the relatively dense colony. A study plot which included 27 randomly found ARTE nests was reduced to only 7 active nests within a period of 24 hours, due entirely to fox depredation.

Throughout the study period, the island was visited frequently by avian egg predators. Glaucous Gulls, Arctic Skuas, and Long-tailed Skuas were observed on the island on a daily basis. Common Ravens were also seen occasionally on the island, although this species was mainly observed at the walrus haul-out, and appeared to focus mainly on eating walrus faeces.

The 2007/2008 geo-locator study at Sandøen is a joint venture of the Greenland Institute of Natural Resources, the National Environmental Research Institute in Denmark, and the British Antarctic Survey. This study on ARTE migration has been adopted by the CAFF seabird group and is part of a larger coordinated effort, with parallel research projects currently being carried out in Iceland and in Alaska.

5.7 The breeding system of sanderlings in Zackenberg: single- or double-clutching? And what are the consequences?

Jeroen Reneerkens, Koos Dijksterhuis, Joop Jukema, Hans Schekkerman and Ingrid Tulp

Sanderlings are worldwide common shorebirds on almost every temperate and tropical beach that remains ice-free in winter (Van de Kam et al. 2004). The species breeds on the circumpolar tundra. Next to high arctic areas of the Canadian archipelago west of Ellesmere Island and the Taimyr peninsula of Siberia, high densities of breeding pairs occur in northeast Greenland (Cramp 1998). In Zackenberg, it is with an estimated 70-90 breeding pairs the second most common species (Hansen et al. 2007, see also section 3.3 this report). Despite the common occurrence of sanderlings in NE Greenland and in High Arctic regions elsewhere, much of the breeding biology of the species is still unkown.

Sanderlings in the Canadian Arctic have been supposed to be double-clutching, a breeding system in which mates of a pair of birds divide incubation between clutches that are laid in rapid succession (Parmelee and Payne 1973). This conclusion was based on 24 hr observations at one nest and repeated visits at nine other nests. In all these occasions always a single incubating sanderling was found. In addition, examination of the ovaries of two dissected sanderlings during the incubation period indicated the laying of eight eggs (two complete clutches) in rapid succession. A later study in NE Greenland however found only cooperating pairs of incubating sanderlings (Pienkowski and Green 1976), in contrast to previous studies. The only other published study to the breeding system of sanderlings, after those in the 1970's, is that of Tomkovich and Soloviev (2001) in northern Taimyr, Siberia. They observed both cooperating pairs and solitary incubating birds (Tomkovich and Soloviev 2001) and suggested that some, but not all, sanderlings that reproduce in Siberia may double-clutch. Based on preliminary observational data, it was concluded that such a mixed strategy may occur in the breeding population in Zackenberg as well (Piersma et al. 2006; Meltofte 2001, 2004).

The high breeding densities of sanderlings in Zackenberg make it an unique place to gain more knowledge about the breeding system of sanderlings. We used Passive Integrated Transponders (PIT's) and thermologgers (Tiny Tags) in nests of sanderlings that we individually colour-marked. The PIT's indicate which individual bird is incubating (Fig. 5.4) and when. The thermologgers indicate when and how much a clutch is being incubated but not by which individual. This way we attempted to get more insight in the time spent incubating on sanderlings nests to find out whether the nests were incubated by one or two adults and how pairs divide incubation duties.

Between 5 June and 24 July we daily walked the tundra near Zackenberg research station (area 1a) to look for nests and broods of sanderlings. Incubating birds were trapped on their nest and applied with unique colour-ring combinations on their tarsi. As part of the colour-ringing scheme one of the colour-rings is extended (a 'flag', Reneerkens and Koomson 2008). We glued PIT's to those flags. Nests were fitted with a PIT detecting antennae loop (Fig. 5.5) attached to a datalogger with a 4 m cable. The dataloggers were programmed such that every minute the time and identity of a sanderling applied with a PIT tag was recorded.

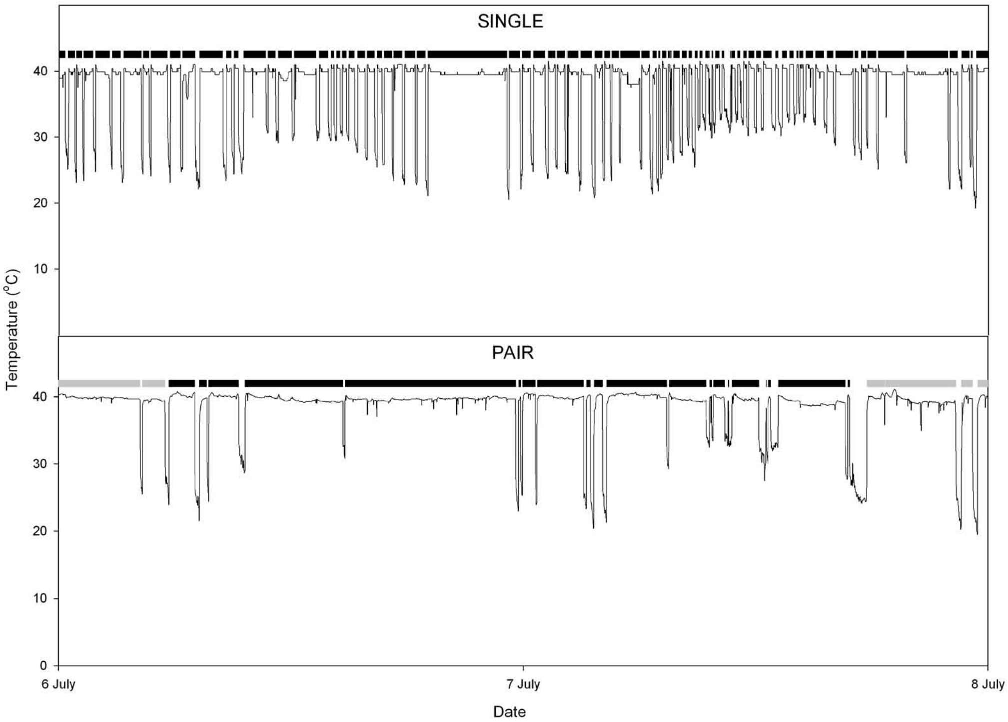


Fig. 5.4. Nest temperatures and attendance during two days of a single incubating sanderling (top panel) and a pair (lower panel). The nest temperatures (thin solid line) indicates the presence of a bird at the nest (temperature of approximately 40 °C indicates an incubating bird at the nest, temperatures lower than that indicate periods when the nest is unattended). The bars on top indicate whether a male (black) or a female (grey) was incubating.

The small waterproof box containing datalogger and battery as well as the connecting cable were dug into the ground in attempt to not increase detection chances of the nests by predators. Additionally, we placed a small temperature logger in the nestcup right between the eggs such that the logger touched the birds' brood patch during incubation. Temperature was logged every minute so that the presence (temperature stable around 40°C) or absence (temperature considerably lower than 40°C, i.e. ambient temperature) of an incubating bird was detected.

In total we found 37 sanderling nests (also see section 3.3 this report). Of 27 nests the incubation behaviour of the attending bird(s) could be studied with enough detail to find out whether one or two adults were incubating. On 22 nests a pair was incubating, the other five nests were incubated by a single bird (three males, two females based on molecular analysis of the sexes and confirmed by biometric data). This is the first evidence that a mixed strategy occurs in sanderlings that breed in Greenland, at least in 2007 in Zackenberg. Of 20 nests we obtained sufficient and valuable enough data from the temperature loggers (often in combination with a PIT) to calculate the percentage of time that nests were being incubated or left unbrooded during foraging bouts of the parents. The percentage incubation for clutches of pairs was 87% (range: 53-95%), whereas that of single incubating sanderlings was only 75% (range: 59-86%). The nest of a pair that was incubated for only 53% of the time is an unexplained outlier. Its little nest attendance is mainly caused by two very long periods of absence off the nest, which we can not explain. It is clear that single incubating sanderlings, that are probably double-clutching birds, spend much less time incubating their eggs compared with pairs. Both partners of a pair have time to forage when their partner is incubating the eggs, whereas for single incubating sanderlings every minute spent foraging is a minute lost to

Fig. 5.5. The incubating sanderlings easily accepted the antenna loop of the PIT-system and continued incubation. This sanderling was a male, single incubating bird of which some data are depicted in Fig. 5.4.

incubation. Single incubating sanderlings limit the cooling down of their clutch during periods off the nest, by having very regular, but relatively short, foraging bouts (Fig. 5.4), which undoubtedly entails that single incubating birds have to work much harder to incubate a clutch to hatch and may be predestinated for birds in good condition (e.g. parasite-free and with enough energy stores left after arrival on the breeding grounds) only. It is unknown whether single-incubating sanderlings have a longer incubation period compared with paired incubating sanderlings or if they have a strategy to compensate for the less time they spend on their nests (e.g. maintaining a higher egg temperature during incubation). Future analyses of nest attendance data will focus on the relation between ambient temperature and incubation for single and paired incubating sanderlings and might show the possibilities and constraints of sanderlings to incubate clutches on their own and on how pairs divide incubation time between the partners.

5.8 Camera trapping of arctic fox (*Alopex lagopus*)

Ditte K. Hendrichsen, Nette Levermann and Safi K. Darden

Monitoring of arctic fox (*Alopex lagopus*) dens in the Zackenberg valley was initiated in 1995 as part of the BioBasic monitoring programme. Currently 15 dens are known from the area, of which at least seven are breeding dens. Dens are monitored weekly during the summer season to establish the minimum number of pups in each den, and thus to give an estimate of pup production in the Zackenberg valley in consecutive years. In addition, all random observations of foxes throughout the season are recorded as part of the monitoring programme.

The monitoring has shown that there is considerable variation in the number of pups between years. Between 1995 and 2006, breeding was recorded in eight years, with the number of pups ranging from seven pups in three dens in the year 2000 to 18 pups in five dens in the year 2004. Years with no registered breeding attempts have occurred every two to three years. No breeding sometimes coincided with a low or decreasing lemming phase, but the pattern has not been consistent (Kyhn 2006).

Prey availability varies profoundly over the year. Arctic foxes are resident in the Zackenberg area throughout the year and must be able to utilise multiple food resources and to switch between them during the course of the year. During winter, food is limited to muskoxen carcasses (*Ovibos moschatus*), ptarmigans (*Lagopus mutus*) and lemmings (*Dicrostonyx groenlandicus*). Lemmings and rodents in general are the primary food resource for arctic foxes through much of their range (Elmhagen et al. 2000), but the availability of lemmings at Zackenberg is limited by snow cover during the winter. During spring and summer other food resources become available as migrating birds arrive and start breeding, providing access to eggs and young, as well as to adult birds. The break-up of the sea ice also gives access to washed-up food items on the shore and the arctic char (*Salvelinus alpinus*) migrate through the Zackenberg River. Also, young arctic hares (*Lepus arcticus*) may be a potential prey resource. The timing and availability of these food resources differs within and between years and foxes must be able to display considerable behavioural plasticity to utilise them.

The aim of this study was to investigate the breeding success of arctic foxes and to establish the feasibility of using camera traps to monitor fox activity and pup production at Zackenberg. In addition, we wished to use the cameras to monitor the amount and type of prey brought to the dens by adult foxes. In early June, we therefore set up digital cameras on three of the known breeding dens. While two cameras were maintained at two of these dens through most of the study period, the third camera was moved between dens. A fourth camera failed early in the study period and was never used. Generally, the cameras turned out to be rather unstable and often the quality of the pictures was somewhat low. The cameras were Cuddeback Digital No Flash Scouting Cameras from Bossbuck.com. The cameras are triggered by heat-in-motion and can usually detect activity within a range of 9-15 meters. The cameras as well as their power source were contained in a sealed box preventing foxes from damaging them. Previous experience has shown that muskoxen can damage equipment left in the field, either by trampling on it, or by rubbing against it when shedding their winter fur. To prevent damage, cameras were therefore fitted inside 4 mm thick flamenco-lined aluminium boxes. Cameras were mounted on aluminium poles, and secured to the ground by wires (Fig. 5.6). Wires were frequently broken by muskox-en and had to be replaced.

The cameras were set up on top of the fox dens, with a good view of the main entrances. On the larger dens not all entrances could be covered with one camera, and in one case, den no. 1, an extra camera was set up in late June. Whenever possible, cameras were facing north, to avoid shadows on the pictures. Cameras were re-visited at 4-6 days intervals, more frequently in the beginning, to retrieve the pictures and change batteries. Foxes did not show any signs of being disturbed by the cameras, however, adult foxes responded to the presence of people on the dens and human activity was therefore kept to a minimum.

The cameras were mounted on the fox dens during a period of 48 days from June 6th to July 25th. After this time pups were only very infrequently using their natal dens and cameras were dismounted. Cameras were in use for a total of 2780 hrs resulting in 4042 pictures of foxes. The summer of 2007 was a good breeding year for the arctic fox with a minimum of 23 pups in four dens. Litter sizes were four, five, six and eight, respectively. The first pups were recorded on June 10th in den no 1 and on June 17th in den no 2.

In two of the dens, adult foxes were photographed while bringing prey to the dens. It was possible to identify 44% of the prey items brought back. The remaining prey items were either too small to be seen clearly, the fox was moving quickly or photographs were taken in poor light conditions. Presumably, foxes have also brought back prey which was not recorded on the photographs because of camera failure, the subject being out of the cameras range for motion detection at the time food was delivered or an event occurred in the one-minute inter-activation pause interval. Arctic char constituted a significant proportion of the prey items at both dens; 23% of all recorded prey events, or 52% of the identifiable prey (Fig. 5.7). The foxes are able to catch char in the river and fresh fish were seen on several pictures and were also observed on the den during one of the visits. Arctic hare also constituted a significant proportion, 25% of the prey identified, or 11% of the total prey. All the hares were young individuals, which had not yet changed to their white fur colour. Other identifiable prey items were lemmings and birds, constituting 21 and 2%, respectably, of the prey items. However, these groups took up a remarkably small proportion of the prey. It is likely that a large proportion of the prey that could not be identified belong to these groups. Cached food and eggs were not recorded, but may have been present amongst the unidentified prey, certainly foxes in Zackenberg are known to use both resources (Kyhn and Berg 2004).

Fig. 5.6. The setup of digital cameras on a fox den.

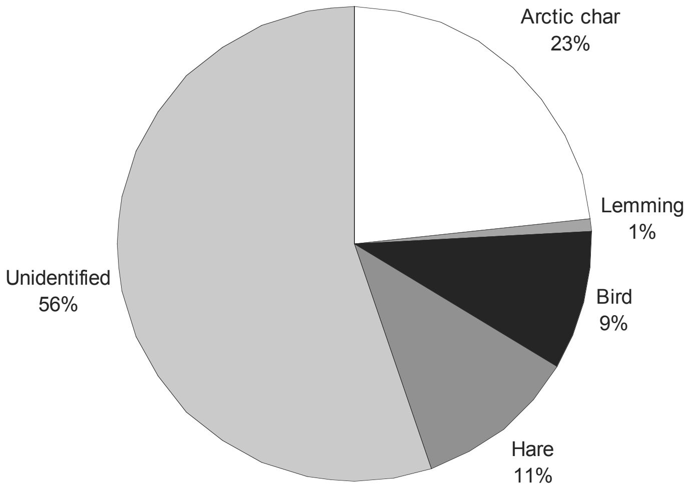


Fig. 5.7. The proportion of different prey items brought back to fox dens no 1 and 2.

The work was supported financially by the Aalborg Zoo's Greenlandic Grant, Bodil

Pedersen Fund, Torben and Alice Frimodt Fund, Aase and Jørgen Münters Fund and Brødrene Hartmanns Fund. In addition we would like to thank the BioBasic programme for assistance in the field, and the Department of Biology, University of Copenhagen, for technical support.

5.9 Studies of plant responses to UV-B radiation 2007

Kristian Albert, Kristine Boesgaard, Helge Ro-Poulsen, Teis N. Mikkelsen, Anders Michelsen and Niels Martin Schmidt

Effect-studies on ecosystem processes influenced by current levels of UV-radiation have been continued in already established plots (see Klitgaard et al. 2006). Additional experimental plots were established in one site in a *Cassiope-Salix* heath area on 27 July 2007 as a part of the BioBasic monitoring program. The site is outlined with five blocks with three treatments: Open Control, Filtered Control (Teflon) and UV-B reducing filters (Mylar). The vegetation consists mainly of *Vaccinium uliginosum* (19% cover), *Cassiope tetragona* (11% cover), *Salix arctica* (15% cover) and moss (36% cover) at the Zackenberg site. Chamber bases to facilitate net ecosystem gas exchange measurements will be established in 2008. The new plots are intended to be investigated with non-invasive methods only, and the long term monitoring program will be based on the experiences from previous studies in the Zackenberg area. No response measurements have been conducted yet at these sites, but initial measurements of vegetation cover and Normalized Differential Vegetation Index (NDVI, an index of vegetation cover) were performed. In 2008, it is planned to conduct measures of net ecosystem CO_2 exchange, photosynthetic performance (Chlorophyll flourescence), vegetation cover and NDVI. The potential of parallel studies in the similar plots established in Nuuk this year is obvious.

Studies at site 1, 2 and 3 (see Klitgaard et al. 2006) were continued with measurements of flourescence parameters, leaf C and N concentration, chlorophyll, and UV-B absorbing compounds in *Betula nana*, *Vaccinium uliginosum* and *Salix arctica*. In these sites the Maximal Photochemical Efficiency (Fv/Fm) and Performance Indexes (PI) (See Rasch and Canning 2005 for discussion of these parameters) were negatively affected by ambient UV-B radiation across season, especially on days with clear sky conditions, in all investigated species *B. nana* (see Fig. 5.8), *V. uliginosum* and *S. arctica* (data not shown). This is in line with the findings from previous years and these data are being included in a publication on the long term response to UV-B. Moreover, in parallel to

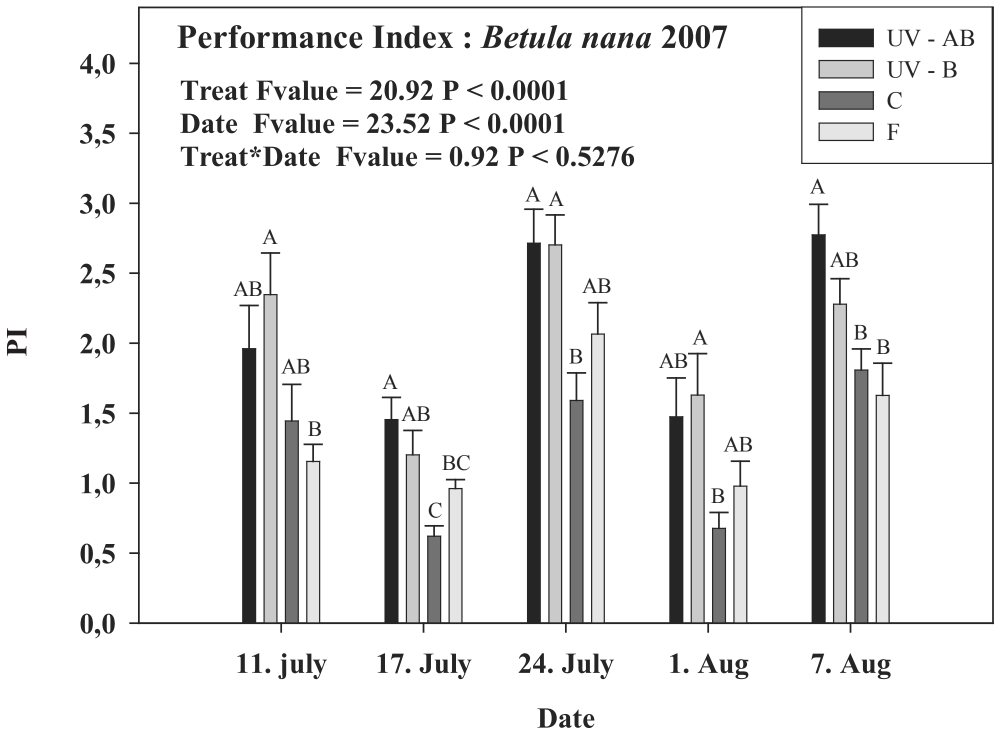


Fig. 5.8. Performance indexes of Betula nana to treatments: Open control (C), Filter Control (F), UV-B reducing Mylar filter (UV-B) and UV-AB reducing Lexan filter (UV-AB). Displayed are means and standard error. Variance analysis was used to test the effects of Treatments, Date and their interaction. Different letters indicate the treatment differences tested with the Tukey test on the individual days.

the higher UV-B radiation dose on site 2, these were more negatively affected by the ambient UV-B level than the leveling site 1. Again this year the diurnal responses of *B. nana* were measured and this confirmed that this species is sensitive to current UV-B fluxes (see Klitgaard et al. 2007 for discussion of this finding).

Additional plots of *Vaccinium* plants within chamber bases have now been exposed to the different treatments for three years without disturbance. In 2008 these plots will be thoroughly investigated and finally harvested.

5.10 Did vascular plants and bryophytes survive the last ice age in Scandinavia?

Kristine Bakke Westergaard and Tina Dahl

Glacial survival versus postglacial immigration of the Scandinavian alpine flora has been debated for more than 100 years, and has recently received increased attention with the development of molecular tools. Many vascular plant species occur disjunctly on both sides of the North Atlantic Ocean, but are lacking from areas east- and westwards. A subset also absent from the Alps, the so-called 'West-arctic' species, has been considered to provide the strongest evidence for local survival in Scandinavia throughout the entire Quaternary, or at least through the last glaciation. Bryophytes have never attained weight in this discussion, even though many of them are exceptionally hardy and therefore more likely as nunatak survivors.

To be able to detect general trends, we need to analyse various species, each represented by several populations and several individual plants from each population. We will carry out a comparative phylogeographic analysis of about 10 species of amphi-Atlantic vascular plants and bryophytes. We use and develop various molecular markers (AFLPs, cpDNA SNPs, and low-copy nuclear genes), phylogenetic analyses, genotype assignment tests, and coalescent-based simulations to test whether the Scandinavian populations originate from recent (post-glacial) cross-oceanic dispersal from the west, and/or whether they descend from long-term glacial in-situ survivors.

During one week at Zackenberg in early august 2007, we collected leaf material of *Carex nardina*, *Pedicularis flammea*, and *P. hirsuta*. In addition, the single known occurrence of *Sagina caespitosa* at Zackenberg known from a herbarium voucher collected by Bent Fredskild in 1991 was intensively searched for, but unfortunately not found. The genetic analyses of the vascular plant material have just started, and no results are ready so far.

We also collected cushions of the bryophytes *Hylocomium splendens*, *Sphagnum* sp., *Tomentypnum nitens*, *Cinclidium stygium*, *Cinclidium* spp., *Funaria arctica*, *Tortella tortuosa*, and *Aulacomium turgidum*, in addition to several bryophytes that was hard to determine in the field. The bryophytes are currently at the Museum of Natural History and Archaeology in Trondheim, Norway, for final determination.

5.11 Early Cretaceous climatic and biotic changes in the high latitudes of North-East Greenland

Peter Alsen and Jörg Mutterlose

The Cretaceous Period is generally characterised by green house climate. However, increasing evidence indicate that the Early Cretaceous differs from this generalised view. It appears that seasonal sea ice formed during this interval and possibly the poles were subject to glaciations. So far the majority of palaeo-climatic investigations have been undertaken at low latitudes. The present study includes relatively high palaeo-latitude data from the Wollaston Forland area in NE Greenland.

The Lower Cretaceous in NE Greenland is represented in small and scattered localities. The most extensive exposures of the sedimentary succession occur in the Wollaston Forland and are relatively easily accessible from the Zackenberg station. Based in Zackenberg a number of localities were visited within walking distance. Localities are situated at Stratumbjerg (Cardiocerasdal) in western Wollaston Forland and Rødryggen (south of Albrechts Bugt) in the northern Wollaston Forland.

The investigated succession belongs to the grey and red calcareous mudstones of the Albrechts Bugt Member and Rødryggen Member, respectively, of the Palnatokesbjerg Formation. These units were deposited in the early post rift phase after one of the most important Mesozoic rift events in the history of the East Greenland rift basin. During rifting a kilometre thick rift succession of deep marine conglomerates was deposited in half grabens of rotated fault blocks. In the post rift phase the fault blocks were fully submerged due to thermal contraction and fine grained, condensed mudstones formed a thin cover. The Albrechts Bugt and Rødryggen Members are characterised by relatively high carbonate content and high diversity and richness in fossils. This contrasts to the underlying black mudstone dominated succession poor in fossils. The studied succession thus represents a time of marked changes in the depositional environment and in the composition of the fossil fauna and flora in North East Greenland. These changes relate to changes in the palaeoceanography and the palaeo-climate. The studied fossil macrofauna and microflora includes exotic elements whose presence in NE Greenland appears totally out of place (Fig. 5.9). Their normal area of distribution lies in the Tethys, the palaeo-equatorial ocean in the Cretaceous. The observations support the hypothesis that a cold climate in the Early Cretaceous caused a palaeoceanographic situation where deep water was formed in the Arcitc Sea, creating an oxygenised bottom current flowing towards the south. This allowed a rich and diverse fauna and flora to inhabit the NE Greenland basin that was formerly a hostile anoxic depositional environment. In response, a surface counter current was formed dragging waters from the southern Tethyan Realm to the NE Greenland area to the north allowing the immigration of various faunal and floral elements thousands of kilometres to NE Greenland where they occur as exotic elements.

Sediment samples and calcite skeletons from belemnite fossils were sampled in narrow intervals throughout the succession and ongoing geochemical and micropalaeontological analysis is expected to provide more details to this palaeoclimatic and palaeoceanographic event in the Early Cretaceous.

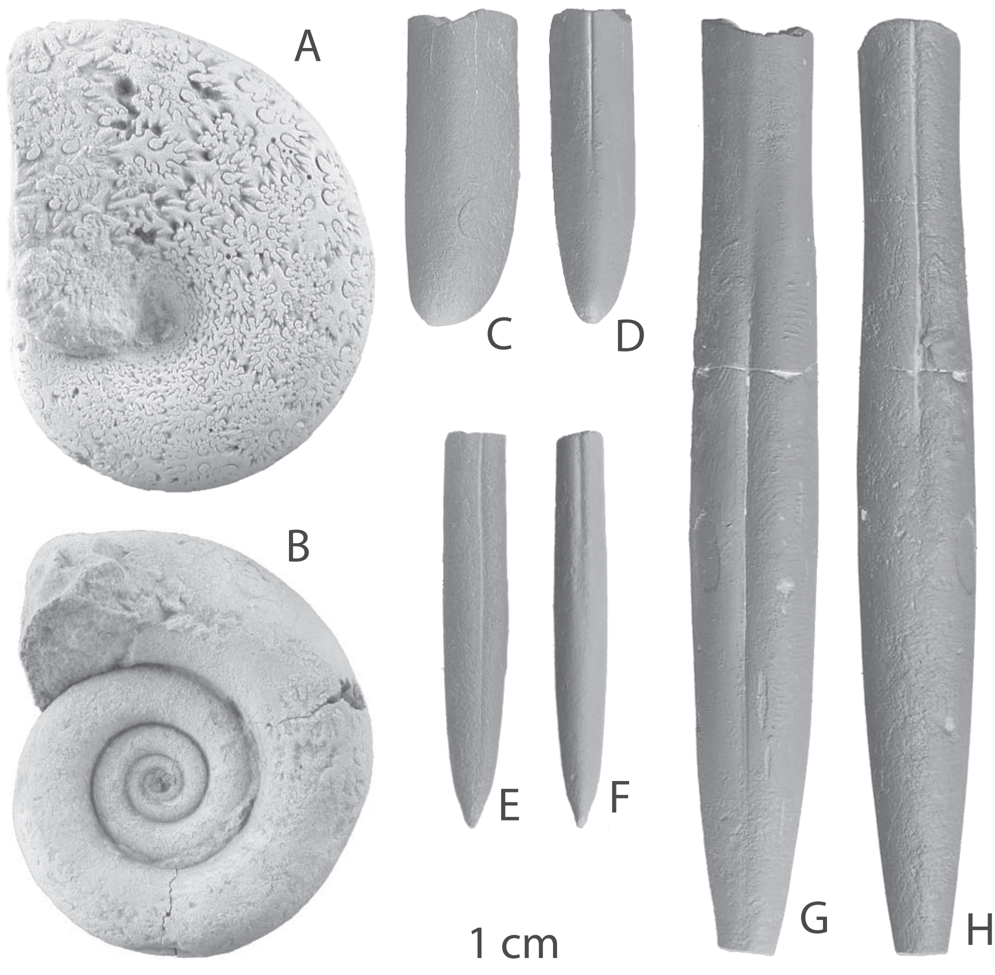


Fig. 5.9. Examples of exotic taxa of the fossil Early Cretaceous cephalopod fauna. A: the ammonite genus Phylloceras*, B: the ammonite genus* Lytoceras.*, C, D: lateral and dorsal views of a specimen of the belemnite genus* Duvalia*, E-H: lateral and dorsal views of two species of the belemnite genus* Pseudobelus.

5.12 GeoArk: Coast, Man and Environment in North East Greenland

Bjarne Grønnow, Bjarne Holm Jacobsen, Anne Birgitte Gotfredsen, Jens Fog Jensen, Aart Kroon, Morten Meldgaard, Jørn Torp Pedersen and Mikkel Sørensen

Based on pilot projects in 2003 and 2005, the GeoArk project conducted its first major field season in the Clavering Island area during the summer of 2007. The project received logistic support from the Zackenberg research facility.

The GeoArk-project was established in 2003 as an interdisciplinary research program exploring the dynamics of the High Arctic environment – climate, coasts, natural resources – and the cultural strategies applied by the native cultures of North East Greenland in order to cope with ever-changing environmental conditions. Researchers from SILA – The Greenland Research Centre at the National Museum of Denmark and The Greenland National Museum representing archaeology and from the University of Copenhagen (Institute of Geography and Geology and The Natural History Museum) representing natural sciences collaborate across disciplinary borders within the framework of the project.

During the International Polar Year (2007-2009) the GeoArk-project focuses on the era during which the inuit of the Thule Culture migrated into North East Greenland and formed a life in this high Arctic environment, from about 1400 AD to 1850 AD. In 1823, Europeans for the first and last time encountered inuit in this part of Greenland. The Thule Culture era provides splendid possibilities to elucidate a number of fundamental questions concerning relations between Man and environment:

Which environmental and cultural preconditions favoured the initial Thule Culture colonization of the High Arctic during the first part of the 15th century after probably more than 1500 years of desolation? And why did the Thule Culture in North East Greenland disappear during the first half of the 19th century?

Which were the key game species of the Thule Culture, and how were their distribution and availability linked to climatic fluctuations, sea ice conditions, snow coverage on land, and other dynamic environmental factors?

In which way and at which time did regional climatic changes, primarily in temperatures, precipitation and wind regimes, determine substantial changes in snow- and ice coverage, ice margins and *polynia* during the Thule era?

How are these critical and often non-linear environmental changes, including sea level changes, connected to the overall Holocene climatic changes as can be deduced from the Greenland ice cores and deep ocean sediments?

Summer 2007, the GeoArk-team concentrated its field work on the south coast of Clavering Island, where major concentrations of Thule sites are found and where optimal conditions for geomorphological and palaeoclimatic research in relation to these sites exist. Thus, the archaeological/zoological investigations included excavations of midden layers with preserved bones as well as extensive surveys of sites. The geographers conducted investigations of coastal geomorphology and retrieved cores from fresh water lake sediments as well as shallow coastal zones.

The yield of the field season is remarkable. The Thule winter sites of the area have been known since the Three Year Expedition in the 1930's, but the entire 'warm season' aspect of the settlement pattern were practically ignored creating a fragmentary picture of inuit life in the area. The GeoArk project now adds about 20 hitherto unknown spring and summer sites consisting of concentrations of tent rings and stone built shelters to the archaeological record of the south coast of Clavering Island.

As a result of the surveys a pattern has emerged: The inner coast to the west is characterized by the presence of quite small summer sites situated on alluvial terraces at river deltas. The central part of the south coast shows a complex coastal topography with several steep granite headlands and coves in which large winter settlements with up to 40 stone and turf built winter houses (Eskimovig and Dødemandsbugten) are situated. The outer coast to the east, along Gael Hamke Bugt, consists of long gravel beaches interrupted by a few, but very conspicuous basalt headlands on which very large warm season sites are situated. Sites like 'Blåklokkenæs', Daels Skær and Kap Breusing each hold up to 40 – 60 tent rings and shelters. Even if all these structures were not used at the same time, these sites definitely represent spring/summer assemblage camps, which were essential to Thule subsistence economy as well as to social life. We are now embarking on comprehensive analyses including the collected faunal material from these sites.

The geographic investigations during the 2007 field campaign included detailed mapping and descriptions of erosion and accumulation patterns due to geomorphological processes in coastal, lagoonal, lacustrian and nivation landscapes. Data on fossil soils, nivation sediments and sediments in lakes and lagoons were gathered on sites along the south coast of Clavering Island, including cores from lakes close to Thule settlements. The cores are now being analysed for climate and environmental indicators. Furthermore, soil samples from excavations of the turf covered culture layers at the Fladstrand site were taken in order to correlate archaeological and geomorphological phases. Particular interest is paid to environmental changes around the 'Little Ice Age', which culminated 300 years ago and which in part could have caused the decline of resources providing the basis of human settlement in the area. The data collected during the GeoArk project has a high resolution allowing detailed descriptions of these local and regional changes. Further work will be carried out during the field season of 2008.

Fig. 5.10. The ITACA² website.

5.13 ITACA² – Dayside aurora joint observations from Greenland and Svalbard

Stefano Massetti

The analysis of the all-sky camera data collected by ITACA-DNB during the 2006/2007 winter campaign, unfortunately confirmed the decrease of the instrument performance, which was initially detected in the past season.

Due to the weak intensity of the dayside aurora, which is produced by the precipitation of low energetic electrons (~100-200 eV) through the geomagnetic cusps, the sensitivity of the all-sky imager cannot drop below a determinate threshold otherwise the data recorded are useless for a scientific point of view. For this reason, the digital all-sky camera that equipped the ITACA-DNB station in Daneborg, was packed and shipped back to Italy for maintenance.

The instrument will be repaired or replaced with a new one, depending on the amount of the next financial support. Anyway, there will be no auroral monitor in ITACA-DNB observatory for the next winter seasons, namely, 2007/2008 and 2008/2009.

ITACA-DNB data quicklooks from previous campaigns, together with ITACA-NAL (Ny-Alesund, Svalbard) ones can be browsed on-line at the new web-server http://itaca2.ifsi-roma.inaf.it/ (Fig. 5.10). Upon request it is possible to have access to the original all-sky images, recorded at 427.8nm (blue line), 557.7nm (green line) and 630.0nm (red line), together with other data analysis products (for example: map projections, both in geographic and magnetic coordinates).

6 Disturbance in the study area

Jannik Hansen

Opening duration of the station

In 2007, the research station was open two months longer than usual; i.e. until 30 October. This account of disturbance covers the period until 3 September.

Surface activities in the study area

The number of 'person-days' (one person in the field one day) spent within the main research area, zone 1 (Table 6.1) was 148. The 'low impact area' 1b was visited a little more than average. The 'goose protection area', zone 1c, was visited only rarely, as in most previous years.

This season, the use of the all terrain vehicle (ATV) was along the designated roads to the climate station and the beach at the delta of Zackenbergelven. Few trips went beyond the climate station, along the designated road. All in all, the use of the ATV was in excess of the usual level.

Aircraft activities in the study area

This season, fixed-wing aircrafts landed and took-off 26 times, which is below average (Table 6.2).

226 helicopter slings were associated with an unloading operation of building materials for the extension to the mess house, while a single sling into Albrechtssletten transported equipment for a geological expedition. Apart from these, two passenger flights by helicopters took place in 2007, in connection with a visit by the organisation Nanok.

The helicopter slings unfortunately had to cross over the goose protection area 1c during the restricted period.

Research zone	May	June	July	Aug.	Total
1	15	41	45	47	148
1b	2	7	6	11	26
1c (20.6-10.8)		2	13		15
2	0	0	4	0	4
ATV-trips	1	6	3	0	10

Table 6.1. 'Person-days' and trips in the terrain with an All Terrain Vehicle (ATV) allocated to the research zones in the Zackenberg study area May –August 2007. Trips on roads to the climate station and the delta of Zackenbergelven are not included.

	May	June	July	Aug.	Total
Fixed-wing aircraft	2	8	10	8	26
Helicopter			226		226

Table 6.2. Numbers of flights with fixed-winged aircrafts and helicopters, respectively, over the study area in Zackenbergdalen May – August 2007. Each ground visit of an aircraft is considered two flights.

Discharges

Combustible waste (paper, card board etc.) was burned at the station, while other materials were sorted (glass, metal and other waste) and flown out of the national park.

In connection with the construction work, a considerable amount of packaging was burned. The materials were wood, card board and paper, amounting to approximately 1310 kg. In addition, plastic materials from packaging, amounting to close to 120 kg, were similarly combusted.

Water closets were in use from 1 July onwards. From here, all toilet waste was ground in an electrical mill and led into the river. Likewise, solid, biodegradable kitchen waste was run through a grinder mill, and into the river. The mill was in use until the end of the season.

Waste stored during May, June, July and August was treated with a total of c. 75 g of fly maggot killing agent, 'Vera-flue-safe'. The active chemical is cyromazine (N-cyclopropyl-1,3,5-treazine-2,4,6-triamine) in a concentration of 2%.

The total amount of untreated wastewater (from kitchen, showers, sinks and laundry machine) equalled approximately 1511 'person-days' during the ordinary field season (with further 173 'person-days' related to the extended field season), which is just under 25% more than average.

Manipulative research projects

The UV stress research project (see section 5.9) used varying UV filters on site 1 (UTM zone 27: 8264000 mN 512700 mE), site 2 (UTM zone 27: 8263800 mN 513000 mE) and site 3 (UTM zone 27: 82637700 mN 513000 mE) with *Salix arctica* and *Vaccinium uliginosum* (site 1 and 2) and *Betula nana* (site 3).

The same project investigated maximum influx at site 5 (UTM zone 27: 8264350 mN 512650 mE), looking at long term effects on the photosynthesis on *Vaccinium uliginosum*. Site 5 will run for the season 2008 as well, before being taken down. Site 4 was taken down and did not run in 2007.

From mid July to the end of August, manipulation UV-filters were set up at two sites, for BioBasic monitoring in subsequent seasons. Likewise ITEX-sites were set in two sites, for monitoring in the coming seasons (See section 3).

For the fourth season, shade, snow melt and temperature was manipulated at two sites, each with 25 plots. UTM zone 27: 8264733 mN 513460 mE and 8264984 mN, 513717 mE (see section 5.2).

Take of organisms and other samples

27,089 land arthropods were collected during the season, as part of the BioBasic programme (see section 3.2). For the same programme 4 l of filtered water samples were collected from two small lakes, to analyse the composition of the zooplankton fauna (section 3.5).

The UV stress research project sampled leaves of *Vaccinium uliginosum* from sites 1 and 2 (see sections 3.1 and 5.9).

111 blood samples of approximately 80 µl (10 µl for chicks) were collected from sanderlings *Calidris alba* for a parentage and breeding strategy study (section 5.7). The same project collected a total of 3,345 arthropods at 4 pitfall trapping stations on the Aucella slopes.

Blood and/or tissue samples were collected from musk oxen *Ovibos moschatus* (from carcasses), rock ptarmigan *Lagopus mutus* (from carcasses), sanderling *Calidris alba* (blood samples from chicks), dunlin *Calidris alpina* (blood samples from chicks), ruddy turnstone *Arenaria interpres* (blood samples from chicks), long-tailed skua *Stercorarius longicaudis* (blood samples from chicks), snow bunting *Plectrophenax nivalis* (from carcasses) and Arctic char *Salvelinus alpinus* (fresh tissue samples (caught by angling, see below) for the BioBasic DNA collections. Surplus material from these collections were sendt to: Eva Fuglei, Norwegian Polar Institute.

108 faecal samples of Arctic fox and 25 samples of muskoxen faeces were collected for analyses of endoparasites.

At the old trapping station, the Sirius Dog Sledge Patrol caught a few arctic char, much fewer than usual. Staff at the research station did not catch any arctic char by angling in 2007.

7 Logistics

Morten Rasch and Henrik Philipsen

7.1 Use of the station

In 2007, the ordinary field season at Zackenberg Research Station was from 25 May until 3 September, in total 101 days. An extended field season started immediately after the ordinary field season and lasted until 30 October, in total 57 days. In total Zackenberg Research Station was open for 158 days.

During this period 48 scientists visited the station. They were serviced by eight logisticians employed by Danish Polar Center and stationed at Zackenberg during different parts of the field season. Besides that six construction workers from the company Venslev stayed at the station during the late part of August and the beginning of September, and a representative from Aage V. Jensen Charity Foundation, Niels Skov, visited the station for one week in the late part of the season. The total number of bed nights during 2007 was 1,684 with 1,511 during the ordinary field season (25 May until 3 September) and 173 during the extension of the field season (3 September-30 October). Of the 1,684 bed nights, 373 were related to logistics during the ordinary field season, and 82 were related to the construction work. During the extended field season 63 bed nights were related to logistics while the remaining 110 bed nights were related to science. In total the numbers of days spend by scientists at Zackenberg were 1,166.

7.2 Transportation

During the ordinary field season fixed winged aircrafts (DeHaviland DHC-6 Twin Otter) landed 13 times at Zackenberg. During the extended field season there were Twin Otters at Zackenberg on 6 September, on 2 October, 17 October and on 30 October.

Helicopter slings with building materials from the cargo ship Arina Arctica to Zackenberg Research Station were carried out in the period 28-30 August with a Eurocopter EC-120 Colibri helicopter. It took 226 helicopter slings to bring all building materials and fuel in to the station.

In 2007 the station benefited from the new all terrain vehicle (ATV) and the new multi-purpose excavator (Bobcat) that both were bought in 2006. Two new snow mobiles were purchased, mainly for research purposes during the extended field season.

7.3 Construction work

In 2007, six construction workers from the company Venslev did the following construction and restoration work at Zackenberg Research Station:

- The canteen was extended with 50 m^2 giving space for a new provision storage, a new and larger kitchen and a larger dinning room
- Two bathrooms in the wet laboratory building were replaced with two smaller laboratories
- The provision storage in the logistics house was replaced with an extra bed room and a storage room for logistics equipment
- New floorings were fitted in the six older houses

7.4 Maintenance

During 2007 the following maintenance work was carried out on the station:

- The floorings were changed in all older houses. The original plastic floorings that were laid in 1996-7 have never functioned very well. It was therefore decided to change them in connection with the other construction activities in 2007. The new floors were laid by carpenters from the company Venslev and were paid for by Aage V. Jensen Charity Foundation
- New sewing system was established to replace the old sewing system

– New electrical power cords were laid between the power station and all houses

The maintenance condition of the station is very good. Besides the normal painting of the houses we do not expect larger maintenance costs during the first years to come.

7.5 Handling of garbage

In relation to the construction work in 2007 it was necessary to burn a considerable amount of packing material, in total c. 1,300 kg of wood, card board and paper and c. 120 kg of plastic.

A bit of non-burnable waste from the construction work during 2006 and 2007 have accumulated at the station together with empty fuel drums from the same period. This garbage will be removed from the station in 2008 by aircraft to Daneborg (on the empty return flights during the fuel lift from Daneborg to Zackenberg) and from there by ship to Denmark.

7.6 Electrical power to field sites

In early August 2007 a c. 1.4 km power cord was laid from the station to different electrical power consuming research installations (for carbon dioxide and methane exchanges studies) in the field (section 2.5). The research installations were earlier supplied with electrical power from solar panels backed up by smaller generators situated close to the installations. With the new power cord we can now supply these installations with electrical power from the generators at the station. This is a much more dependable solution.

8 Personnel and visitors

Compiled by Morten Rasch

Research

Zackenberg

Peter Alsen, Post Doc, University of Copenhagen (Early Cretaceous stratigraphy, 18-27 July, 31 July-1 August, 5-7 August)

Kristine Boesgaard, Research assistant, University of Copenhagen (Climate and UV-B manipulation effects on vegetation, 10 July-14 August)

Tina Dahl, Student, University of Tromsø, Norway (Vascular plants, 31 July-7 August)

Koos Dijksterhuis, Ornithologist, University of Groningen, The Netherlands (Ornithology, 5 June-4 July)

Julie Marie Falk, GeoBasic assistant, National Environmental Research Institute (GeoBasic, 19 June-31 July)

Andreas Fritz, Research associate, University of Innsbruck, Austria (Ecology, 7-22 August)

Jannik Hansen, BioBasic assistant, National Environmental Research Institute (BioBasic, 5 June-31 July)

Lise Bach Hansen, BioBasic assistant, National Environmental Research Institute (BioBasic, 28 August-2 October)

Lars Holst Hansen, BioBasic assistant, National Environmental Research Institute (BioBasic, 25 May-3 September)

Ditte Katrine Hendrichsen, PhD student, National Environmental Research Institute (Zoology, 5 June-4 July)

Bernhard Hynek, Research associate, Central Institute of Meteorology and Geodynamics, Austria (Glaciology, 7-22 August)

Karl Martin Iversen, GeoBasic assistant, Asiaq, (GeoBasic, 31 July-14 August)

Joop Jukema, Ornithologist, University of Groningen (Ornithology, 19 June-18 July)

Heidi Sjursen Konestabo, Post Doc, Oslo University, Norway (microarthropods, 24-31 July)

Line Anker Kyhn, BioBasic assistant, National Environmental Research Institute (BioBasic, 4-31 July)

Stefano Masseti, Scientist, Instituto di Fisica dello Spazia Interplanetario, Italy (Aurora, 25-28 August)

Mikhael Mastepanov, Researcher, University of Lund (GeoBasic and carbon exchange research, 19 June-4 July, 28 August-3 September)

Anders Michelsen, Associate Professor, University of Copenhagen (Climate and UV-B manipulation effects on vegetation, 24-31 July)

Jörg Mutterlose, Professor, Ruhr University Bochum, Germany (Early Cretaceous stratigraphy, 18 July-1 August, 5-7 August)

Bent Olsen, Technician, Asiaq (ClimateBasic, 24-31 July)

Michaela Panzenböck, Research associate, University of Vienna, Austria (Limnology, 7-22 August)

Sebastian Pauly, Student, Ruhr University Bochum, Germany (Early Cretaceous stratigraphy, 18-27 July, 31 July-1 August, 5-7 August)

Maria Rask Pedersen, GeoBasic assistant, National Environmental Research Institute (GeoBasic, 24 July-3 September)

Jonathan Petersen, Technician, Asiaq (ClimateBasic, 24-31 July)

Karl Reiter, Associate Professor, University of Vienna, Austria (Botany, 7-22 August)

Jeroen Reneerkens, Ornithologist, University of Gronningen, The Netherlands (Ornithology, 5 June-24 July)

Andreas Richter, Professor, Central University of Vienna, Austria (Ecology, 7-22 August)

Helge Ro-Poulsen, Associate Professor, University of Copenhagen (Climate and UV-B manipulation effects on vegetation, 24-31 July)

Hans Schekkerman, Ornithologist, Netherlands Institute of Ecology, The Netherlands (Ornithology, 19 June-10 July)

Niels Martin Schmidt, BioBasic manager, National Environmental Research Institute (BioBasic, 25 May-19 June, 28 August-3 September)

Wolfgang Schöner, Senior scientist, Central

Institute of Meteorology and Geodynamics, Austria (Glaciology, 7-22 August)
Charlotte Sigsgaard, GeoBasic assistant, University of Copenhagen (GeoBasic, 25 May-4 July, 28 August-30 October)
Lena Ström, Docent, University of Lund, Sweden (Carbon exchange research, 19 June-4 July)
Torbern Tagesson, Scientist, University of Lund, Sweden (Carbon exchange research, 19 June-7 August)
Mikkel Peter Tamstorf, GeoBasic manager, National Environmental Research Institute (GeoBasic, 25 May-5 June, 31 July-7 August)
Ingrid Tulp, Ornithologist, Institute for Marine Resources and Ecosystem Studies, The Netherlands (Ornithology, 4-24 July)
Kristine Bakke Westergaard, PhD student, Tromsø Museum, Norway (Vascular plants, 31 July-7 August)

Daneborg

Peter Alsen, Post Doc, University of Copenhagen (Early Cretaceous stratigraphy, 17-18 July)
Carsten Egevang, Scientist, Greenland Institute of Natural Resources, Greenland (Ornithology, 10 July-7 August)
Egon R. Frandsen, Technician, National Environmental Research Insitute (MarineBasic, 24 July-14 August)
Morten Frederiksen, PhD student, Greenland Institute of Natural Resources, Greenland (MarineBasic, 24 July-14 August)
Anne Birgitte Gotfredsen, Scientist, University of Copenhagen (Archaeology and Holocene climate, 31 July-28 August)
Bjarne Grønnow, Director of SILA, National Museum of Denmark (Archaeology and Holocene climate, 31 July-28 August)
Bjarne Holm Jakobsen, Associate Professor, University of Copenhagen (Archaeology and Holocene climate, 31 July-28 August)
Jens Fog Jensen, Post Doc, University of Copenhagen (Archaeology and Holocene climate, 31 July-28 August)
Aart Kroon, Associate Professor, University of Copenhagen (Archaeology and Holocene climate, 31 July-28 August)
Kunuk Lennart, Logistician, Greenland Insitute of Natural Resources, Greenland (MarineBasic, 24 July-14 August)
Stefano Masseti, Scientist, Instituto di Fisica dello Spazia Interplanetario, Italy (Aurora, 21-25 August)
Morten Meldgaard, Director of Natural History Museum of Denmark, University of Copenhagen (Archaeology and Holocene climate, 31 July-22 August)
Ditte Marie Mikkelsen, Researcher, Greenland Institute of Natural Resources, Greenland (MarineBasic, 24 July-14 August)
Jörg Mutterlose, Professor, Ruhr University Bochum, Germany (Early Cretaceous stratigraphy, 17-18 July)
Sebastian Pauly, Student, Ruhr University Bochum, Germany (Early Cretaceous stratigraphy, 17-18 July)
Mikael K. Sejr, Senior Scientist, National Environmental Research Institute (MarineBasic, 24 July-14 August)
Iain J. Stenhouse, Ornithologist, Audubon Alaska, United States of America (Ornithology, 10 July-7 August)

Logistics

Zackenberg

Henrik Rejnhardt Jensen, Logistics assistant, Danish Polar Center, Danish Agency for Science, Technology and Innovation (10 July – 14 August)
Irene Lundbjerg Larsen, Cook, Danish Polar Center, Danish Agency for Science, Technology and Innovation (5 June – 14 August)
Emil Madsen, Logistics assistant, Danish Polar Center, Danish Agency for Science, Technology and Innovation (5 June-2 August, 4-28 August)
Kenny Madsen, Logistics assistant, Danish Polar Center, Danish Agency for Science, Technology and Innovation (24 July-7 August)
Henrik Spanggård Munch, Logistics leader and Logistics assistant, Danish Polar Center, Danish Agency for Science, Technology and Innovation (27 June-21 August, 25-28 August)
Allan Palmqvist, Cook, Danish Polar Center, Danish Agency for Science, Technology and Innovation (14 August-6 September)
Henrik Philipsen, Logistics leader, Danish Polar Center, Danish Agency for Science, Technology and Innovation (25 May-4 July, 31 July-2 August, 4 August-3 September, 2-30 October)
Morten Rasch, Scientific leader, Danish Polar Center, Danish Agency for

Science, Technology and Innovation (25 May-5 June and 31 July-1 August, 2-7 August, 28 August-3 September)

Jørgen Skafte, Logistics coordinator, Danish Polar Center, Danish Agency for Science, Technology and Innovation (28 August-2 October)

Daneborg

Emil Madsen, Logistics assistant, Danish Polar Center, Danish Agency for Science, Technology and Innovation (2 – 4 August)

Henrik Spanggård Munch, Logistics leader and Logistics assistant, Danish Agency for Science, Technology and Innovation (21-25 August)

Henrik Philipsen, Logistics leader, Danish Polar Center, Danish Agency for Science, Technology and Innovation (2-4 August)

Morten Rasch, Scientific leader, Danish Polar Center, Danish Agency for Science, Technology and Innovation (1-2 August)

Construction workers

Zackenberg

Kenneth Andersen, Plumber, Venslev (28 August-6 September)

Keld Jonsen, Electrician, Venslev (28 August-6 September)

Lasse Kamper, Carpenter, Venslev (17-24 August, 30 August-6 September)

Lasse Nielsen, Carpenter, Venslev (14-28 August)

Rasmus Olsen, Carpenter, Venslev (14 August-6 September)

Martin Pedersen, Carpenter, Venslev (17-24 August)

Others

Zackenberg

Niels Skov, Aage V. Jensen Charity Foundation (28 August-3. september)

Further contributors to the annual report

Kristian Albert, PhD student, University of Copenhagen

Marie Arndal, PhD student, University of Copenhagen

Torben Røjle Christensen, Professor, University of Lund, Sweden

Kirsten Christoffersen, Associate Professor, University of Copenhagen

Safi K. Darden, Biologist, Bangor University, United Kingdom

Birger Ulf Hansen, Associate Professor, University of Copenhagen

Vibeke Sloth Jakobsen, Librarian, Danish Polar Center

Erik Jeppesen, Professor, National Environmental Research Institute

Thomas Juul-Pedersen, Scientist, Greenland Institute of Natural Resources, Greenland

Nette Levermann, Biologist, Greenland Home Rule, Greenland

Teis N. Mikkelsen, Senior Scientist, Research Center Risø

Jørn Torp Pedersen, Student, University of Copenhagen

Søren Højmark Rasmussen, Asiaq, Greenland

Søren Rysgaard, Professor, Greenland Institute of Natural Resources, Greenland

Mikkel Sørensen, Postdoc, SILA – The Greenland Research Centre at the National Museum of Denmark

Kisser Thorsøe, ClimateBasic manager, Asiaq, Greenland

9 Publications

Compiled by Vibeke Sloth Jakobsen

Scientific papers

Bendtsen, J., Gustafsson, K.E., Rysgaard, S. and Vang, T. 2007: Physical conditions, dynamics and model simulations during the ice-free period of the Young Sound/Tyrolerfjord system. pp. 45-59. In: Rysgaard, S. and Glud, R.N. (eds.): Carbon cycling in Arctic marine ecosystems: case study Young Sound. – Meddelelser om Grønland. Bioscience 58: 214 pp.

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Mernild, S.H., Sigsgaard, C., Rasch, M., Hasholt, B., Hansen, B.U., Stjernholm, M. and Petersen, D. 2007: Climate, river discharge and suspended sediment transport in the Zackenberg River drainage basin and Young Sound/ Tyrolerfjord, Northeast Greenland, 1995-2003. pp. 23-43. In: Rysgaard, S. and Glud, R.N. (eds.): Carbon cycling in Arctic marine ecosystems: case study Young Sound. – Meddelelser om Grønland. Bioscience 58: 214 pp.

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General information

Damsgaard, M.H. 2007: Flere planter og dyr i Grønland. – Augustus 1:27-28

Damsgaard, M.H. 2007: Tundraen optager drivhusgasser. – Augustus 1:29

Hansen, E.S. 2007: Laver sladrer om dyreliv og klimaændringer i Nordøstgrønland. – Naturens verden 90(1):22-31

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Appendix

Julian Dates

Leap years

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	32	61	92	122	153	183	214	245	275	306	336
2	2	33	62	93	123	154	184	215	246	276	307	337
3	3	34	63	94	124	155	185	216	247	277	308	338
4	4	35	64	95	125	156	186	217	248	278	309	339
5	5	36	65	96	126	157	187	218	249	279	310	340
6	6	37	66	97	127	158	188	219	250	280	311	341
7	7	38	67	98	128	159	189	220	251	281	312	342
8	8	39	68	99	129	160	190	221	252	282	313	343
9	9	40	69	100	130	161	191	222	253	283	314	344
10	10	41	70	101	131	162	192	223	254	284	315	345
11	11	42	71	102	132	163	193	224	255	285	316	346
12	12	43	72	103	133	164	194	225	256	286	317	347
13	13	44	73	104	134	165	195	226	257	287	318	348
14	14	45	74	105	135	166	196	227	258	288	319	349
15	15	46	75	106	136	167	197	228	259	289	320	350
16	16	47	76	107	137	168	198	229	260	290	321	351
17	17	48	77	108	138	169	199	230	261	291	322	352
18	18	49	78	109	139	170	200	231	262	292	323	353
19	19	50	79	110	140	171	201	232	263	293	324	354
20	20	51	80	111	141	172	202	233	264	294	325	355
21	21	52	81	112	142	173	203	234	265	295	326	356
22	22	53	82	113	143	174	204	235	266	296	327	357
23	23	54	83	114	144	175	205	236	267	297	328	358
24	24	55	84	115	145	176	206	237	268	298	329	359
25	25	56	85	116	146	177	207	238	269	299	330	360
26	26	57	86	117	147	178	208	239	270	300	331	361
27	27	58	87	118	148	179	209	240	271	301	332	362
28	28	59	88	119	149	180	210	241	272	302	333	363
29	29	60	89	120	150	181	211	242	273	303	334	364
30	30		90	121	151	182	212	243	274	304	335	365
31	31		91		152		213	244		305		366

Regular years

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1	32	60	91	121	152	182	213	244	274	305	335
2	2	33	61	92	122	153	183	214	245	275	306	336
3	3	34	62	93	123	154	184	215	246	276	307	337
4	4	35	63	94	124	155	185	216	247	277	308	338
5	5	36	64	95	125	156	186	217	248	278	309	339
6	6	37	65	96	126	157	187	218	249	279	310	340
7	7	38	66	97	127	158	188	219	250	280	311	341
8	8	39	67	98	128	159	189	220	251	281	312	342
9	9	40	68	99	129	160	190	221	252	282	313	343
10	10	41	69	100	130	161	191	222	253	283	314	344
11	11	42	70	101	131	162	192	223	254	284	315	345
12	12	43	71	102	132	163	193	224	255	285	316	346
13	13	44	72	103	133	164	194	225	256	286	317	347
14	14	45	73	104	134	165	195	226	257	287	318	348
15	15	46	74	105	135	166	196	227	258	288	319	349
16	16	47	75	106	136	167	197	228	259	289	320	350
17	17	48	76	107	137	168	198	229	260	290	321	351
18	18	49	77	108	138	169	199	230	261	291	322	352
19	19	50	78	109	139	170	200	231	262	292	323	353
20	20	51	79	110	140	171	201	232	263	293	324	354
21	21	52	80	111	141	172	202	233	264	294	325	355
22	22	53	81	112	142	173	203	234	265	295	326	356
23	23	54	82	113	143	174	204	235	266	296	327	357
24	24	55	83	114	144	175	205	236	267	297	328	358
25	25	56	84	115	145	176	206	237	268	298	329	359
26	26	57	85	116	146	177	207	238	269	299	330	360
27	27	58	86	117	147	178	208	239	270	300	331	361
28	28	59	87	118	148	179	209	240	271	301	332	362
29	29		88	119	149	180	210	241	272	302	333	363
30	30		89	120	150	181	211	242	273	303	334	364
31	31		90		151		212	243		304		365