Zackenberg Ecological Research Operations

11th Annual Report, 2005

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Front cover: DeHavilland DHC-6 Twin Otters from Iceland have connected
Zackenberg Research Station to the outer world since the start in 1995. Photo Henning Thing.
Back of cover: A curious Arctic fox (*Alopex lagopus*) investigating the shoelace palatability
of the photographer. Photo Kristian Albert.

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Executive summary

Charlotte Sigsgaard, Hans Meltofte and Morten Rasch

In 2005, Research Station Zackenberg was open for 106 days from 19 May to 30 August. In this period 31 scientist and five logisticians and staff from Danish Polar Center worked from the station. The station was visited in August by Rear Admiral Niels Wang, Royal Danish Navy, and four other guests. The field season was extended due to the researchers experiences that spring melt occurs earlier and earlier at Zackenberg. Zackenberg´s branch facility at the old weather station in Daneborg was used by one scientist and one logistician from 18 to 25 July, and by six scientists from 2 to 23 August. The total number of person days at Zackenberg and Daneborg was 1091.

During the last four years, we have experienced again and again the beating of parameter records. 2005 was no exception, as snow and ice melt was much earlier than recorded before, due to exceptionally high temperatures in the early spring. This was not restricted to the Zackenberg area, similar early snow and ice melt was found in all of southern Northeast Greenland.

At the meteorological station, positive diurnal air temperatures were recorded from 18 May and onward with only few exceptions. Monthly mean temperatures in May (–2.5°C) and June (2.7°C) were the warmest recorded during the 10 years of monitoring. July and August had mean monthly temperatures of 6.9°C and 4.7°C, respectively, which is within the range of earlier measurements. The last part of June and first part of July was characterized by relatively cold, cloudy and foggy weather, rain and drizzle. The period was followed by a warm and dry period where a record high temperature of 21.6°C was measured 21 July 18:00. This is the highest maximum temperature measured since the meteorological measurements started in 1995.

During winter a pronounced hot spell was measured 26-27 January 2005 where the temperature reached 10.7°C at the meteorological station and remained positive for 13 consecutive hours. At the snow and micrometeorological station M3 (420 m a.s.l.) the same event caused temperature to remain positive for 22 hours with maximum of 6.8°C. This episode was easily recognized in the snow pack throughout most of the valley as an almost continuous ice layer of 1-3 cm. It was also the first winter where episodes of positive air temperatures were registered in February.

A continuous snow cover build up only in December 2004 and the main part of the snow fell between 9 December and 12 February during five major events. Maximum snow depth measured at the meteorological station was 0.73 m (registered 12 February) almost the same as last year and in the low end of the range (0.49 m in 2000 and 1.30 m in 1999). Snow cover was, however, less extensive than measured before during our 10 years of monitoring. On 10 June, the snow cover was way below previous years in most sub-zones in Zackenbergdalen, and at the meteorological station snow melt was complete 9 June, which is early compared to previous years where snow has disappeared from the ground below the sensor in the period between 14 June (2004) and 3 July (1999).

During summer a total precipitation of 38 mm was measured which is close to average. Rain events primarily occurred in early and late July whereas June and August were relatively dry.

In the melting period there was a snow event 2-3 June resulting in about 5 cm of new snow in the valley.

The river Zackenbergelven started to run 3 June as a small stream upon the snow. During the following days the stream increased and from 15 June the river was no longer bordered by snow or ice. On 25 July, after a period of extremely warm and dry weather a large flood from Store Sødal made the river rise dramatically and the hydrometric station was washed away by the water pressure. Probably, this extreme event was caused by drainage of an ice dammed lake/reservoir in the glaciated part of the drainage basin. Due to the flood, the topography of the cross profile changed significantly and the total runoff in 2005 has not been calculated yet, as more manual discharge measurements must be performed in order to establish a new stage-discharge relation. From 3 June to 25 July the runoff from the drainage basin was 144 million m^3. Due to the missing discharge data in the last part of the season, the total seasonal transport of suspended sediment and organic material can not be presented in this annual report. The maximum concentration of suspended sediment measured during the flood was 5.7 g/l. In 1998, suspended sediment concentrations of up to 46 g/l were measured in a flood in mid August. The large difference reflects different initiations of the events. Whereas the flood in 1998 was initiated by heavy rain and massive overland flow, the flood in 2005 originated from the glaciers in the less erodible area of the drainage basin. After the peak in 2005, the concentration of suspended sediment remained at a level almost the double of before the flood for the remaining season, probably because of the large amount of material from the severe erosion along the river banks after the flood.

In July, a CTD-diver measuring water level, water temperature and conductivity were installed in the river from Lindemansdalen near the confluence with Zackenbergelven. Data from this station show that water from Lindemanselven constitutes on average 8 % of the total water discharge in Zackenbergelven in the period from 14 July to 25 July.

From 7 July the fiord Young Sund was open all the way to the sea. It is almost exactly the same date as the previous two years where the fiord broke up 8 July.

In the well drained *Cassiope* heath near the meteorological station, the average thaw depth in the gridnet ZEROCALM-1 reached a maximum of 79 cm in the end of August. This is a record so far and likewise in ZEROCALM-2, where the average maximum thaw depth reached 68 cm. Since 2000, an almost steady increase in the active layer depth has been observed correlating with an earlier snow melt and earlier initiation of soil thaw.

At the micrometeorological station where CO_2 exchange rates between the heath and the atmosphere have been measured since 2000, a total of 29.6 g C/m^2 accumulated during the period of 21 May to 25 August 2005. This is the highest total accumulation measured so far and reveals that the *Cassiope* heath acts as a sink of carbon during the summer. The growing season (the period when assimilation exceeds respiration) started almost a week earlier than registered before and lasted from 17 June to 18 August resulting in the longest growing season registered. Highest daily uptake of CO_2 (1.15 gC/m^2) was measured 16 July.

The most marked characteristics of the ecosystems at Zackenberg during the 2005 season were the effects of the extremely early spring, which was even earlier than the previous three very early seasons, and the drought during the last few summers. The very early start of the growing season resulted in a prolonged growing season. It also resulted in the earliest flowering recorded during the 10 years of monitoring for 23 of 28 plant plots, while flowering in four of the remaining plots resembled the earliest hitherto recorded snowmelt. Also for 11 arctic poppy *Papaver radicatum*, arctic willow *Salix arctica* and purple saxifrage *Saxifraga oppositifolia* plots, the date of 50% open seeds capsules was the earliest or the same as previous earliest records.

Despite the length of the growing season, 2005 was not a top year with regard to amount of flowers produced. This is due to flower buds being established one or more growing seasons prior to flowering. The observed drop in numbers of flowers from 2004 to 2005 in early snowfree *Dryas* and *Salix* plots might be ascribed to water deficiency, as an early snowmelt in conjunction with little precipitation gave rise to a prolonged, but dry growing season in 2004. For species depending on a protective snow-cover, and therefore experiencing late snowmelt such as white arctic bell-heather *Cassiope tetragona*, there has been a positive correlation between length of growing season the previous year and amount of flowers the following year since 1999/2000.

In accordance with the past five years, berry production in relation to number of flowers was very low, and the years of top production are concurrent with the years of greatest precipitation in July. The amount of precipitation over summer has been decreasing during recent years.

The culmination of greening in the plant plots occurred extremely early this year and was followed by a second peak two or three weeks later during the normal time span and of approximately the same order as the early peak. A reasonable explanation for the early NDVI peak is the very early snowmelt giving rise to an extended growth period in the beginning of the season. However, the early snow clearance may have caused water depletion, since a heavy rain fall of 22.6 mm during 5-8 July gave rise to a sudden rise in NDVI on 9 July. Greening index data from a satellite image from 25 July 2005 were lower than average for the 1995 to 2005 period, but still higher than the lowest values that occurred in 1999. The 2005 season values are similar to the values for 2001 and 2002 although they in some areas are slightly lower.

The 6 km long transect, the ZERO line, from the coast of Young Sund to the top of Aucellabjerg was reanalysed in 2005. In all types of plant communities along the line except for salt marsh, an increase in number of species since 2000 was found. The number of species new to the plant communities varied from one to eight species with the largest increase in the plant community with high species diversity – *Salix arctica* snowbed. There were differences in the changes of frequency among the different life strategies. Woody dwarf shrubs (*Cassiope tetragona*, *Vaccinium uliginosum* ssp. *microphyllum*, *Dryas* sp. and *Salix arctica*) with a long term life strategy, showed no or only minor changes in frequency, whereas perennials both among herbs and graminoids (i.e. grasses, sedges and rushes) showed many increases or decreases in frequency.

The reproduction of selected vascular plant species with their northern distribution limit in the study area were checked in the plots established in 2000. For almost all the species and in nearly all the plots there was a marked reduction in the number of flowers or inflorescences of plants growing in moist, wet or dry soils.

With some exceptions, the epigaeic lichens along the ZERO-line had adapted to drier soil conditions since 2000. Moisture via melt water and precipitation evidently had decreased in the lichen substrates since 2000, and strong winds had influenced the lichens to a great extent, which may be associated with more limited snow cover since then. The influence of UV-radiation upon the *Cladonia thalli* appeared to have been at the same level in 2005 as in 2000.

The total number of arthropods caught in the window traps this season (9444) was the second highest since 1996. The chironomids had a very distinct peak one week earlier than average for the years 1996-2004, which could be related to the extraordinary early ice melt on the pond around the traps. Also extremely high numbers of sciarids were caught this year, constituting the highest number ever recorded.

A total of 38,217 arthropods were caught in the pitfall traps. This number is low compared to other years, and was due to a major reduction in number of mites (Acari) and springtails (Collombola). Most other groups were either caught in equal or higher numbers than in recent years. Two groups of flies Syrphidae and Agromyzidae were caught in higher numbers than in all previous years. The anthomyiids and the agromyzids showed a pronounced peak in the beginning of the season. Larvae from both families are plant-parasites, and their early occurrence and high numbers this year could be explained by an early emergence of the plants, in which the adults lay their eggs, due to the extraordinary early thaw. Like last year, the catch of coccoids, calcidoids and the heteropteran *Nysius groenlandicus* were remarkably high. With 471 individuals, *Nysius groenlandicus* showed the highest number ever recorded.

The population size of a number of bird species changed markedly as compared to previous years. Sanderlings and common ringed plovers were recorded in the lowest numbers since the beginning of the monitoring programme. Also, dunlin numbers were lower than the last four years, and the peak seen during 2001-2003 could be coming down. Ruddy turnstones were more numerous than previously, and red knot numbers were in the high end of the range measured in the programme. Nest initiation was early to average. Nearly 70% of all wader nests were initiated before 15 June, but median first egg dates were later than in 2004, except for dunlin, which had the same median date.

Nest success was very low in 2005, and the number of juvenile waders in the deltas at low tide was by far the lowest recorded at Zackenberg to date. Ruddy turnstone and common ringed plover numbers have previously been lower or equal to this year's numbers, but dunlin and, in particular, sanderling numbers were well below other years' figures. The low hatching success and possibly low fledging success in waders may account for the low numbers. However, the considerable amounts of sediment washed out from Zackenbergelven during the days of surge flooding in late July is also likely to have reduced the food availability in the deltas.

2005 was again an early breeding season for the long-tailed skuas. Nests were initiated between 7 June and 20 June, but due to low lemming numbers only a minor proportion of the population attempted to breed. Despite a high number of foxes the skuas' nest success was around average, but most young were taken very early, and only one chick was still alive at the last check.

The mean brood size in barnacle geese was around average, as was the number of broods. Data from the wintering grounds on Isle of Islay off the western coast of Scotland indicated a poor breeding season with only 6.3% juveniles among Greenland barnacle geese and an average brood size of only 1.67. The line transect revealed approximately 300 moulting barnacle geese in Store Sødal and Morænebakkerne, which together with birds at the coast of Zackenbergdalen etc. adds up to an estimated total of 412 for the entire study area.

Immature pink-footed geese from Iceland were seen migrating northwards between 11 June and 2 July, when a total of 1319 migrating geese were recorded. Only 53 moulting immature pink-footed geese were recorded in the study area this year. This is the lowest figure so far.

Following the 'missed' lemming winter peak of 01/02 and the low of 02/03, a continued growth from the medium peak last winter was expected for the winter 04/05 probably in conjunction with an apparently absent stoat population in winter 03/04. However, the growth did not continue, and the 232 winter nests of 04/05 were medium low for Zackenberg. Again this year, not a single of the examined winter nests was found to have been depredated by stoats. The lemming population has not experienced a full peak since 97/98 and this might explain the absence of stoat predated winter nests in 03/04 and 04/05.

The pattern of musk ox occurrence in Zackenbergdalen closely matched the pattern observed in 2004 with high numbers in May-June, lower in July and again increasing to the highest counts in August. This pattern with many oxen in June correlates well with the extremely early snowmelt, as last year. In 2005, the number of musk oxen per observation was extremely high and the record so far both within the 40 km^2 census area and in the entire visible area of 135 km^2. 26% of the aged animals were calves, and 25% were females active in reproduction. This gives a mother/calf ratio of app. 1:1, which is the double of the expected ratio. In 2004 there were two calves per cow, and the high ratio again this year likely reflects that the last couple of years have provided good conditions for the musk oxen.

2005 was not the best year for foxes as no pups or intense den use indicating offspring were observed. However, the number of adult foxes recorded was the second highest, which may indicate that many of the minimum of 18 pups produced in 2004 actually made it through the winter.

Totally, a factor 10 more hares were observed in 2005 than previous years. The number of arctic hares observed at other sites than Zackenberg mountain was correspondingly high this season.

On average three seals per count were hauled out on the fjord ice, which is few compared to a mean of 24 for all years.

Sommerfuglesø and Langemandssø in Morænebakkerne saw the earliest ice-out since the onset of the programme, and water temperatures were in the upper end of the range recorded since 1997. However, the average values for conductivity, total nitrogen and total phosphorus remained within the normal year-to-year fluctuations. In both lakes, the phytoplankton communities were totally dominated by chrysophytes. Regarding the zooplankton community in Sommerfuglesø, the cladoceran *Daphnia pulex* was found to occur frequently, while in Langemandssø *D. pulex* was absent. This reflects the occurrence of arctic char in Langemandssø.

1 Introduction

Morten Rasch

In 2005, Zackenberg Research Station was open for 106 days from 19 May to 30 August. In this period 31 scientist and five logisticians and staff from Danish Polar Center worked from the station. The station was visited by Rear Admiral Niels Wang, Royal Danish Navy and four other guests in August. The field season was extended due to the researchers experiences that spring melting occurs earlier and earlier at Zackenberg.

Zackenberg´s branch facility in Daneborg was used by one scientist and one logistician from 18 to 25 July, and by six scientists from 2 to 23 August. The total number of person days at Zackenberg and Daneborg was 1091. A total of 15 research projects worked from the station during this summer.

International cooperation

Zackenberg Research Station is still a member of the networks ENVINET (European Network of Arctic-Alpine Environmental Research) and SCANNET (Scandinavian / North European Network of Terrestrial Field Bases) and is still involved in the establishment of CEON (Circum-Arctic Environmental Observatories Network). Zackenberg is further involved in a large number of international organizations, programs and networks including Arctic Monitoring and Assessment Programme (AMAP), Conservation of Arctic Flora and Fauna (CAFF), Arctic Climate Impact Assessment (ACIA), International Tundra Experiment (ITEX), Global Runoff Data Center (GRDC), Global Terrestrial Observing System (GTOS), Circumpolar Active Layer Monitoring Programme (CALM), Arctic Coastal Dynamics (ACD), Arctic Birds Breeding Conditions Survey (ABBCS) and Pan-Arctic Shorebird Researcher Network (PASNR).

Extension and restoration of the facilities

The final decision to build a new accommodation building and a new combined workshop, power station and garage at Zackenberg, and a boat house in Daneborg, was taken early in 2005. The new buildings will be erected in 2006 and will be funded by Aage V. Jensen Charity Foundation. Materials for the foundations of the buildings were shipped to Daneborg in 2005. The building of the three houses will start in mid July 2006, and hopefully they will be ready for use by late August 2006. The houses are not meant to be an extension of Zackenberg Research Station but rather an improvement of the facilities. When the houses are ready for use, the weatherhaven shelters which have been used for accommodation since 1995 will be taken down.

Transfer of ownership to the Greenland Home Rule

In cooperation with The Ministry of Science, Technology and Innovation and the Greenland Home Rule, Danish Polar Center is planning to transfer the ownership of Zackenberg Research Station to Greenland Home Rule, represented by Asiaq (Greenland Survey). There is a lot of paperwork involved in such a transfer, but it is expected that the transfer will take place in early 2006. The transfer of the ownership of the station to Greenland Home Rule will not immediately effect the run of the station, as Danish Polar Center and Asiaq will sign a ten year cooperation agreement stating that Danish Polar Center is obliged to continue running the station for the next ten years.

Nuuk Basic, a new monitoring program

The Danish Environmental Protection Agency has asked the group of people involved in the monitoring program Zackenberg Basic to design a West Greenland, low arctic equivalent based in the area around Nuuk. This new program should start in the summer of 2006. A working group has been appointed, and Danish Polar Center has accepted to coordinate the work and to act as secretariat for Nuuk Basic.

‘The Dynamics of a High Arctic Ecosystem in Relation to Climate Variability and Change’

Scientists involved in research at Zackenberg since 1995 are working on a book about the first ten years of research and monitoring at Zackenberg. The book is planned to be published in autumn of 2007. In 2005, Aage V. Jensens Fonde provided means for appointment of a first editor, Dr. Hans Meltofte, and Elsevier accepted to publish the book. An editor group consisting of Dr. Hans Meltofte, Professor Bo Elberling, Professor Torben Røjle Kristensen, Professor Mads Forchhammer and Dr. Morten Rasch has been established, and the writing process has started. The book has the working title ‘The Dynamics of a High Arctic Ecosystem in Relation to Climate Variability and Change : Ten years of monitoring and research at Zackenberg Research Station, Northeast Greenland’ and is planned to consist of 24 chapters.

Plans for the 2006 field season

In 2006, we expect that the activity level at Zackenberg measured in bed nights spend at the station during late May – early September will be much higher than in 2005, mainly due to the building activities at Zackenberg and in Daneborg. The building of the new houses will start in mid-July and the houses are planned to be ready for use in late-August.

Further information

Details about Zackenberg Research Station and the study area at Zackenberg have been given in previous annual reports (Meltofte and Thing 1996, 1997; Meltofte and Rasch 1998; Rasch 1999, Caning and Rasch 2000, 2001, 2003; Rasch and Caning 2003, 2004, 2005) and the information is also available on the Zackenberg website (www.zackenberg.dk). The ZERO Site Manual has information for scientists planning to use Zackenberg Research Station and is found together with an application form at the Zackenberg website. The address of the 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@dpc.dk.

2 Zackenberg Basic: The ClimateBasis and GeoBasis programmes

Charlotte Sigsgaard, Dorthe Petersen, Louise Grøndahl, Kisser Thorsøe, Hans Meltofte, Mikkel Tamstorf and Birger Ulf Hansen

The objective of GeoBasis and Climate Basis is to provide long term data of climatic, hydrological and physical landscape variables describing the dynamics of the physical and geomorphological environment at Zackenberg. GeoBasis is operated by the National Environmental Research Institute, Department for Arctic Environment in co-operation with Institute of Geography, University of Copenhagen. Since 2003, GeoBasis has been funded by the Danish Environmental Protection Agency as part of the environmental support programme Dancea – Danish Cooperation for Environment in the Arctic. ClimateBasis is funded by the Greenland Home Rule and operated by ASIAQ, Greenland Survey, who operates and maintains 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 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.

More details about the GeoBasis programme, sampling procedures, instrumentation, locations and installations are given in the GeoBasis Manual which is available from the Zackenberg homepage: www.zackenberg.dk. Through this internet homepage all validated data from the Zackenberg Basic monitoring are accessible. If some data collected by Climate Basis and GeoBasis are not available through the database yet, they can be ordered from ASIAQ (dop@asiaq.gl) or Institute of Geography (cs@geogr.ku.dk).

In the following section, ClimateBasis and GeoBasis monitoring data are summarised and the season 2005 is presented. Locations of most GeoBasis and ClimateBasis stations and plots, referred to in the text, are given in Fig. 2.1.

GeoBasis had applied this season for an opening of the station earlier than 1 June, and we ended up being able to start manual measurements in Zackenberg on 19 May, almost two weeks earlier than usual. In the future it will hopefully be

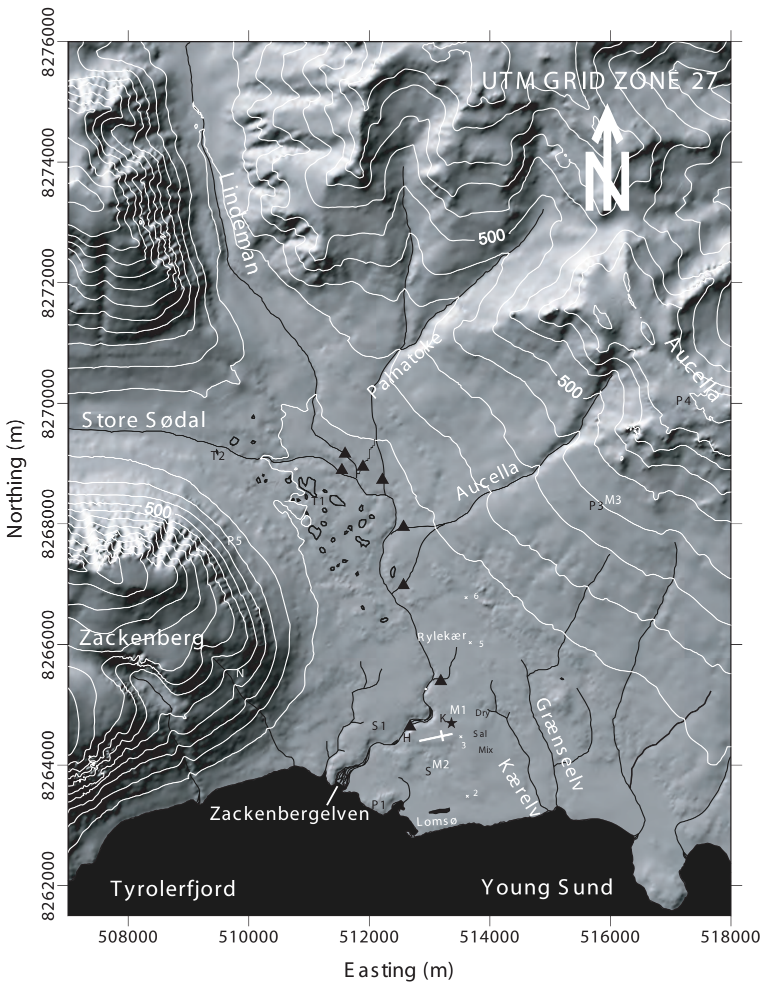


Fig. 2.1. Location of GeoBasis and ClimateBasis stations and plots. The climate station is marked with an asterix. H= Hydrometric station. M1= Micrometeorological station. M2 and M3= New snow- and micrometeorological stations. Triangles = Water sampling sites from tributaries to Zackenbergelven. N = Nansenblokken. K, S, Dry, Sal, and Mix = Soil water sites. P1, P3, P4, P5, S1, T1 and T2 = TinyTag temperature sites. Small crosses (x) = Snow stakes 2, 3, 5 and 6.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
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	–
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
Relative air humidity 2 m above terrain (%)	67	68	73	70	70	71	72	71	72	71
Air Pressure (hPa)	1009	1007	1010	1006	1008	1009	1009	1008	1007	1008
Incoming shortwave radiation (W/m^2)	113	104	101	100	107	112	105	104	99	101
Outgoing shortwave radiation (W/m^2)	52	56	55	56	52	56	54	49	42	43
Net Radiation (W/m^2)	16	9	6	4	14	13	–	8	–	–
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	2.8
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
Precipitation (mm w.eq.), total	223	307	255	161	176	236	174	263	253	–
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	–
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
Relative air humidity 2 m above terrain (%)	99	99	99	99	100	100	100	100	100	99
Air Pressure (hPa)	1042	1035	1036	1035	1036	1043	1038	1038	1033	1038
Incoming shortwave radiation (W/m^2)	857	864	833	889	810	818	920	802	795	790
Outgoing shortwave radiation (W/m^2)	683	566	632	603	581	620	741	549	698	629
Net Radiation (W/m2)	609	634	556	471	627	602	–	580	–	–
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	19.0
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	21.2
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	–
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
Relative air humidity 2 m above terrain (%)	20	18	31	30	19	22	23	21	17	22
Air Pressure (hPa)	956	953	975	961	969	972	955	967	955	967
Incoming shortwave radiation (W/m^2)	0	0	0	0	0	0	0	0	0	0
Outgoing shortwave radiation (W/m^2)	0	0	0	0	0	0	0	0	0	0
Net Radiation (W/m^2)	–86	–165	–199	–100	–129	–124	–	–98	–	–
Wind Velocity, 2 m above terrain (m/s)	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

Table 2.1. Annual mean, maximum and minimum values of climate parameters 1996 to 2005. Data for 2005 are preliminary. Some of the figures differ from earlier publications due to re-evaluation of data.

standard procedure to open in mid May, as the transition period between winter and summer is of great importance for most of the monitored parameters. In order to carry out the snow monitoring programme we also need to be able to be there before onset of the melting.

2.1 Meteorological data

The meteorological station at Zackenberg was constructed in 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. In the summer of 2005, a satellite modem was established on the eastern climate mast from which data is transferred once a day and made available on the Zackenberg homepage: www.zackenberg.dk/weather. For the period September to December 2005 there is only data available from the eastern mast, and the quality control of data is provisional until data from the western mast has been retrieved in the summer of 2006. Some parameters are only measured at the western mast (e.g. precipitation) and will be presented in the next annual report. Some of the data presented in Table 2.1 and 2.2 differ from earlier publications due to re-evaluation of data.

Meteorological data from 2004

In 2004, the mean air temperature measured 2 m above terrain was –8.5°C. This is the highest annual air temperature measured since the meteorological station was installed in 1995. A maximum temperature of 19.1°C was measured 20 June (14:00) and a minimum temperature of –34.0°C was measured 5 February (14:00) (Table 2.1). Periods with frequent temperatures above 0°C started in late May and ended in late

Year	Month	Shortwave Rad. W/m^2 mean in	W/m^2 mean put	Net Rad. W/m^2 mean	PAR µmol/m^2/s mean	Air temperature °C mean 2 m	°C minimum 2 m	°C max 2 m	Precipitation mm total	Wind velocity m/s mean 7.5 m	m/s max[1] 7.5 m	Vind direction dominant 7. 5m
	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	20	–	321	4.6	–2.7	14.0	4	3.2	11.0	SE

Table 2.2. Climate parameters for June, July and August, 1996 to 2005. [1)]Wind velocity, max is the maximum of 10 minutes mean values. Some of the figures differ from earlier publications due to re-evaluation of data.

September (Fig. 2.2). Monthly mean temperature in February 2004 was colder than previous years, whereas April 2004 was warmer than measured before (Fig. 2.3).

The total amount of measured precipitation in 2004 was 253 mm of which only 17 mm fell during the summer period. Rain events occurred primarily in July whereas June and August were rather dry (Table 2.2).

Mean relative humidity was 72% and lowest humidity of 17% was measured 8 July. The mean air pressure was 1007 hPa and the air pressure was more stable during summer than winter. Monthly mean net radiation was positive in May, June, July and August and negative in January to April. Unfortunately, net radiation data is not available in the period September 2004 until August 2005.

Wind speed measured 2 m and 7.5 m above the ground had an average of 3.0 m/s and 3.6 m/s, respectively. The highest 10 minutes mean value was 22.2 m/s at 2 m above ground and 25.6 m/s at 7.5 m above ground – both measured during a storm 1 January 2004 with wind gusts up to 40 m/s. The wind speeds are generally higher in winter than in summer (Table 2.3). Annual wind statistic for 2004 is in good agreement with the years 1997, 1998, 2000 and 2002. Wind statistics for the remaining years are not given due to signifi-

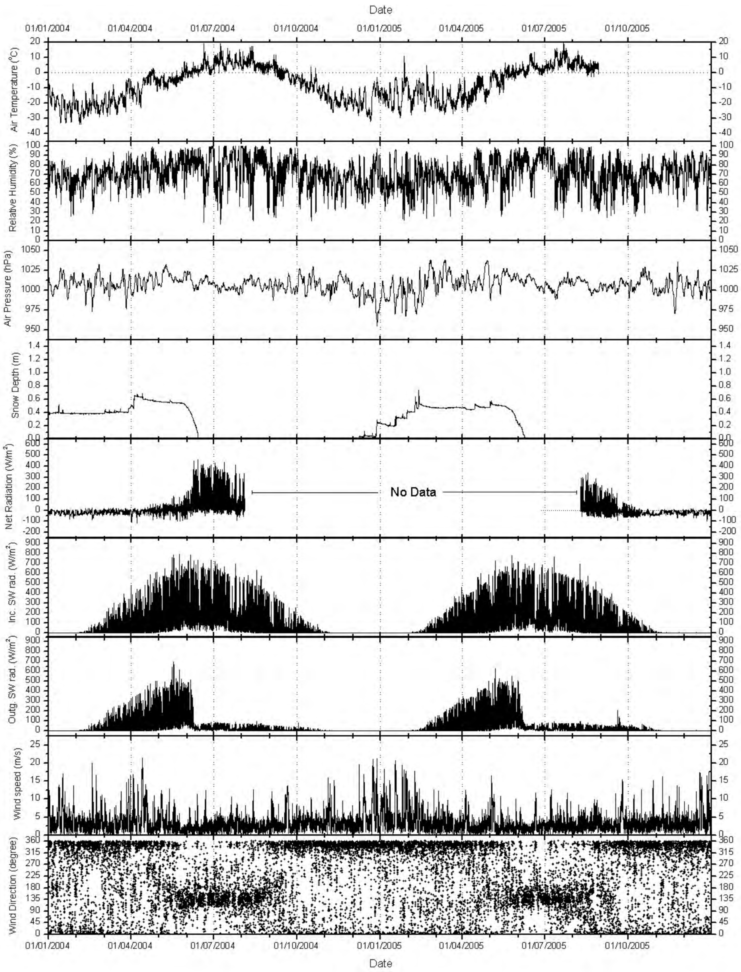


Fig. 2.2. Variation of selected climate parameters during 2004 and 2005. From above: Air temperature, relative humidity, air pressure, snow depth, net radiation, incoming short wave radiation, outgoing short wave radiation, wind speed and wind direction. Wind speed and direction are measured 7.5 m above terrain; the remaining parameters are measured 2 m above terrain.

cant periods with missing data. In 2004, the winds were coming from N and NNW 38% of the time, mainly in the winter period, and from ESE to SSE app. 22% of the time, mainly in the summer period (Table 2.3 and 2.4).

Meteorological data from 2005

In 2005, there were some problems with the air temperature sensor 2 m above terrain at the east mast and therefore, the annual mean can not be given until data from the west mast has been retrieved in summer 2006. Mean air temperature measured 7.5 m above terrain was –6.9°C. This is the highest among the years 1996-2005 and more than one degree higher than in 2004 which was the warmest year so far (Table 2.1).

The winter 2005 was extremely warm and January and February was the warmest recorded so far (Fig. 2.3). The minimum temperature measured 22 January was only –27.9°C (Table 2.1).

Positive diurnal air temperatures were recorded from 18 May and the period with frequent temperatures above 0°C ended in mid September. May and June were also extraordinary warm with mean monthly temperatures of –2.5 °C and 2.7°C, respectively (Table 2.3 and Fig. 2.3). The last part of June and first part of July were characterized by relatively cold, cloudy and foggy weather with rain and drizzle. Then, a very warm and dry period followed (lasting from 12 July to 26 July) with average diurnal mean temperatures above 10°C. A record high air temperature of 21.8°C was measured during a *Föhn* wind situation 21 July (18:00).

The high annual mean air temperature in 2005 was mainly due to the unusually warm January and February as well as high monthly temperatures in May and June. In contrast, the extreme year 2002 was mainly due to a warm autumn whereas the winter of 2002 was cold compared to other years. In 2004, the high annual mean temperature was mainly due to very high temperatures in April. Fig. 2.3, show the variation in mean monthly air temperatures from the last ten years. Large year to year variations (up to 20°C) can be observed in the winter months, whereas summer temperatures are more stable.

Mean relative humidity was 71% and mean air pressure was 1008 hPa. Unfortunately, net radiation data is not available in the period September 2004 until August 2005 due to malfunction of the sensor. Monthly mean net radiation was positive in September 2005 and negative in October to December.

Mean wind speed 2 m and 7.5 m above the ground was 2.8 m/s and 3.5 m/s, respectively. The highest 10 minutes mean value was 19.0 m/s at 2 m above ground and 21.2 m/s at 7.5 m above ground – both measured during a storm 25 January. The annual wind statistics for 2005 is in good agreement with the years 1997, 1998, 2000, 2002 and 2004. Wind statistics for the remaining years are not given due to significant periods with missing data. In 2005, the winds were coming from N and NNW app. 38% of the time, mainly in the winter period, and from ESE to SSE app. 20% of the time, mainly in the summer period (Table 2.3 and 2.4).

The total precipitation during the summer 2005 was 38 mm and rain events occurred primarily in early and late July whereas June and August were rather dry as in 2004 (Table 2.2).

Positive degree days calculated on a

monthly basis as the sum of daily mean air temperatures above 0°C are shown in Table 2.5. The warm spring in 2005 is illustrated with May and June having the second highest and the highest sum of degree days, respectively. No positive degree day was recorded in November, December, January, February and March until the winter 2005, where a *Föhn* wind situation 26 and 27 January resulted in temperatures as high as 10.7°C and constant positive temperatures for a consecutive period of 13 hours. As a result of this event, an ice layer of up to several centimetres could be recognized in the snow pack throughout most of the valley. Ice layers caused by positive temperature events during the winter are of special concern to animals seeking food below the snow, as ice crusts in the snow pack can impede access to the vegetation. Throughout the winter 2004-2005, additional hot spells (positive temperature events with fluctuations of short duration above the freezing point) was recorded 16 and 21 October and again 21 and 28 February, every time in relation with *Föhn* wind situations.

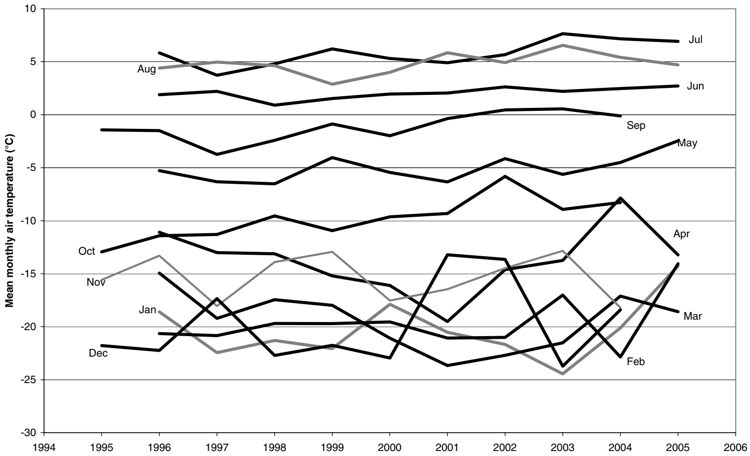


Fig. 2.3. Monthly mean temperatures from September 1995 to August 2005.

2.2 Climate gradients, snow, ice and permafrost

New micrometeorological stations

Monthly mean values of selected parameters from the new snow- and micrometeorological stations M2 and M3 (see section 2.2 in Rasch and Caning 2004) are reported in Table 2.6 and Figs. 2.4 and 2.5. Data are missing from a long period in the winter. The station is powered by solar panels and

Table 2.3. Monthly mean values of climate parameters 2004 and 2005. Data for 2005 are preliminary.

		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
2004	Jan	–20.1	–19.4	66	1009.1	–20	0	0	4.0	4.6	NNW
2004	Feb	–22.9	–21.5	65	1008.8	–23	6	6	2.9	3.4	NNW
2004	Mar	–17.1	–16.5	72	1005.7	–14	54	46	3.1	3.6	NNW
2004	Apr	–7.9	–7.5	75	1009.9	–10	136	114	4.0	4.7	NNW
2004	May	–4.5	–4.6	76	1016.5	3	259	202	2.7	3.1	SE
2004	Jun	2.5	2.1	82	1011.4	111	279	73	2.1	2.3	SE
2004	Jul	7.2	6.8	75	1002.8	95	225	30	2.4	2.8	SE
2004	Aug	5.6	5.6	79	1008.6	62	150	20	2.0	2.4	SE
2004	Sept	–0.1	0.4	74	1004.8	–	65	10	3.0	3.7	NNW
2004	Oct	–8.3	–7.3	68	1009.1	–	14	3	2.7	3.5	N
2004	Nov	–18.2	–16.7	65	1008.4	–	0	0	3.0	3.8	NNW
2004	Dec	–18.4	–17.2	66	990.9	–	0	0	4.2	5.3	NNW
2005	Jan	–14.3	–12.9	62	996.0	–	0	0	5.0	6.0	NNW
2005	Feb	–14.1	–12.5	65	1004.6	–	7	6	3.3	4.1	NNW
2005	Mar	–18.6	–17.1	68	1014.3	–	62	53	2.4	2.8	NNW
2005	Apr	–13.2	–11.9	67	1013.5	–	164	136	2.3	2.7	NNW
2005	May	–2.5	–1.8	76	1014.8	–	256	197	2.5	3.1	N
2005	Jun	2.7	2.9	84	1010.2	–	261	53	2.0	2.4	SE
2005	Jul	6.9	7.1	75	1006.3	–	215	29	2.4	2.9	SE
2005	Aug	4.6	4.8	69	1006.7	–	151	20	2.6	3.2	SE
2005	Sept	–	–1.3	68	1005.8	1	73	15	2.6	3.4	N
2005	Oct	–	–12.3	67	1010.0	–31	17	6	2.6	3.4	NNW
2005	Nov	–	–14.7	72	1003.8	–21	0	0	2.7	3.4	NNW
2005	Dec	–	–13.5	73	1004.4	–18	0	0	3.8	4.4	NNW

Direction	Frequency	Mean[1]			2004			2005		
		Velocity, m/s			Frequency	Velocity, m/s		Frequency	Velocity, m/s	
	%	mean	mean of maxs	max	%	mean	max	%	mean	max
N	13.4	4.2	24.3	29.5	17.1	4.8	25.6	17.4	4.8	21.2
NNE	3.5	2.7	18.4	25.4	3.7	2.9	15.3	3.7	2.6	15.8
NE	2.5	2.5	15.9	19.4	2.3	2.1	12.5	2.7	2.4	11.0
ENE	2.7	2.3	13.7	17.4	2.8	3.0	13.6	3.1	2.9	11.9
E	4.2	2.1	9.0	10.4	3.4	2.1	10.5	3.5	2.3	10.7
ESE	7.1	2.2	9.4	10.3	6.6	2.3	8.3	5.7	2.4	8.5
SE	8.4	2.4	10.3	18.1	8.5	2.5	10.5	8.4	2.6	7.9
SSE	5.3	2.4	9.8	16.2	6.6	2.6	11.3	6.2	2.5	8.1
S	3.7	2.4	8.1	9.9	4.5	2.7	9.6	4.8	2.5	6.8
SSW	2.8	2.2	9.6	13.4	3.3	2.5	8.2	2.7	2.3	7.2
SW	2.5	2.1	8.9	12.2	2.6	2.3	7.2	2.6	2.2	7.1
WSW	2.7	2.4	10.0	15.9	3.0	2.6	13.4	3.2	2.4	6.7
W	2.8	2.5	18.1	23.5	2.9	2.7	21.1	3.0	2.6	18.1
WNW	3.3	2.7	16.9	19.3	3.0	2.8	17.7	3.2	2.8	18.1
NW	6.7	3.7	20.3	25.1	5.8	3.8	20.2	6.5	3.8	18.4
NNW	23.9	5.0	23.0	25.8	21.1	5.6	24.7	21.0	5.0	22.0
Calm	4.4				2.9			2.1		

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

Table 2.4. Mean wind statistics based on wind velocity and direction measured 7.5 m above terrain in 1997, 1998, 2000, 2002 and 2003. Furthermore wind statistics for the years 2004 and 2005. 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.

the datalogger is programmed to enter sleep mode if the voltage attain a certain low level during the dark period and to start up again as soon as the voltage exceed 10 Volt. Unfortunately, the automatic restart did not work in 2005 and therefore, no measurements are available from February and until field staff arrived in Zackenberg 19 May. Due to the missing data, it has not been possible to calculate monthly mean values for February, March, April and May.

In Fig. 2.6, periods where the temperature is higher at M3 than at M2 (inversion) have a negative value, whereas periods where the temperature are highest at M2 (no inversion) have a positive value. The pattern is not even distributed over the year. In September, inversion takes place less than 10% of the time, whereas in December inversion takes place up to 80% of the time. During June and July it is about 50% of the time. Daily mean temperature variations can be as high as 13°C when the temperature is higher at M3 than at M2, but in periods where temperatures are lower at M3 than at M2 (no inversion), the variation is less than 4°C – corresponding to the dry adiabatic lowering of temperature of 1°C/100 m altitude.

There is a high correlation between the variations in relative humidity and the variations in temperatures. When the temperature is higher at M3 than at M2, the relative humidity is lower (Fig. 2.6). Highest temperature at M3 was 18.5°C measured 21 July (18:00) and at M2 the highest temperature was 21.8°C measured 21 July (19:00). The high temperatures recorded in the valley during the *Föhn* situation 26 January was likewise recorded at M3, where maximum was 6.8°C and temperatures were above freezing in consecutive 22 hours.

Snow depth

In 1997 automatic point measurements of snow depth was started in Zackenbergdalen near the meteorological station; see Meltofte and Rasch (1998). The snow depth during the winter is summarised for all six winters in Table 2.7 and the accumulation for all years is shown in Fig. 2.7 In the winter 2004/2005 only sparse snowfall was observed before 8 December (Figs 2.2 and 2.7) and the snow depth did not reach 0.1 m before 27 December, which is relatively late. The maximum measured snow depth was 0.73 m. That is approximately the same level as in the winters 2000/2001, 2002/2003 and 2003/2004. Relatively sparse snow cover and an early snow melt characterized the end of winter situation in 2005. Melting of the snow around the snow mast began mid May

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
January											1.5
February											
March											
April									0.2	1.1	
May		1.1	1.3	0.1	3.6	0.5	0.5	18.2	3.3	4.1	5.40
June		63.7	74.6	32.5	52.9	71.8	68.2	81.8	74.2	73.9	84.6
July		181.0	115.4	147.36	192.7	164.4	152.0	175.6	237.2	222.2	214.7
August		140.5	154.2	143.6	89.2	127.3	181.2	152.5	203.2	169.4	130.5
September	11.7	15.3	4.5	11.3	19.7	5.7	31.1	41.2	42.5	41.4	??
October			1.5				0.3	1.8			
November											
December											
Sum	11.7	401.7	351.5	334.8	358.0	369.7	433.2	471.18	560.6	514.8	*436.7

Table 2.5. 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). Some of the figures differ from earlier publications due to re-evaluation of data.

and was complete 9 June which is early compared to previous years where snow have disappeared from the ground below the sensor somewhere between 14 June (2004) and 3 July (1999). During the melt period there was a snow event 2-3 June resulting in about 5 cm of new snow upon the old snow in the valley.

At M2, the snow pack was more than 100 cm from 27 December and at M3 snow depth reached 43 cm, but most of the snow at M3 was blown away during a storm 5 January (Figs. 2.4 and 2.5). Snow melt was complete 27 May at M3, whereas snow persisted until 13 June at M2.

Between 22 and 24 May 2005, snow depth were measured along two main transects; one starting from Lomsø following a line along the snow stakes in the valley and another 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 meters and data are available along with GPS positions and altitudes for each point. Preferably, these measurements should be performed prior to spring melt for a calculation of the end of winter snow accumulation in the valley. This year snow melt started between 14 and 19 May at the meteorological station, – illustrating the importance of being able to start the field season earlier than beginning of June.

In Table 2.8, snow depth at the end of May is given as highest daily average in the period from 21-31 May at some fixed positions representing a transect through the main study area in the valley (Fig. 2.1).

Snow density

Snow densities were measured 20 May at all permanent soil sites covered by snow in order to calculate snow water equivalent (SWE). The soil plots; Dry-1 and Sal-1 were free of snow when we arrived. In the

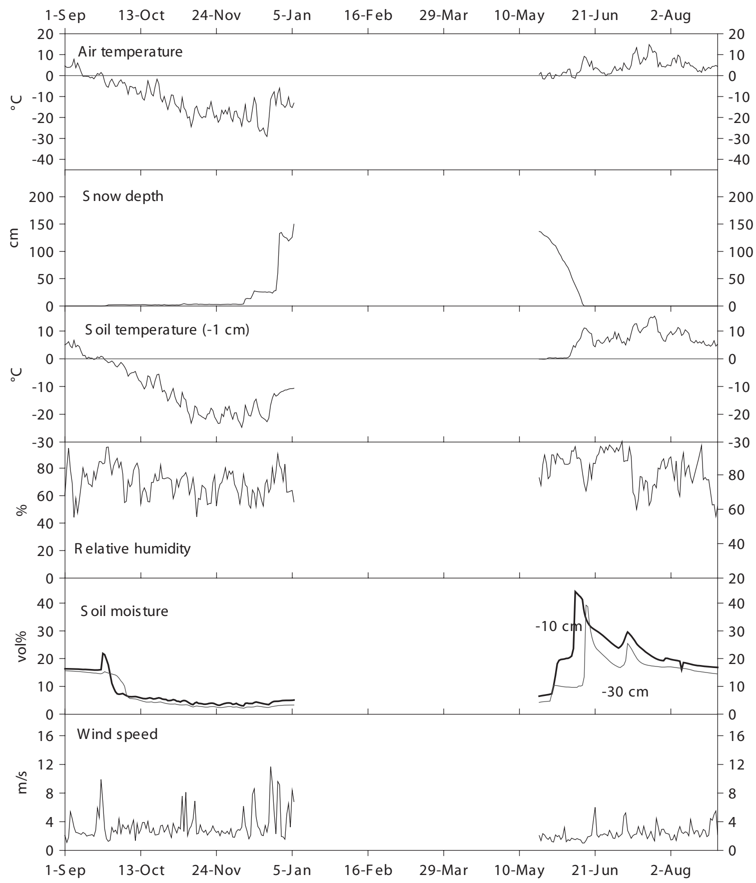


Fig. 2.4. Daily mean values of selected parameters from snow- and micrometeorological station M2 (17 m a.s.l.) from September 2004 to August 2005. From above: Air temperature, snow depth, soil temperature 1 cm below surface, relative humidity, soil moisture 10 cm and 30 cm below surface, and wind speed. Due to malfunction, no data are obtained in the period from 6 January to 20 May.

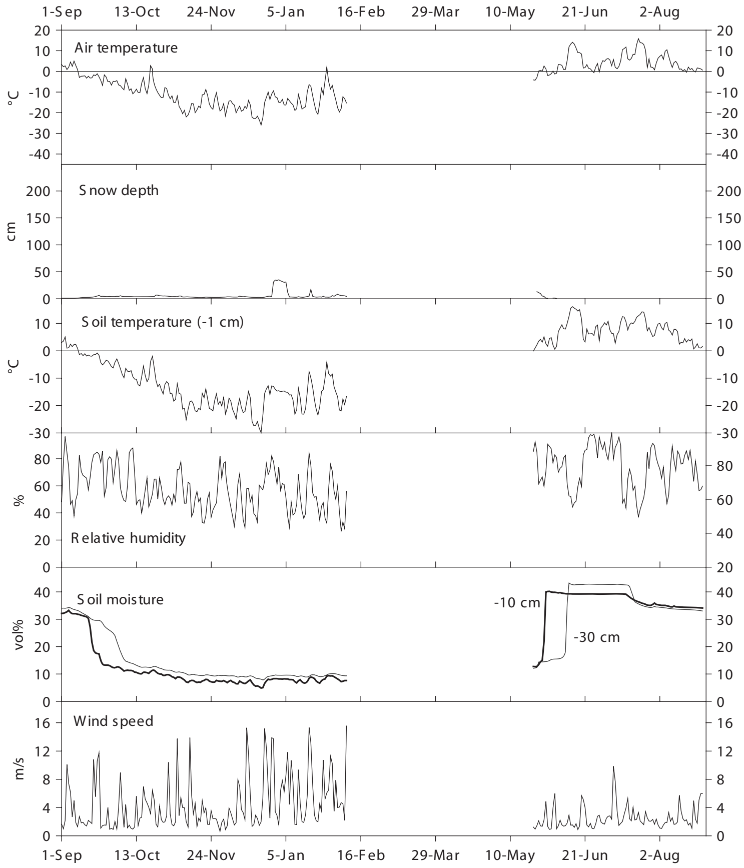


Fig. 2.5. Daily mean values of selected parameters from snow- and micrometeorological station M3 (420 m a.s.l.) in the period September 2004 to August 2005. From above: Air temperature, snow depth, soil temperature 1 cm below surface, relative humidity, soil moisture 10 cm and 30 cm below surface, and wind speed. Due to malfunction, no data are obtained in the period from 8 February to 22 May.

active layer monitoring site ZEROCALM-1, densities were measured on a regular basis throughout the ablation period. Finally, densities were measured 22 May and 5 June along the west facing slope of Aucellabjerg at altitudes of 90, 200, 300 and 400 m a.s.l.

In the seasonal snow patch in ZEROCALM-2, a profile of 235 cm was excavated 23 May and densities were measured for layers of 25 cm. At that time, the snow had become isothermal and a thin layer of basal ice was observed. Several ice layers were present throughout the snow as a result of several episodes with positive temperatures during winter.

Snow cover

The extent of spring snow cover at Zackenberg was the lowest recorded during our 10 years of monitoring (Table 2.9). On 10 June, the snow cover was way below previous years in most sub-zones in Zackenbergdalen, and only in sub-zone 12, the coverage was close to average. Snow cover was particularly limited below 150 m a.s.l. On the other hand, snow depth at the beginning of the melt season in the second half of May was not much different from several other years (Table 2.8). This indicates, that it was the record high spring temperatures, which caused the rapid snow melt.

Photos from the digital cameras on Nansenblokken (477 m a.s.l. on the east facing slope of Zackenberg) has not yet been analysed and therefore a snow depletion curve for 2005 will not be presented in this annual report. However, photos exist and will be analyzed and presented in the next annual report. Fig. 2.8 show the view from Nansenblokken 3 June 2005, where

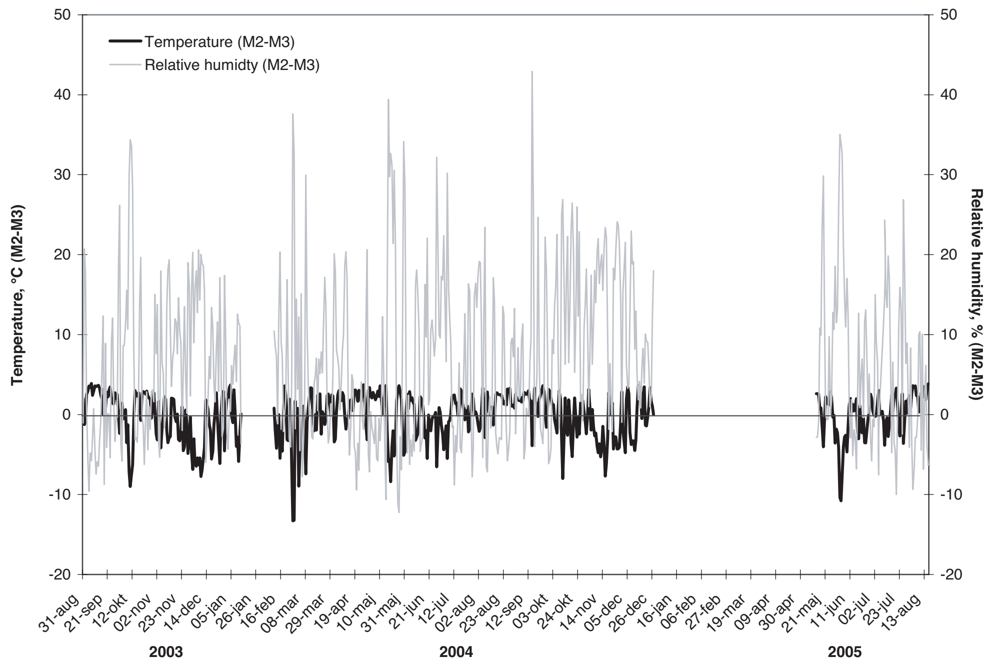


Fig. 2.6. The difference in mean daily air temperature and relative humidity between M2 and M3. Positive values indicate lower temperature/relative humidity at M3 than at M2 whereas negative values indicate higher temperature/relative humidity at M3 than at M2.

M2		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 %
Sep	2003	2.6	68.2	0.6	1.1	1.6	1.4	0.4	12.4	12.3
Oct	2003	3.0	72.1	–8.7	–8.3	–6.8	–4.3	–1.8	4.8	4.6
Nov	2003	4.5	76.1	–12.9	–13.1	–12.1	–10.2	–6.9	4.0	3.2
Dec	2003	2.9	65.2	–23.9	–9.2	–8.9	–8.2	–7.2	4.4	3.3
Jan	2004	(3.8)	(–65)	(–20.7)	(–9.8)	(–9.4)	(–8.7)	(–7.5)	(4.3)	(3.3)
Feb	2004									
Mar	2004	3.0	75.8	–17.3	–11.1	–10.7	–10.1	–9.0	4.1	3.1
Apr	2004	3.8	78.4	–7.9	–8.9	–8.9	–8.7	–8.3	4.3	3.2
May	2004	2.6	79.0	–4.3	–5.6	–5.9	–6.4	–6.8	4.6	3.5
Jun	2004	2.1	82.7	2.2	3.7	2.5	0.6	–1.6	27.1	17.5
Jul	2004	2.5	77.0	6.8	9.8	8.4	5.6	0.7	20.0	17.1
Aug	2004	2.2	80.0	5.6	7.9	7.1	5.1	1.6	17.2	16.2
Sep	2004	3.1	76.0	0.1	1.2	1.5	1.3	0.5	15.3	14.9
Oct	2004	3.0	69.3	–7.9	–8.1	–7.0	–4.6	–1.7	5.9	5.2
Nov	2004	3.2	66.4	–17.6	–19.1	–17.9	–15.0	–9.7	4.0	2.8
Dec	2004	4.1	67.6	–18.0	–18.1	–17.4	–15.7	–12.4	4.0	2.7
Jun	2005	2.1	85.9	2.5	5.4	3.9	1.7	–1.1	29.2	17.6
Jul	2005	2.6	77.1	6.8	9.8	8.5	6.1	1.3	23.5	18.6

M3		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 %
Sep	2003	3.0	69.2	–1.8	–1.1	0.4	0.9	0.6	23.7	28.2
Oct	2003	3.1	63.6	–8.7	–8.7	–6.0	–4.0	–1.9	10.6	13.4
Nov	2003	4.7	70.0	–13.0	–11.6	–10.3	–9.1	–7.5	9.4	11.5
Dec	2003	2.5	55.2	–20.6	–18.7	–16.9	–15.2	–12.7	7.7	10.2
Jan	2004	(5.2)	(62.1)	(–19.3)	(–19.6)	(–18.3)	(–17.3)	(–15.6)	(7.2)	(9.8)
Feb	2004									
Mar	2004	3.7	69.3	–15.6	–16.9	–17.0	–16.9	–16.4	7.4	9.6
Apr	2004	5.3	73.1	–9.0	–10.5	–11.3	–11.9	–12.6	9.1	10.7
May	2004	2.6	72.7	–4.9	–2.9	–4.8	–6.0	–7.4	14.5	12.6
Jun	2004	2.2	78.0	2.4	8.3	6.1	2.5	–0.9	43.9	39.3
Jul	2004	2.5	67.5	7.3	9.8	8.6	6.4	3.2	35.4	36.2
Aug	2004	2.1	73.8	4.9	6.6	6.1	4.9	3.0	33.6	37.4
Sep	2004	3.5	70.3	–1.6	–1.3	0.3	0.6	0.4	23.9	30.5
Oct	2004	3.4	58.7	–7.9	–9.4	–6.3	–4.0	–1.8	10.8	13.6
Nov	2004	3.5	53.5	–16.0	–18.9	–16.6	–14.4	–11.4	7.7	9.9
Dec	2004	5.2	56.0	–17.1	–19.9	–18.8	–17.6	–15.7	7.0	9.0
Jan	2005	6.4	51.4	–12.7	–15.5	–15.3	–15.0	–14.3	8.0	9.5
Jun	2005	2.1	76.5	4.0	8.3	6.0	2.2	–1.2	39.4	33.5
Jul	2005	2.9	71.9	6.8	9.3	8.4	6.1	3.0	37.6	39.2

Table 2.6. Monthly mean values of selected meteorological parameters from M2 (17 m a.s.l.) and M3 (420 m a.s.l.) from September 2003 to July 2005. Values from January 2004 are in brackets as they are based on data from 1-27 January for M2 and 1-23 January for M3. Due to malfunction, no data were obtained from 6 January to 20 May 2005 at M2 and from 8 February to 22 May 2005 at M3.

large parts of the landscape is already free of snow. Unfortunately, the long period with low clouds and foggy weather from 20 June to 11 July results in lack of sight, and information.

The NDVI-camera was installed 25 May and captured two daily photos until 23 August where it was removed and the digital cameras emptied for the last time during the 2005 season. The digital camera

	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005
Max. snow depth, meter	0.88	1.3	0.49	0.68	1.33	0.6	0.69	0.73
Max. snow depth reached	29 Apr	11 Mar	19 May	25 Mar	15 Apr	13 Apr	13 Apr	12 Feb
Snow depth exceeds 0.1m from	19 Nov	27 Oct	1 Jan	16 Nov	19 Nov	6 Dec	24 Nov	27 Dec
Snow depth is below 0.1m from	25 Jun	3 Jul	14 Jun	24 Jun	20 Jun	14 Jun	13 Jun	7 Jun

Table 2.7. Key figures describing the amount of snow in the last eight winters; the maximum snow depth during the winter and the date at which it is reached, the date when the snow depth reaches 0.1 m in the beginning of the winter, and the date in spring when the depth gets below 0.1 m due to melting.

	1998	1999	2000	2001	2002	2003	2004	2005
Hy st	–	>101	44	79	131	–	–	47
M2	–	–	–	–	–	–	172	170
St 2	–	–	–	177	265	197	188	180
St 3	–	–	–	–	205	91	155	149
Climate St.	81	118	48	61	110	50	55	52
St 5	–	–	–	–	–	50	61	57
St 6	–	–	–	–	90	33	32	51
M3	–	–	–	–	–	–	6	14

Table 2.8. Snow depth at eight permanent positions in Zackenbergdalen in late May given as the highest daily average during 21-31 May. Data from M2 has been enhanced by 25 cm to compensate for a hollow under the sensor.

covering the central part of the valley (camera 2) was replaced 30 June with a new model (KODAK, RDC 365 ver.2).

Ice melting on ponds and lakes

The average air temperature during early spring, *i.e.* 21 May – 10 June, was positive (0.13°C) only for the second time during our study years, but not as warm as in the all time record warm spring of 2002 (1.17°C). But 2002 had much deeper snow (Table 2.8 and Fig. 2.7) so that the high temperatures in 2005 resulted in record early and fast snow and ice melt. Hence, the ice on the ponds north and south of the research station disappeared much earlier than recorded before during our 10 years of observations (Table 2.10). Already in late May, all ponds in Gadekæret and Sydkærene were free of ice, which is 1-4 weeks earlier than previous years. Also Lomsø became ice free much earlier than before (Table 2.10), *i.e.* five days earlier than hitherto recorded, in 2004, and more than three weeks earlier than the late year of 1999. Also, the two monitored lakes in Morænebakkerne; Langemandssø and Sommerfuglesø, melted much earlier than recorded before (see chapter 3.7). Store Sø was free of ice on 11 July.

Teltdammen was dry already on 12 June, and in mid July the ponds in Gadekæret and Sydkærene began to dry out. Such dry conditions have only been recorded in similar early snowmelt and dry years like 2000 and 2003; see also Table 2.2 and Fig. 2.7. Since there was rain in late July and August, most ponds never

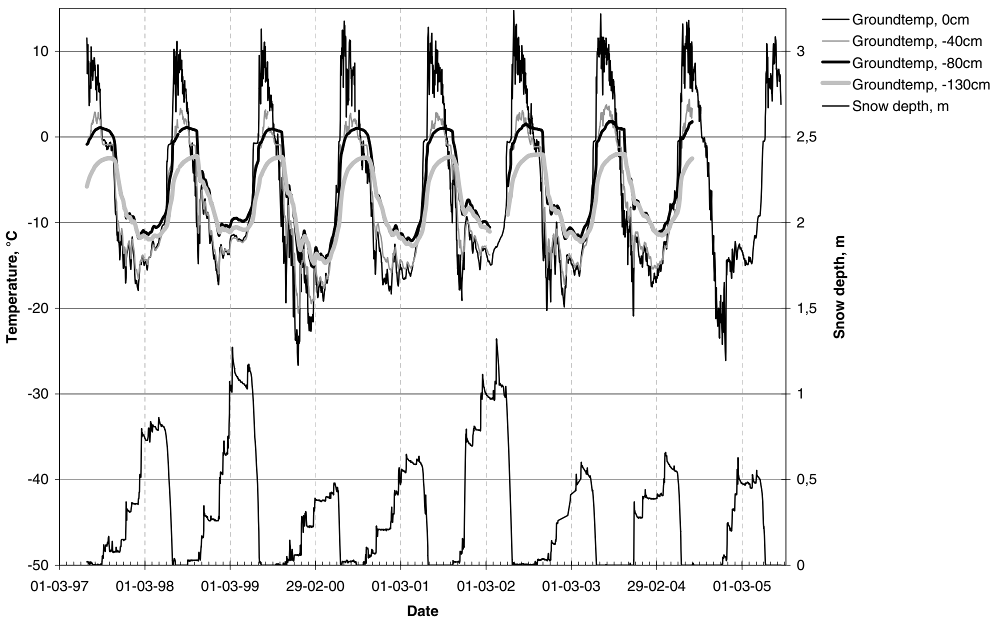


Fig. 2.7. Daily mean temperatures at surface of the ground and at 40 cm, 80 cm and 130 cm below the surface. The snow depth is shown in the lower half of the figure.

Section	Area (km²)	Area hidden (%)	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
1 (0-50 m)	3.52	3.5	78	74	65	77	91	60	73	77	68	48	31	67
2 (0-50 m)	7.97	1.2	89	88	90	85	91	57	87	87	92	49	25	76
3 (50-150 m)	3.52	0.0	88	81	83	83	94	51	89	82	83	51	35	74
4 (150-300 m)	2.62	0.0	73	74	68	66	86	33	79	56	73	39	28	61
5 (300-600 m)	2.17	0.0	16	54	73	43	85	31	56	36	49	16	25	44
6 (50-150 m)	2.15	75.3	86	86	84	87	98	55	84	78	74	56	50	76
7 (150-300 m)	3.36	69.3	90	81	76	90	97	54	84	74	90	56	46	76
8 (300-600 m)	4.56	27.5	49	55	66	64	84	37	45	52	66	30	29	52
9 (0-50 m)	5.01	6.2	92	87	96	91	97	54	96	96	100	58	23	81
10 (50-150 m)	3.84	2.9	94	85	95	97	98	60	97	93	100	56	47	84
11 (150-300 m)	3.18	0.2	91	72	86	92	96	77*	97	88	100	66	61	85
12 (300-600 m)	3.82	0.0	40	66	89	68	89	65	73	65	98	53	70	70
13 (Lemmings)	2.05	1.0	89	80	76	80	87	58	83	83	89	46	25	72
Total area	45.70	12.9	76	77	81	80	92	54	82	77	83	49	37	72

* Partly cloud covered, giving too high snow cover

Table 2.9. Area size and snow cover on 10 June in 13 bird and mammal study sections in Zackenbergdalen and on the slopes of Aucellabjerg 1995-2005 (see Fig. 4.1 in Caning and Rasch 2003 for map of sections). Photos were taken from a fixed point 477 m a.s.l. on the east facing slope of Zackenbergfjeldet within +/- 3 days of 10 June and extrapolated according to the methods described by Pedersen and Hinkler (2000). Furthermore, the proportions of the areas not visible from the photo point are given. Data from 1995 and 1996 are from satellite images taken on 9 and 11 June, respectively.

dried up completely, but by late August, the "West pond" in Gadekæret was dry.

New ice formed on small streams in late August, but no ice was recorded on ponds.

Active layer depth

Development of the active layer (the layer above the permafrost that annually experiences freeze and thaw) starts as soon as snow disappears from the ground. The thaw rate was monitored throughout the season at two grid-plots; the homogenous ZEROCALM-1 grid (ZC-1) and the heteorogeneous ZEROCALM-2 grid (ZC-2). A detailed description of the two sites was given in section 5.1.12 in Meltofte and Thing (1997). In ZC-1, the first grid node was free of snow 1 June and snow melt was complete 15 June. The active layer had started to develop in 40 out of 208 grid nodes in ZC-2 when we arrived on 20 May and the maximum thaw depth had already reached 40 cm. The seasonal snow patch, that affect the melt rate in ZC-2, disappeared 14 July which is three days earlier than in 2004 and the earliest date observed so far. Figs. 2.9 and 2.10 show the seasonal development of the active layer in ZC-1 and ZC-2, respectively. At the end of the season, when thaw depth is close to maximum, the active layer in ZC-1 reached an average depth of 79 cm and in ZC-2 an average depth of 68 cm. For both sites, this is the deepest ever measured since monitoring began in 1997 (Table 2.11). Variations of up to 20-25 cm in the average maximum thaw depth have been observed during the ten years. The lowest development of the active layer was measured in 1999 when completion of snow melt was between three and four weeks later than in 2005.

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

Data from the ZEROCALM-sites are reported to the circumpolar monitoring programme CALM (Circumpolar Active Layer Monitoring-Network-II (2004-2008) that is maintained by the University of Delaware, Center for International Studies (www.udel.edu/Geography/calm).

Point measurements of thaw depth pro-

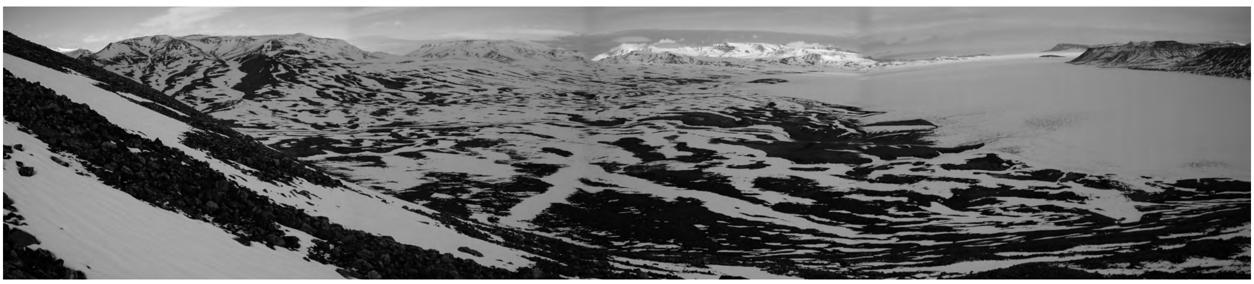


Fig. 2.8. The view from Nansenblokken 3 June 2005.

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

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 1995-2003. "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 and in the fiord in general. The 50% ice cover date for Lomsø is tentative, as it is estimated from the research station.

gression are also measured throughout the season at all the soil water sites.

Soil temperature

Soil temperatures from the climate station are not presented in this annual report due to malfunction of some of the buried temperature sensors. The soil temperature profile at the climate station is planned to be replaced by ASIAQ in August 2006.

Monthly mean soil temperatures from M2 and M3 are given in Table 2.6. At these stations soil temperatures are measured continuously at 1 cm, 10 cm, 30 cm and 60 cm below the soil surface. Mean daily soil temperatures near the soil surface are shown in Figs 2.4 and 2.5. The warmer soil at M2 is a result of the isolating effect from the large seasonal snow patch.

Temperature in different settings and altitudes

GeoBasis operates a total of 40 TinyTag dataloggers for temperature monitoring in different altitudes and different geomorphological settings in the periglacial landscape of Zackenberg. Positions of sites are given in Table 3.1 in Caning and Rasch (2001) and in Fig. 2.1.

During the winter 2004/2005 arctic foxes had eaten a lot of the installations. All together 12 out of the 40 TinyTags had cables and sensors chewed by foxes, and at the soil profiles P1, P6 and Sal-2 new sensors had to be installed.

Annual mean temperatures in the period 1996-2004 are given in Table 2.12. Due to periodic failures, it has not been possible to calculate annual statistic for all loggers. However, data exist during a greater part of the year for several of these loggers. The new TinyTag installed in 2004 on top of Domebjerget (1278 m a.s.l.) show low temperatures in September and October compared to the Climate station (40 m a.s.l.) and M3 (420 m a.s.l.), but at several occasions during February, March and April, the mean diurnal temperatures were way above the temperatures measured at lower altitudes (Fig. 2.11) and

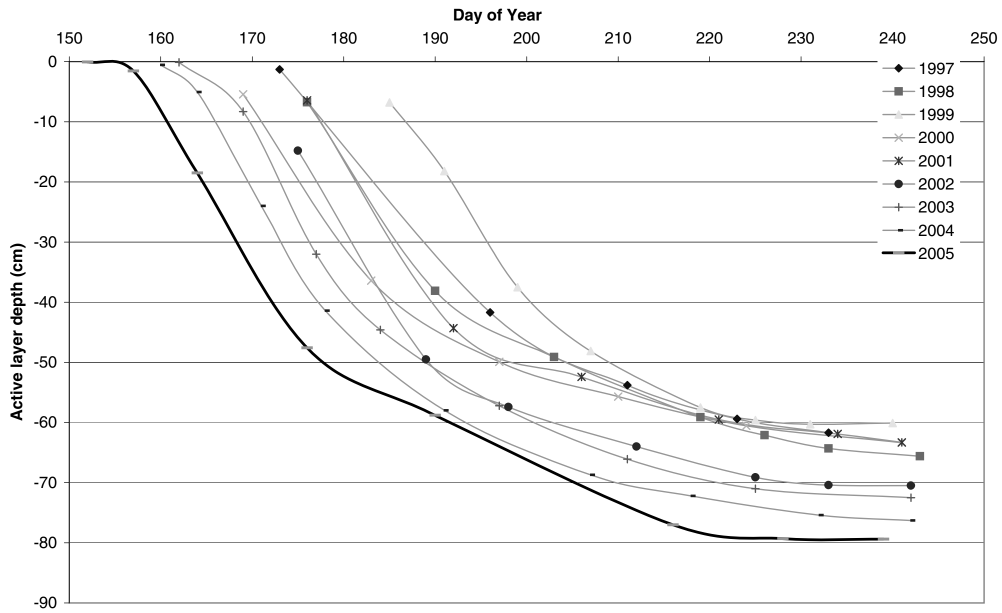


Fig. 2.9. Thaw depth progression in ZEROCALM-1, 1997-2005.

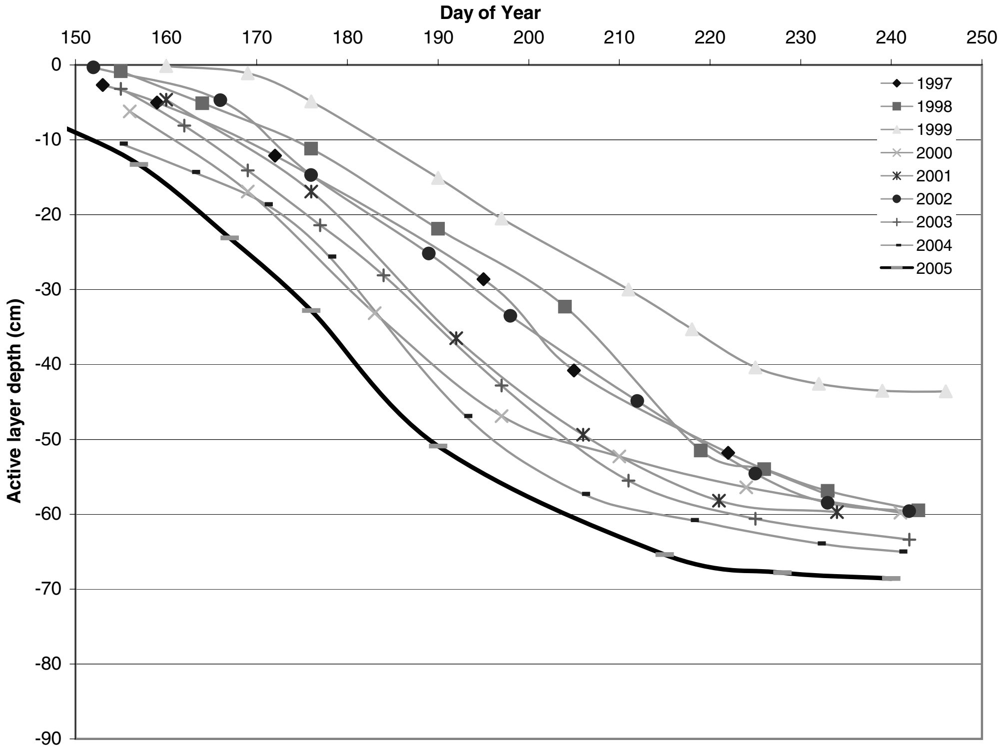


Fig. 2.10. Thaw depth progression in ZERO-CALM-2, 1997-2005.

positive degree days were measured in February (9.5) and April (3.8). In 2006, it is planned to install a meteorological station at Domebjerget in order to collect more climatic variables from this altitude.

Break up of the fjord ice in Young Sund

On 31 May, the ice edge off Young Sund was observed to be many kilometres east of the fiord mouth and no open water was present around Sandøen. But already on 16 June there was open water between the island and the mainland coast, and a large open water area covered almost the whole width of the fjord towards Clavering Ø. In mid June, open water began to form in the fiord ice off the rivers, and the fiord ice between Zackenbergdalen and Clavering Ø broke up during 30 June – 3 July. Already on 7 July, the ice had broken up all the way out to the sea. This is in line with the conditions during the three previous record early years (Table 2.10).

Drifting pack ice entered the fjord on 10 July, where it remained for about two weeks. Again on 8 August, much drift ice entered the outer part of Young Sund, whereas very little drift ice occurred during the rest of the season.

2.3 River water discharge and chemistry

Spring break up of Zackenbergelven and secondary streams

Water began to run in Zackenbergelven 3 June 2005, which is not exceptionally early even though the spring temperatures were higher than the previous years (Table 2.2). Clear melt water was running in a small channel in the snow and ice covered bed and during the following week the stream increased gradually. The first water came from Lindemansdalen and when a small flood passed the station 5 June it was probably due to water entering from Store Sødal. The first water samples from the tributaries to Zackenbergelven were collected 7 June (Table 2.14). At that time, water was running in channels in the snow from Aucellabjerg and just starting to run

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

Table 2.11. Maximum active layer depth in ZEROCALM-1 and ZERO-CALM-2 measured late August, 1997-2005.

	Tiny Tag Site	Elevation m a.s.l.	1996 °C	1997 °C	1998 °C	1999 °C	2000 °C	2001 °C	2002 °C	2003 °C	2004 °C
Ground temperature profile	**P1**										
	0 cm	20	–7.7	–9.8	–9.1	–9.3	–	–	–8.3	–9.3	–
	10 cm	20	–	–9.6	–8.8	–8.7	–9.4	–8.7	–7.5	–8.7	–
	50 cm	20	–6.7	–9.0	–8.3	–8.3	–9.0	–8.7	–7.8	–8.4	–
	118 cm	20	–5.9	–8.1	–7.8	–8.0	–8.1	–8.3	–7.5	–7.4	–
Ground temperature profile	**P3**										
	0 cm	420	–6.2	–9.6	–7.6	–10.5	–8.3	–9.6	–7.6	–7.7	–7.5
	10 cm	420	–5.9	–8.6	–	–9.0	–7.5	–9.0	–	NV	–6.9
	66 cm	420	–5.5	–8.7	–	–	–7.4	–8.5	–6.9	–6.5	–6.9
Ground temperature profile	**P4**										
	0 cm	820	–8.5	–10.7	–8.2	–10.9	–	–9.5	–5.7	–8.2	–10.3
	10 cm	820	–8.0	–10.5	–8.0	–10.4	–9.2	–9.4	–8.4	–9.2	–
	85 cm	820	–7.6	–10.4	–8.6	–9.7	–9.4	–9.5	–8.6	–8.9	–8.9
Ground temperature profile	**P5**										
	0 cm	260	–	–9.2	–	–9.9	–	–9.4	–8.2	–8.6	–7.3
	75 cm	260	–	–8.9	–	–9.2	–	–	–7.8	–8.2	–7.8
	140 cm	260	–	–8.6	–	–14.8	–	–	–	NV	NV
Ground temperature profile	P6										
	0 cm ny	11	–	–10.1	–9.5	–8.2	–	–9.1	–7.4	–8.7	–7.8
	10 cm	11	–	–9.9	–	–	–	–8.7	–7.2	–7.8	–7.4
	30 cm	11	–	–	–	–	–	–9.1	–7.7	–7.8	–7.9
	50 cm	11	–	–	–	–	–	–9.1	–7.9	–7.3	–8.0
Temperature in snow patch	**S1**										
	Plateau above	29	–8.1	–	–12.5	–10.0	–10.0	–9.3	–8.5	–8.4	–7.8
	Slope high	25	–	–	–5.8	–6.5	–5.3	–5.4	–4.3	–4.5	–5.8
	Slope low	23	–5.9	–	–	–	–	–5.5	–4.5	–5.4	–6.7
	Plateau below	16	–	–	–8.0	–13.0	–11.7	–9.9	–8.2	–9.4	–9.9
Air temperature in Morænebakkerne	**T1**										
	air, 5 cm	85	–7.3	–9.8	–9.2	–9.8	–10.2	–10.0	–8.9	–9.9	–8.4
Air temperature in Store Sødal	**T2**										
	air, 5 cm	129	–7.9	–10.3	–9.8	–11.1	–10.0	–10.5	–9.3	–9.8	–
Air temperature on Aucellabjerg	**T3**										
	air, 5 cm	965	–9.2	–	–10.2	–	–	–	–	–10.7	–10.0
Water temperature in Gadekæret	**V2**										
	water	35	–10.8	–8.0	–	–	–	–	–6.0	–8.1	–7.9
Air temperature on Nansenblokken	**T4**										
	air	480								–6.7	–6.6
	Dry2										
Ground temperature	0 cm	45								–5.4	–
	15 cm									–5.7	–
	Sal1										
Ground temperature	0 cm	36								–7.3	–7.1
	15 cm									–7.9	–7.6

Table 2.12. Annual mean temperatures from Tiny-Tags operated by GeoBasis.

in the rivulets from Palnatokebjerg (Table 2.10). Water from Store Sødal was running in a wide and diffuse pattern on the snow and it was still possible to wade/cross it.

Zackenbergelven

The hydrological measurements started at Zackenbergelven in 1995. The drainage basin for Zackenbergelven includes Zackenbergdalen, Store Sødal, Lindemansdalen

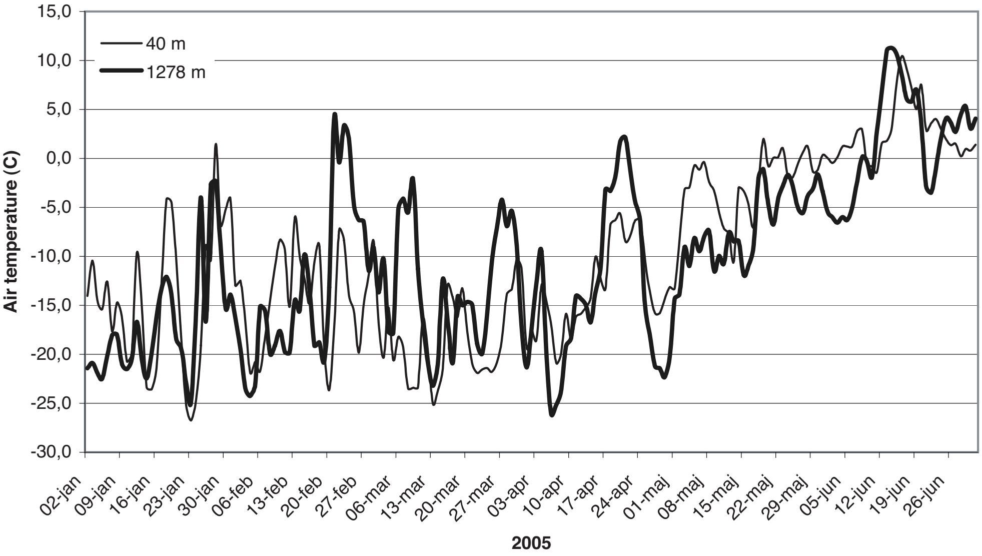


Fig. 2.11. Diurnal mean temperatures 2 m above ground measured at the climate station (40 m a.s.l.) and on top of Domebjerget (1278 m a.s.l.) from 1 January to 1 July 2005.

and Slettedalen (Fig. 2.12). The basin covers an area of 514 km^2, of which 106 km^2 are covered by glaciers.

The hydrometric station was established at the lower part of the river, at the west side (Meltofte & Thing 1996). In 1998 the hydrometric station was moved to the eastern bank of the river, due to problems with the station being buried beneath a thick snowdrift each winter.

At the station, the water level, water temperature, and air temperature are logged 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 2005 is only based on data from the sonic range sensor. The measured water level is recalculated to meter above sea level, which can be transformed to a discharge using an established relation between water level and discharge (a Q/h-relation).

At the moment, discharge data can only be shown until 25 July 2005 when the hydrometric station was washed away in a flood (Figs. 2.13 and 2.14). In the period right after the flood, water level was measured manually at a new installed stage-level several times a day. Fortunately, it was planned to set up a new hydrometric station anyway, so when technicians from ASIAQ arrived, they were able to install a new hydrometric station and data was collected automatically from 5 August.

Q/h-relation

Discharges and corresponding water levels have been manually measured by use of a current meter in the field seasons from 1995 to 2005. The function that describes the relation between water level and discharge is shown in Fig. 2.12 in Rasch and Caning (2005) The Q/h-relation is based on discharge measurements performed in the years 1995 to 1998, at discharges ranging from 5.98 to 70 m^3/s. The good correlation of the data and the Q/h-relation indi-

Table 2.13. Total and monthly discharge in Zackenbergelven in the years 1996-2005, corresponding water loss for the drainage area (514 km^2) and precipitation measured at the climate station. [1)] The hydrological year is from 1 October previous year to 30 September present year. [*)] For 2005, data is only available until 25 July at present.

Hydrological year[1]	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Total Discharge, mill m^3	132	188	232	181	150	137	338	189	212	>143*
June	43	45	50	41	41	53	143	71	46	66
July	67	80	98	123	61	47	150	71	100	??
August	21	61	78	17	47	34	46	43	64	??
September	1	2	4	0	0	3	0	4	2	??
Water loss, mm	257	366	451	352	292	267	658	368	412	>278
Precipitation, mm	239	263	255	227	171	240	156	184	279	258
Total annual transport										
Suspended sediment (ton)		29,444	130,133	18,716	16,129	16,883	60,079	18,229	21,860	28,328*
Suspended organic matter (ton)		1,643	11,510	2,297	1,247	1,098	3,267	1,351	1,388	1,427*

Table 2.14. Suspended sediment, organic matter in percent of total suspended sediment, conductivity and DOC, NH_4-N and DTN in water sampled from main tributaries to Zackenbergelven (streams from Store Sødal, Lindeman, PalnatokeNW, PalnatokeE, AucellaN, AucellaS and Rylekær. ND= No data.

Suspended sediment (mg/l)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
7 Jun	35	113	ND	26	487	65	4
20 Jun	40	110	108	6	33	728	<2
4 Jul	59	61	4,997	9	161	4,069	<2
17 Jul	76	110	210	<2	7	701	<2
29 Jul	450	155	840	Dry	6	1,086	<2
12 Aug	316	15	714	Dry	Dry	929	Dry
26 Aug	202	<2	13	Dry	Dry	10	Dry

Organic matter as part of total suspended sediment (%)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
7 Jun	23	8	ND	17	5	11	ND
20 Jun	11	9	10	52	15	14	ND
4 Jul	8		5	47	10	6	ND
17 Jul	7		17		47	7	ND
29 Jul	4	8	8	Dry	42	8	ND
12 Aug	4	5	7	Dry	Dry	8	ND
26 Aug	5	23	29	Dry	Dry	35	ND

Conductivity (µS/cm)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
7 Jun	7.4	102.0	51.4	38.0	68.8	94.7	34.4
20 Jun	8.4	36.8	27.6	25.1	36.4	66.2	42.7
4 Jul	8.8	37.1	29.6	54.1	64.5	77.9	56.1
17 Jul	9.0	84.0	43.2	120.7	173.5	136.3	65.1
29 Jul	10.5	93.1	42.9	Dry	209.0	160.8	59.0
12 Aug	11.8	159.1	46.0	Dry	Dry	163.2	Dry
26 Aug	10.5	214.9	103.5	Dry	Dry	344.2	Dry

DOC (mg/l)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
7 Jun	9.3	24.2	ND	ND	ND	ND	ND
20 Jun	3.7	2.1	4.7	11.9	21.7	17.3	12.8
4 Jul	17.1	57.2	8.4	2.5	5.8	10.8	112.6
17 Jul	20.9	23.0	14.8	11.0	43.8	13.1	30.8
29 Jul	9.1	10.3	17.2	Dry	15.9	4.4	16.3
12 Aug	1.5	1.2	1.3	Dry	Dry	1.3	Dry
26 Aug	1.6	1.4	1.5	Dry	Dry	1.5	Dry

NH_4-N (µg/l)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
7 Jun	0.0	0.0	ND	ND	ND	ND	ND
20 Jun	0.0	16.7	0.0	0.0	12.8	16.8	3.2
4 Jul	0.0	12.9	30.4	13.7	15.7	14.0	0.8
17 Jul	0.0	0.0	0.0	13.2	16.1	13.5	13.4
29 Jul	47.8	10.0	12.1	Dry	0.1	0.0	15.2
12 Aug	0.0	0.0	0.0	Dry	Dry	0.0	Dry
26 Aug	0.0	0.0	15.1	Dry	Dry	0.0	Dry

DTN (µg/l)

	Store Sødal	Lindeman	PalnatokeNW	PalnatokeE	AucellaN	AucellaS	Rylekær
7 Jun	306.2	437.5	ND	ND	ND	ND	ND
20 Jun	160.0	182.9	446.4	370.5	322.7	357.9	453.0
4 Jul	300.1	201.7	520.9	133.2	142.6	165.6	204.4
17 Jul	91.6	69.3	157.8	270.7	124.7	362.2	270.3
29 Jul	597.7	170.4	ND	Dry	228.8	251.3	ND
12 Aug	368.0	319.4	339.4	Dry	Dry	230.6	Dry
26 Aug	370.0	130.1	258.2	Dry	Dry	290.7	Dry

cates that the cross profile at the hydrometric station was stable in the period 1995 to 1998. Manual discharge measurements in 1999 – 2004 support that the cross profile has been stable in the last years, too. In 2005, manual discharge measurements were only conducted while the river was not at full size and therefore it can only be assumed, that the cross profile has been stable until it was washed away. The Q/h-relation is only valid when the riverbed and -banks are ice- and snow free, as 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. As a consequence of the flood, large changes in the river cross profile occurred (Fig. 2.15) and the Q/h-relation used so far is therefore not valid anymore. A new Q/h-relation has not been established yet but after the field season 2006, we should have enough new manual discharge measurements to be able to establish a new relation and present the total discharge from 2005.

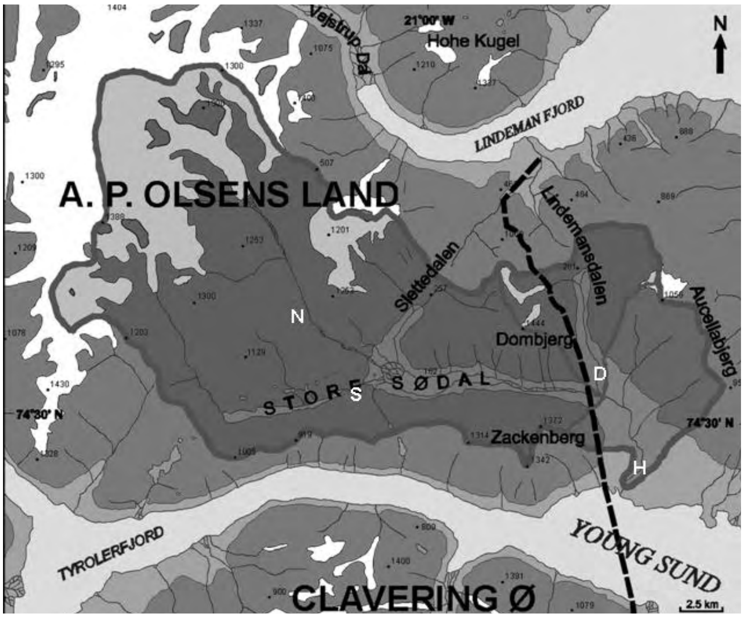
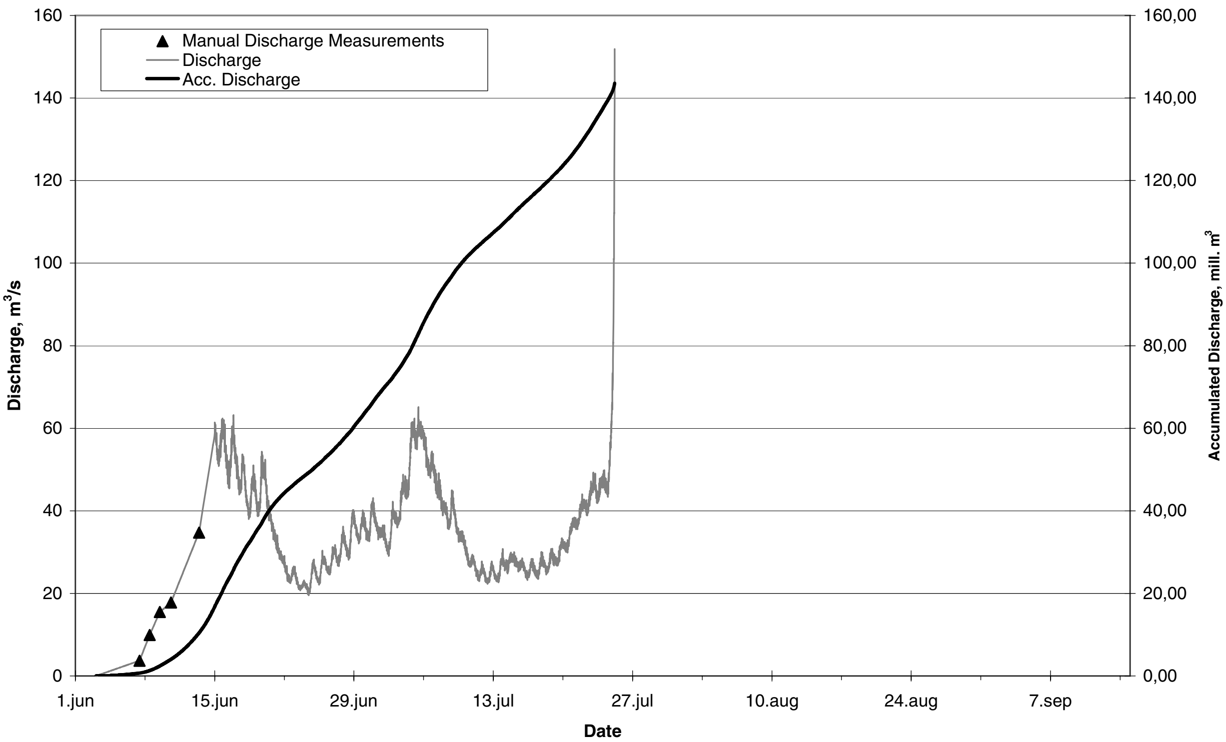


Fig. 2.12. The drainage basin of Zackenbergelven. H=Hydrometric station, D=Diver station, N= StreamN, S=StreamS.

River water discharge

Total discharge in 2004 has now been updated (Table 2.13) and data show, that the last measurement of running water in Zackenbergelven was 12 September 2004. The water discharge in Zackenbergelven until 25 July 2005 is shown in Fig. 2.13. In the first period – from the river started flowing 3 June and until 15 June – the riverbed and -banks were covered in ice and/or snow and the Q/h-relation therefore not valid. Instead, the discharge in these days is approximated by letting the discharge increase linear from zero to the discharge found at the manual measurement 7 June, and again by linear interpolation between the manual measurement on

Fig. 2.13. Discharge in Zackenbergelven during summer 2005.



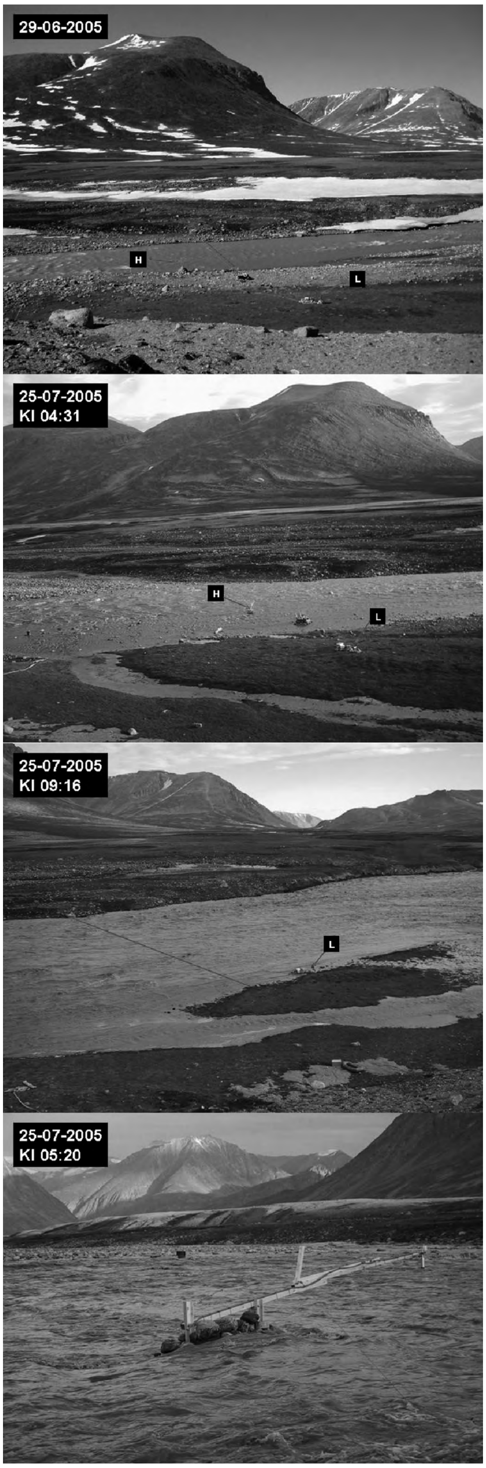


Fig. 2.14. Zackenbergelven was flooded on 25 July 2005. One month earlier the size of the river at the cross section was c. 38 m, but during the flood the size increased to c. 100 m and the hydrometric station was flushed away. H = hydrometric station; L = datalogger and power supply. (Photos PolarPhotos/Henrik Philipsen).

8 June, 9 June, 10 June, and 13 June. From 13 June until 15 June the increase is also linear until the western bank is free of snow. After 15 June the Q/h-relation is assumed to be valid. The total amount of water drained from the catchment in the period from 3 June until 25 July was approximately 143 million m^3. This amount is a bit more than for the same period in 2004, when it was 129 million m^3. In June, the discharge was mainly controlled by snow melt. After 20 June, the discharge drops significantly due to depletion of snow in the valley and the cold cloudy weather. The peak discharge in early July followed a rainy period. In the evening 24 July, the river suddenly started to increase dramatically. From a normal bank full size where the cross profile at the river crossing is 38 m wide it increased to c.100 m and by 5:30 in the morning 25 July the hydrometric station was flushed away by the pressure of the water. The river was still rising at that time and the absolute maximum was reached around 9 o'clock in the morning (Fig. 2.14). Most likely, a collapse of an ice dammed lake in the glaciers on A.P. Olsen land led to this extraordinary flood event. We know, that water came from the glacier fed stream (Stream N in Fig.2.12) and passed through the lake Store Sø, where the water level increased by more than 1 m.

The total precipitation in the hydrological year 2005 (1 October 2004 to 30 September 2005) was 258 mm at the climate station in Zackenberg.

A distinct diurnal variation in the river discharge is observed in periods with no rain. Maximum discharge measured at the river crossing is close to midnight (22-00) and minimum discharge is close to midday (10-12). The daily discharge amplitude is dampened with exhaustion of the snow pack.

Daily discharge data from Zackenberg are being reported to the Global Runoff Data Centre (GRDC) who maintains and promotes a global database on river discharge (www.grdc.bafg.de).

Suspended sediment

Estimated total annual transport of suspended sediment and organic matter from Zackenbergelven 1997-2004 are given in Table 2.13. The total transport of suspended sediment and organic matter in 2005 can not be estimated before we have the total river discharge from the season. However, in the period from 3 June to 25 July an amount of 28,328 ton suspended sediment was transported from the Zackenberg drainage basin and into Young Sund. Of this amount, organic matter constitutes 1,427 ton. The total transport is based on concentrations measured in water sampled at 08:00 assuming this value can be used as a diurnal mean value. This assumption is likely to cause an un-

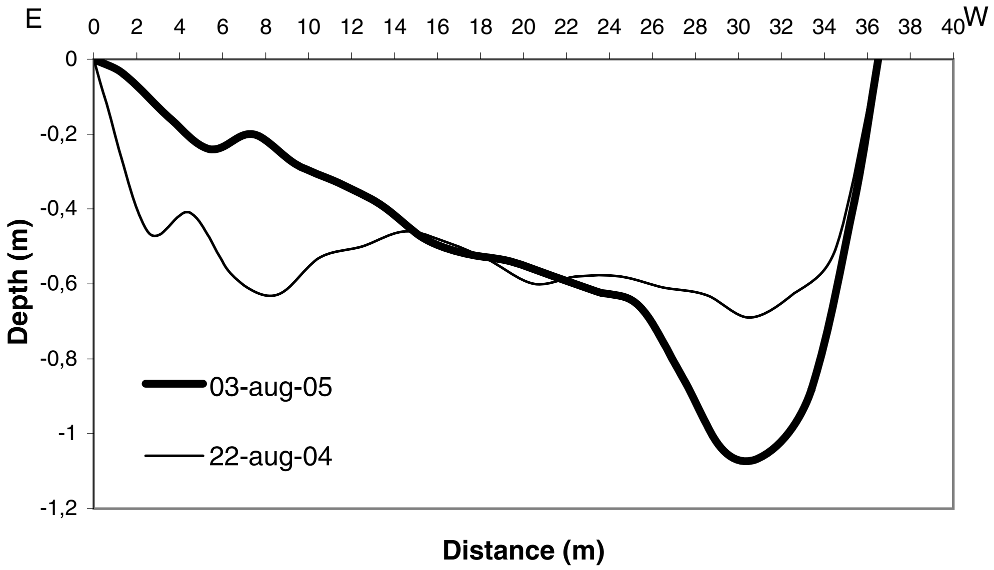


Fig. 2.15. The river cross profile before and after the flood 25 July 2005.

derestimation of the total transport as the suspended sediment concentration often increases during days of fine weather. In Fig. 2.16, crosses represents concentrations in water sampled at 20:00. Especially early in the season the diurnal amplitude is very large.

The highest concentration in 2005 was 5,729 mg/l measured 25 July 8:00 when the flood was close to peak (Fig. 2.14). Concentrations dropped right after the flood but remained above the average level during the rest of the season (Fig. 2.16). The high level of suspended sediment after the flood was likely due to the source of newly exposed sediment caused by the erosion along the river banks (Fig. 2.19). In order to describe the diurnal variation water was sampled every second hour between 7 and 8 August. At that time, the sample from 8:00 was close to the average value.

Suspended sediment has been analysed for organic carbon and organic nitrogen at National Environmental Research Institute in Silkeborg and the ratio of carbon to nitrogen (C/N-ratio) is shown in Fig. 2.16. Right after the flood, the C/N-ratio peaked and the level remained above the early season level for about 20 days. The

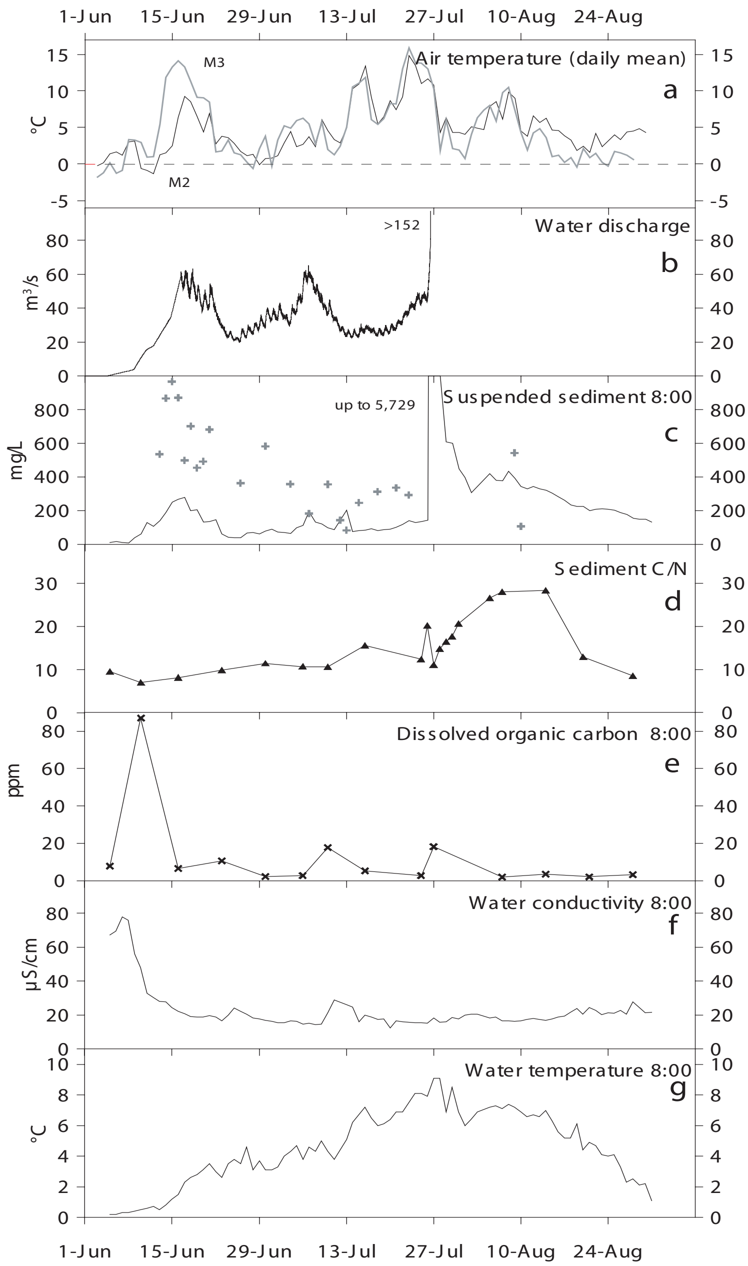


Fig. 2.16. a) Daily mean air temperatures at M3 420 m a.s.l. and at M2 17 m a.s.l. b) water discharge, c) concentration of suspended sediment at 8:00, concentrations at 20:00 is marked by crosses, d) C/N relation in suspended sediment, e) dissolved organic carbon, f) conductivity, and g) water temperature, in Zackenbergelven 2005. Discharge is measured every 15 minutes, whereas all other curves are based on daily measurements performed at 08:00.

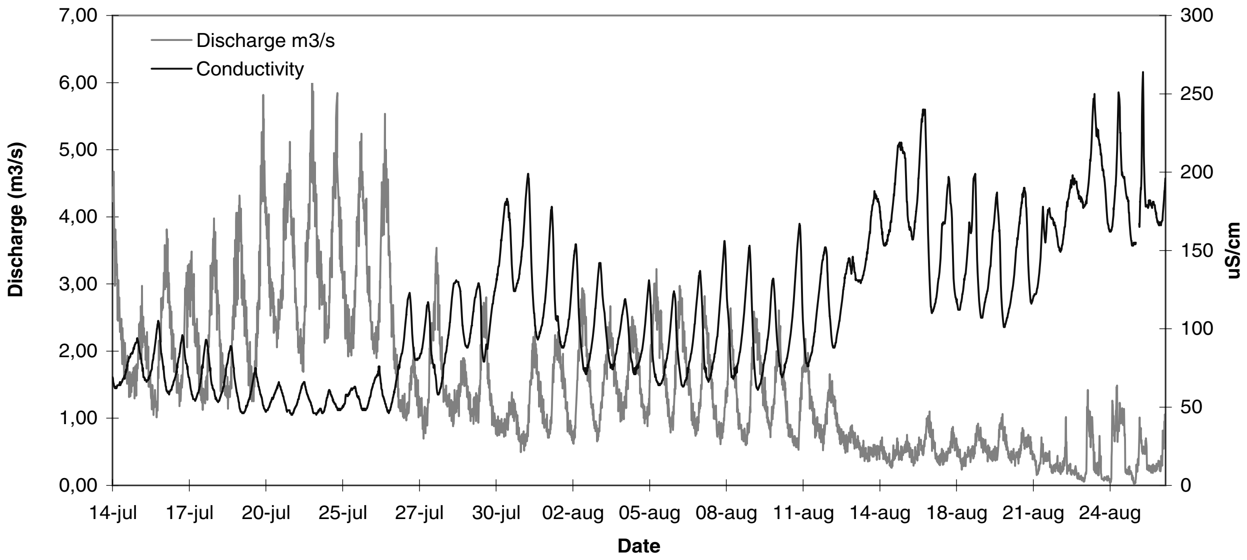


Fig. 2.17. Discharge and conductivity in the river/stream from Lindemansdalen in the period from 14 July to 26 August 2005.

increase reflects a change in source of organic material. Less decomposed organic material with lower nutrient status typically originates from newly exposed soil layers found all along the river after the flood (Fig. 2.19).

River water chemistry

Water was sampled from Zackenbergelven near the hydrometric station every morning at 08:00. Conductivity, water temperature, pH and alkalinity of the river water were measured in Zackenberg and chemical analyses of solute concentrations (Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, Al^{3+}, Mn^{3+}, Cl^-, NO_3^{2-}, SO_4^{2-}) were carried out at Institute of Geography, University of Copenhagen. In addition dissolved organic carbon (DOC), ammonia (NH_4-N) and dissolved total nitrogen (DTN) was analysed in 14 of the samples picked on a regular basis throughout the season. Analyses were carried out at the department for terrestrial ecology at Biological Institute, University of Copenhagen.

Daily variations in conductivity and water temperature in Zackenbergelven are shown in Fig. 2.16. The conductivity was high during the first days, where Zackenbergelven was dominated by water from Lindemanselven and streams from Aucella and Palnatoke as water from the sedimentary part of the basin has a higher conductivity than water from Store Sødal (Table 2.14). As water from Store Sødal increased, the conductivity dropped as a response to the diluting effect. Water from Store Sødal, normally have constant conductivities around 8-10 µS/cm. Except, from the high levels during the first week, concentrations of solutes were fairly constant over the season and the conductivity in the river water ranged between 12 and 30 µS/cm. A rise in conductivity was observed in early July during a period with rain, as rain increases the input of soil water with a higher content of dissolved nutrients than the melt water. During the flood, no increase in the conductivity was observed, indicating that water arised from the glaciers in the bedrock dominated part of the catchment.

In Zackenbergelven, DOC peaked 8 June when the conductivity was also high and smaller peaks were observed in relation to the rainy period in early July and again during the flood (Fig. 2.16). This pattern is closely related to the conductivity.

Suspended sediment and solutes in tributaries to Zackenbergelven

As a new thing in 2005, three pressure transducers were installed in some of the main tributaries to Zackenbergelven in order to estimate their relative contribution to Zackenbergelven. Positions of the divers are given in Fig. 2.12. In Lindemanselven 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 14 July and data was logged continuously every 15 minutes until 26 August where the diver was removed. Five manual discharge measurements were performed and a preliminary Q/h-relation

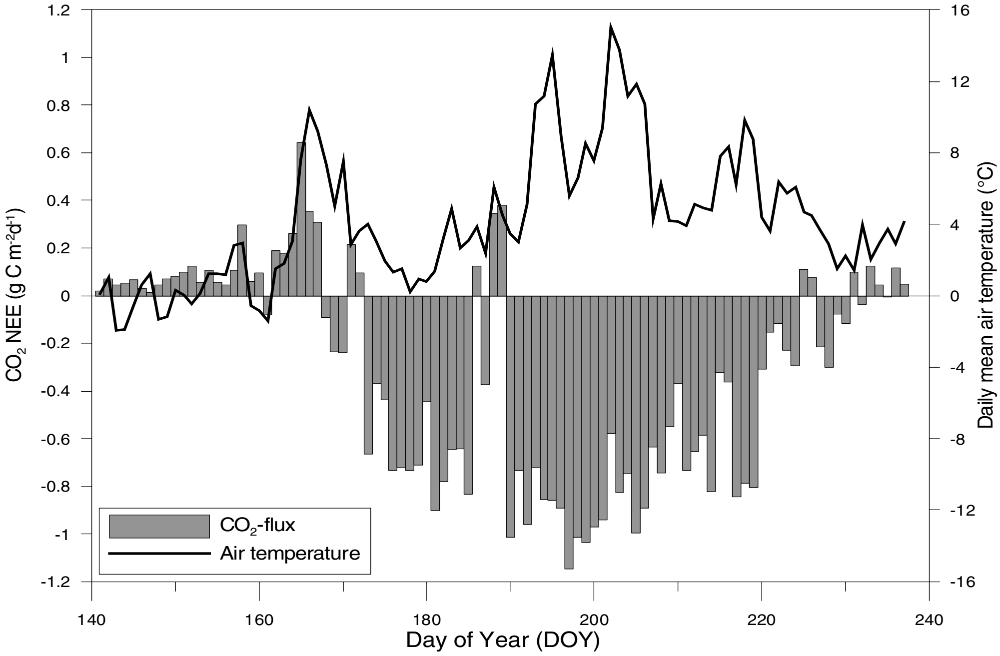


Fig. 2.18. Temporal variation in Net Ecosystem Exchange (NEE) and daily mean air temperature at the heath in 2004.

based on these data was used to calculate the discharge (Fig. 2.17). The maximum discharge of 6.2 m^3/s was measured 22 July at 18:00 in the period with high temperatures. A pronounced diurnal variation is observed with a maximum in the evening between 18:00 and 20:00 and a minimum in the morning between 8:00 and 10:00.

Conductivity ranged from 45-264 µS/cm with the highest conductivities found at the end of the season when the river discharge decreased (Fig. 2.17). Close to midnight the conductivity has a minimum and close to midday a maximum. The relation between discharge and conductivity shows an opposite pattern where discharge increases when conductivity decreases, and vice versa. The conductivity in Lindemanselven was significantly higher than in Zackenbergelven.

In the period from 14 July until 25 July it was possible to compare the water from Lindemanselven with total discharge in Zackenbergelven -water from Lindemanselven constituted between 4 and 17% with an average of 8%.

Another two divers were installed at the main tributaries to Store Sø unofficially called Stream S (UTM: 497657 E, 8270246 N, 160 m a.s.l.) and Stream N (UTM: 497546 E, 8271007 N, 178 m a.s.l.) (Fig. 2.12). These divers were installed 25 July when the water level was extreme and therefore they were accidentally placed on locations that dried out shortly after. It was only possible to cross Stream S at that time. Stream N was too violent and the water was very rich in fine sediment. There is no doubt that the flood originated from the glaciers drained by Stream N. No discharge measurements could be performed in Stream N but two discharge measurements were made in Stream S (25 July at 11:00 and 22:00) with discharges of 13 m^3/s and 26 m^3/s, respectively.

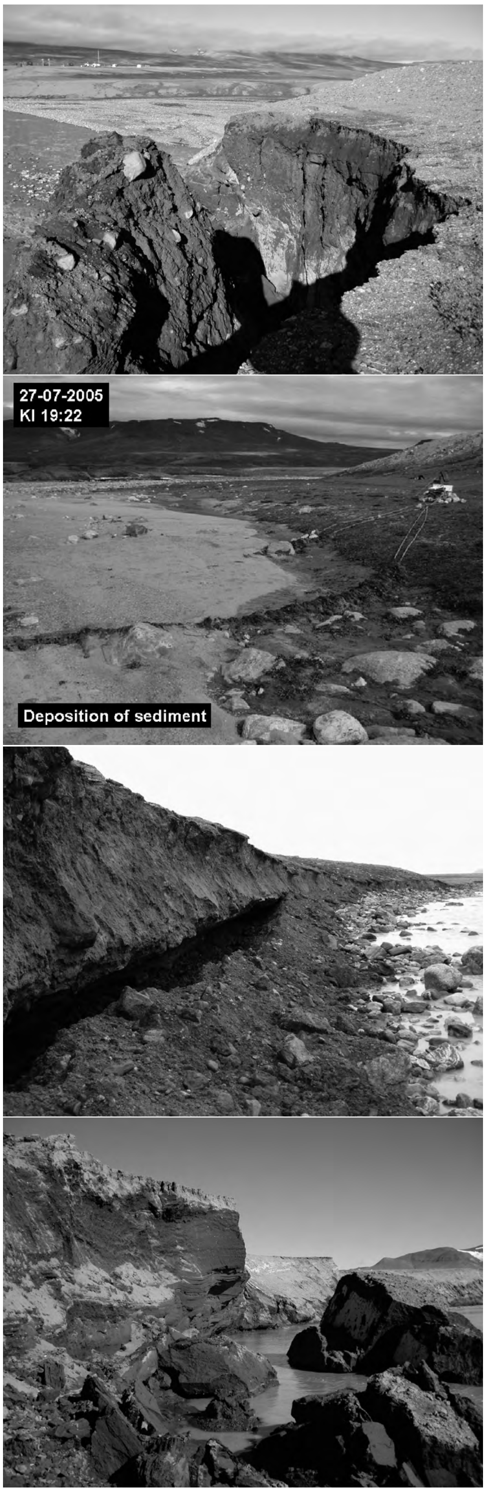
In 2005, water was sampled seven times from the main tributaries to Zackenbergelven. Location of sample sites is given in Fig. 2.1. Water temperature and conductivity were measured on location, whereas water chemistry, suspended sediment and organic matter concentration were determined from collected samples. When the first samples were collected 7 June it was not possible to collect water from Palnatoke NW, as this stream was moving slowly downstream in the snow and the area around was totally water soaked. However, conductivity could be measured by throwing the probe from a distance. Table 2.14 show variations in suspended sediment, organic matter, conductivity, dissolved organic carbon (DOC) and dissolved total nitrogen from the different streams throughout the season.

2.4 Precipitation and soil water chemistry

Precipitation

During the 2005 season, water from the precipitation collector was sampled on 3

Fig. 2.19. Photos showing erosion along Zackenbergelven and at the delta cliff as a response of the flood 25 July.



June (snow/rain), 5 July, 9 July, 29 July and 31 July after rain events of varying duration. Conductivity and pH were measured in Zackenberg and filtered sub samples were analysed for the same components as the river water and soil water (see section 2.3 River water chemistry and section 2.4 Soil water). Rain water had pH around 4.5, conductivity of 10-40 µS/cm and DOC of 4.3 mg/l.

Soil Moisture

Soil moisture at 10 cm and 30 cm below soil surface are measured year round at the snow- and micrometeorological stations M2 and M3 (Figs. 2.4 and 2.5). At M2, the soil dried at a much faster rate than at M3, where soil moisture remained close to saturation for almost a month due to overland flow from a large snow drift above. A pronounced increase in soil moisture were observed as soon as the air temperature turned positive and melt water started to seep through the snow and penetrate into the frozen soil. The soil moisture content at M2 showed a clear response to the rain event 5 July (Fig. 2.4). 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). Once a week, soil moisture in the upper 5 cm is measured 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. Finally, soil moisture in the upper 5 cm is continuously logged at 30 minutes intervals throughout the summer season at the micrometeorological station M1.

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 2005, soil water was collected four times during the season and the chemical composition of the soil water analysed. Alkalinity, pH and conductivity were measured in Zackenberg and analyses of dissolved major cations and anions (Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, Al^{3+}, Mn^{3+}, Cl^-, NO_3^{2-}, and SO_4^{2-}) were carried out at Institute of Geography, University of Copenhagen. Furthermore, water was analysed for dissolved organic carbon (DOC), ammonia (NH_4-N) and dissolved total nitrogen

(DTN) at Botanical Institute, University of Copenhagen.

Due to problems of getting water at the Dry-1 site, the soil water samplers were reinstalled at a nearby location covered by the same vegetation but not used in 2005 since the soil need time to settle after the disturbance.

2.5 Carbon dioxide flux

Exchange of CO_2 between the heath ecosystem and the atmosphere was measured for the sixth season at the well drained heath. In contrast to previous years the measurements started almost two weeks earlier in 2005. Measurements were initiated on 21 May and continued until 25 August giving a total of 97 days of measurements with only few interruptions. By the end of the season less than 1% of the data were lost due to malfunctioning, maintenance and calibration.

Vertical fluxes of water vapour and carbon dioxide are measured with a three-dimensional sonic anemometer and an infrared gasanalyser (IRGA). Further details on the instrumentation are given in section 4.2 in Rasch and Caning (2003).

Fig. 2.18 shows the temporal variation in daily net exchange of carbon dioxide and mean daily air temperature, during the 3 months of continuous measurements. The seasonal dynamics of daily carbon exchange with the atmosphere in a tundra ecosystem is described by three characteristic periods. Two seasons of marked emission delimit a period with net assimilation of CO_2. Prior to the first large seasonal pulse, a stabile period of loss is observed. 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. 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 governed by the climatic conditions during the growing season with solar radiation and temperature being key variables. 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 started 21 May, the snow had just started to melt and the period was characterized by air temperatures fluctuating around zero and daily average NEE around 0.1 g C m^{-2} d^{-1}. The early start of the measurements gave a unique opportunity to observe fluxes at the winter-time level. By early June, when air temperatures increased and snow cover disintegrated, a pulse of CO_2 from the tundra to the atmosphere was captured, with NEE reaching a maximum of 0.64 g C m^{-2} d^{-1} on 14 June (DOY 165) coinciding with high air temperatures. The loss of CO_2 continued until 16 June (DOY 167).

As photosynthesis increased, the assimilation exceeded the respiration and there was a net accumulation of CO_2 switching the ecosystem from a source to a sink of CO_2 on 17 June (DOY168). The net accumulation of CO_2 into the ecosystem lasted for 63 days, the longest period of net uptake since measurements were initiated. A period of cold weather with mean daily air temperatures below 4°C occurred from mid June to early July. During this period a few occasions of reversed fluxes occurred and the ecosystem turned into a source of CO_2 due to low level of incoming PAR-radiation. From 10 July (DOY 191) air temperatures rose rapidly and a maximum daily mean air temperature of 15°C was recorded on 21 July (DOY 202). This is the highest daily mean temperature recorded since the measurements were initiated in 1996. Maximum daily uptake of –1.15 gC m^{-2} d^{-1} occurred on 16 July (DOY 197). Uptake of CO_2 remained high until 8 August (DOY 220) where senescence started and photosynthesis decreased. As the respiration exceeded the photosynthesis, the ecosystem turned into a net source of CO_2. The growing season (defined as the period with positive ecosystem assimilation) ended by 18 August – a few days earlier than the previous years. Air temperatures decreased rapidly and remained around 3°C. Daily mean losses during the latter part of August were approximately at the same low level as seen in late May.

The possibility to measure the spring ecosystem flux before the snow melted gave information of the flux-characteristics during the time of snow coverage and hence an impression of the wintertime fluxes from the area. Generally, the uptake during the season was high, although a period of rain and fog during late June and early July reversed the fluxes and the

	2000	2001	2002	2003	2004	2005
Beginning of growing season	25 June	6 July	2 July	28 June	23 June	17 June
End of growing season	11 August	18 august	16 August	20 August	21 August	18 August
Length of growing season	47 days	43 days	45 days	53 days	59 days	63 days
Beginning of measuring season	6 June	8 June	3 June	5 June	3 June	21 May
End of measuring season	25 August	27 August	27 August	30 August	28 August	25 August
Length of measuring season	80 days	81 days	86 days	86 days	86 days	97 days
NEE for growing season (g C m^{-2})	(–) 22.7	(–) 19.1	(–) 18.2	(–) 30.4	(–) 29.7	(–) 33.4
NEE for measuring season (g C m^{-2})	(–) 19.1	(–) 8.7	(–) 9.5	(–) 23	(–) 22.4	(–) 29.6
Maximum daily accumulation (g C m^{-2} d^{-1})	(–) 0.92	(–) 0.94	(–) 1.00	(–) 1.4	(–) 1.3	(–) 1.15

Table 2.15. Summary of summer season environmental variables and CO_2 exchange 2000-2004.

ecosystem lost CO_2 to the atmosphere. The uptake during the season was higher than the previous years, as seen from Table 2.15. During the growing season, the weather was dominated by periods of very high air temperatures providing favorable conditions for assimilation of CO_2, which for the growing season resulted in a net ecosystem uptake of 33.4 g C m^{-2}. This is the highest recorded gain during the 6 years of measurements. In total 29.6 g C m^{-2} was accumulated during the period from 21 May until the end of the measurements by 25 August, which was higher than the previous years.

High air temperature seems to enhance accumulation of carbon in the ecosystem and this is further emphasized with the results from this season, where high air temperatures had a positive impact on the amount of accumulated carbon. Also the length of the growing season has increased compared to previous years, due to a tendency of earlier snowmelt in the area.

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 GeoBasis monitoring.

Severe erosion took place all along Zackenbergelven during the flood 25 July. Not only the river cross profile was changed, riverbanks were eroded all the way from the delta to Store Sødal (Fig. 2.19). Several tons of suspended material were washed out into the fiord system. In the end of July, the effect of a flood is much more dramatic than earlier in the season. In early summer, the landscape is protected by snow and the soil is still frozen whereas in late July the river bed and -banks are no longer frozen and therefore much more susceptible to erosion and collapse due to excavation (Fig. 2.19). At some points retreats of up to 10 meter were observed after the flood.

Frost blister

In the river bed, just north of the station a seasonal frost mound/blister was observed when we arrived in May. The blister was 5-6 m long and up to 75 cm high with a crack through it. The interior had a core of pore ice crystals aligned in a vertical columnar fashion. A frost blister is formed from expulsion of free water confined by downward freezing. It is the first time we have observed a feature like this in the nearby surroundings of the station.

Coastal geomorphology

Coastal monitoring in Zackenberg comprises measurements of morphological changes at two cross shore profiles, recurrent photography of dynamic coastal landscape features, measurements of coastal cliff retreat rates and measurements of vertical accretion of salt marsh. Locations of the coastal monitoring sites are given in Fig. 2.17 in Rasch and Caning 2004.

Cliff recession along the southern coast of Zackenbergdalen is given in Table 2.16. From 2004 to 2005 only minor erosion took place at site 2.

Four profile lines at the coastal cliff west of the Zackenbergelven river delta were established in August 2000 (D1-D4 in Fig. 2.17 in Rasch and Caning 2004). Two times during the season, block slumping was observed at the delta cliff. The first time was 10 July and the second time was after the flood 25 July (Fig. 2.19). Only two of the original pegs (D1 and D2) are still left, while the others (D3 and D4) have been lost due to erosion. More than 25 meter of the 5-10 m high cliff has been lost on a distance of 50 meter. In the period from 2004 to 2005, no changes happened at D1 but additional 0.2 m was eroded at D2.

In 2005, the topographic cross shore profiles near the old delta (Profile 1 and Profile 2) were not resurveyed, as the reflector for the electronic theodolite was lost during survey in the river.

	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

Table 2.16. Cumulated coastal cliff recession at the southern coast of Zackenbergdalen 1996-2005.

3 ZACKENBERG BASIC
The BioBasis programme

Hans Meltofte (ed.)

The BioBasis programme at Zackenberg is carried out by the National Environmental Research Institute (NERI), Department of Arctic Environment, Ministry of Environment, 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.

Details on BioBasis methods and sampling procedures are presented in a manual (Meltofte and Berg 2005), which is available from the home page of NERI (http://biobasis.dmu.dk). A map with locality names used in this chapter is found at the same place. Also, a synopsis of the entire BioBasis programme and primary data are presented on the website.

Jannik Hansen kindly criticised an earlier draft of the manuscript.

3.1 Vegetation

Line A. Kyhn and Mikkel P. Tamstorf

The weekly records of snow-cover, flowering and reproduction were made by Niels Martin Schmidt during 19 May – 15 June and Line A. Kyhn 16 June – 29 August. Vegetation maps based on hyperspectral measurements carried out in 2000 were ground truthed by Christian Bay during 27 July – 2 August assisted by Marie-Luise Øllgaard Meyhoff. This material will be used as basis for the construction of a more detailed vegetation map of the study area of Zackenbergdalen than was previously possible (Bay 1998).

Reproductive phenology, amounts of flowering and berry production

This year, the field season began already on 20 May or about 7-10 days earlier than previous years. However, 2005 turned out to have a very early start of the season with the highest mean May ground temperature (measured at vegetation level) and earliest snowmelt ever recorded. On 10 June, snow covered only 37% in the 12 sections of the study area as opposed to an average of 72% for all recorded years (see section 2.2). The same pattern is visible on a plot scale, as the dates of 50% snowcover in 26 of 28 plant plots also were the earliest recorded (Table 3.1). For the two remaining plots, Cassiope 4 and Papaver 1, the dates equal the hitherto earliest. The result of this early snowmelt was a prolonged growing season in 2005.

The high spring temperatures and early snowmelt also resulted in the earliest flowering recorded during the 10 years of monitoring for 23 of 28 plant plots, while flowering in four of the remaining plots resembled the earliest hitherto recorded snowmelt (Table 3.2).

Of 22 species of plants for which dates of first observations of flowers have been recorded incidentally during the study years, 13 species were recorded this year. Five of these flowered earlier than in all other years, while the remaining flowered early, but within the previous recorded time span.

The prolonged growing season is also reflected in date of 50% open seed capsules. For the three species monitored, arctic poppy *Papaver radicatum*, arctic willow *Salix arctica* and purple saxifrage *Saxifraga oppositifolia*, the date was the earliest or the same as previously earliest records in the 11 plots, where we have multi year data (Table 3.3). This was not the case in Salix 5, 6 and 7, which have only been studied since 2003.

Despite the length of the growing season, 2005 was not a top year with regard to amount of flowers produced (Table 3.4). As most monitored plant species set flower buds one or more growing seasons prior to flowering (Sørensen 1941), the amount of flowers this season should be regarded as a result of different abiotic parameters such as precipitation, incoming

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cassiope 1	14.6	9.6	13.6	27.6	2.6	7.6	13.6	6.6	<3.6	23.5
Cassiope 2	19.6	21.6	27.6	4.7	<4.6	21.6	20.6	13.6	16.6	7.6
Cassiope 3	15.6	21.6	20.6	3.7	13.6	20.6	20.6	7.6	7.6	28.5
Cassiope 4	20.6	15.6	20.6	4.7	13.6	21.6	17.6	7.6	7.6	7.6
Dryas 1	<3.6	<27.5	(23.5)	6.6	<4.6	<31.5	<30.5	4.6	<2.6	<20.5
Dryas 2	26.6	27.6	4.7	12.7	21.6	3.7	28.6	22.6	21.6	14.6
Dryas 3	6.6	<27.5	7.6	19.6	<4.6	6.6	6.6	6.6	<3.6	<20.5
Dryas 4	1.6	3.6	13.6	21.6	<4.6	7.6	6.6	(31.5)	<1.6	(28.4)
Dryas 5	6.6	31.5	4.6	14.6	<4.6	5.6	6.6	6.6	<1.6	<20.5
Dryas 6	21.6	4.7	5.7	11.7	20.6	28.6	30.6	19.6	21.6	14.6
Papaver 1	20.6	18.6	21.6	3.7	1.6	20.6	18.6	12.6	14.6	1.6
Papaver 2	20.6	20.6	21.6	4.7	14.6	21.6	20.6	21.6	11.6	7.6
Papaver 3	21.6	15.6	20.6	3.7	13.6	21.6	19.6	14.6	8.6	7.6
Papaver 4	21.6	4.7	5.7	11.7	20.6	27.6	30.6	19.6	21.6	13.6
Salix 1	<3.6	<27.5	<27.5	<1.6	<3.6	<31.5	<30.5	(31.5)	<3.6	<20.5
Salix 2	14.6	20.6	23.6	1.7	13.6	21.6	14.6	14.6	9.6	7.6
Salix 3	7.6	8.6	12.6	24.6	<3.6	7.6	7.6	(2.6)	<3.6	(18.5)
Salix 4	20.6	5.6	21.6	22.6	7.6	11.6	10.6	13.6	5.6	31.5
Salix 5	–	–	–	–	–	–	–	21.6	11.6	7.6
Salix 6	–	–	–	–	–	–	–	–	21.6	13.6
Salix 7	–	–	–	–	–	–	–	–	21.6	13.6
Saxifraga 1	<3.6	<27.5	<27.5	<1.6	<3.6	<31.5	<30.5	(1.6)	<2.6	<20.5
Saxifraga 2	<3.6	<27.5	<27.5	(27.5)	<3.6	<31.5	<30.5	(31.5)	<2.6	<20.5
Saxifraga 3	–	<27.5	27.5	6.6	<3.6	(27.5)	<30.5	(1.6)	<2.6	(8.5)
Silene 1	<3.6	<27.5	<27.5	<1.6	<3.6	<31.5	<30.5	(1.6)	<2.6	<20.5
Silene 2	<3.6	<27.5	<27.5	(27.5)	<3.6	<31.5	<30.5	(31.5)	<2.6	<20.5
Silene 3	–	<27.5	27.5	6.6	<3.6	(27.5)	<30.5	(1.6)	<2.6	(8.5)
Silene 4	24.6	28.6	20.6	6.7	21.6	28.6	25.6	19.6	18.6	11.6

Table 3.1. Inter- and extrapolated dates 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 1996-2005. Brackets denote extrapolated dates.

radiation (PAR), temperatures and length of growing season in previous years as well as in the year in question. The reactions though, differ inter-and intraspecifically, the latter probably as a result of *in situ* variations in abiotic factors such as build up of snow-pack, timing of snowmelt and amount of soil water between different plots of the same species. The record high amount of precipitation in July and August 1998 (see section 2) thus resulted in different responses for the same species in the following year (Caning and Rasch 2001). Arctic willow *Salix arctica* in early snow-free plots (Sal 1 and 4) reacted positively, whereas late snow-free *Salix* (Sal 2) plots did not show a similar response in increasing the amount of flowers (Table 3.4). This may indicate that growth and flower production in early snow-free plots can be water restricted, which is probably also the reason for the extremely early NDVI top in 2005, as a marked peak came right after a few days of rain. Early snow-free *Salix* plots reacted by having a large early peak in NDVI right after the rain, whereas late snow-free plots also had a second or third peak of comparable size (see below).

The mechanism behind the observed drop in numbers of flowers from 2004 to 2005 in early snow-free *Dryas* and *Salix* plots might also be ascribed to water deficiency, as an early snowmelt in conjunction with little precipitation gave rise to a prolonged, but dry growing season in 2004 (precipitation in June was only one third compared to the 1996-2003 mean, and in August it was only one fourth). Taken into a broader perspective, global warming with increasingly earlier snowmelt might not be beneficial for these

Table 3.2. Inter- and extrapolated dates 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 1996-2005. Brackets denote interpolated dates based on less than 50 buds+flowers.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cassiope 1	2.7	6.7	6.7	13.7	(28.6)	4.7	3.7	27.6	23.6	17.6
Cassiope 2	6.7	20.7	(21.7)	(26.7)	–	12.7	7.7	3.7	5.7	20.6
Cassiope 3	9.7	18.7	(19.7)	(26.7)	–	11.7	9.7	2.7	30.6	20.6
Cassiope 4	15.7	15.7	(21.7)	(26.7)	–	19.7	7.7	5.7	3.7	4.7
Dryas 1	19.6	22.6	26.6	3.7	26.6	22.6	25.6	30.6	21.6	13.6
Dryas 2	13.7	4.8	8.8	–	24.7	1.8	29.7	19.7	18.7	18.7
Dryas 3	2.7	26.6	6.7	13.7	27.6	6.7	28.6	29.6	23.6	13.6
Dryas 4	27.6	6.7	(9.7)	14.7	26.6	6.7	28.6	23.6	22.6	13.6
Dryas 5	30.6	5.7	1.7	7.7	22.6	5.7	28.6	28.6	20.6	13.6
Dryas 6	19.7	9.8	(7.8)	19.8	21.7	29.7	1.8	17.7	17.7	11.7
Papaver 1	14.7	20.7	24.7	2.8	4.7	12.7	12.7	5.7	11.7	4.7
Papaver 2	14.7	23.7	26.7	30.7	15.7	14.7	13.7	8.7	8.7	11.7
Papaver 3	14.7	19.7	26.7	1.8	10.7	17.7	13.7	11.7	5.7	4.7
Papaver 4	15.7	7.8	11.8	15.8	(20.7)	(27.7)	2.8	17.7	12.7	11.7
Salix 1	6.6	6.6	12.6	14.6	11.6	8.6	9.6	17.6	4.6	7.6
Salix 2	21.6	29.6	10.7	17.7	28.6	29.6	28.6	28.6	21.6	20.6
Salix 3	20.6	25.6	(28.6)	5.7	11.6	24.6	16.6	15.6	7.6	7.6
Salix 4	29.6	23.6	2.7	3.7	17.6	28.6	26.6	23.6	21.6	13.6
Salix 5	–	–	–	–	–	–	–	5.7	23.6	13.6
Salix 6	–	–	–	–	–	–	–	–	15.7	4.7
Salix 7	–	–	–	–	–	–	–	–	5.7	4.7
Saxifraga 1	–	31.5	5.6	7.6	6.6	8.6	3.6	14.6	5.6	23.5
Saxifraga 2	–	2.6	7.6	14.6	9.6	8.6	6.6	14.6	5.6	31.5
Saxifraga 3	5.6	1.6	9.6	16.6	7.6	9.6	7.6	14.6	<2.6	23.5
Silene 1	20.6	24.6	21.6	28.6	26.6	28.6	23.6	1.7	21.6	13.6
Silene 2	23.6	29.6	1.7	30.6	2.7	30.6	27.6	4.7	29.6	13.6
Silene 3	30.6	26.6	23.6	6.7	28.6	4.7	28.6	4.7	20.6	13.6
Silene 4	26.7	10.8	20.8	–	28.7	29.7	28.7	20.7	19.7	18.7

Table 3.3. Inter- and extrapolated dates of 50% open seed capsules for arctic poppy Papaver radicatum, arctic willow Salix arctica and purple saxifrage Saxifraga oppositifolia 1995-2005. Brackets denote interpolated dates based on less than 50 flowers+open capsules.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Papaver 1	5.8	15.8	–	30.8	>26.8	9.8	16.8	20.8	1.8	6.8	1.8
Papaver 2	15.8	15.8	24.8	–	>26.8	(17.8)	16.8	17.8	3.8	6.8	1.8
Papaver 3	6.8	13.8	19.8	–	29.8	14.8	18.8	20.8	6.8	3.8	1.8
Papaver 4	20.8	–	>27.8	–	(>26.8)	(16.8)	24.8	(26.8)	10.8	14.8	8.8
Salix 1	8.8	8.8	8.8	5.8	13.8	12.8	2.8	29.7	2.8	26.7	18.7
Salix 2	12.8	9.8	19.8	30.8	25.8	20.8	18.8	11.8	3.8	5.8	1.8
Salix 3	2.8	8.8	16.8	(19.8)	16.8	12.8	14.8	5.8	28.7	27.7	25.7
Salix 4	12.8	17.8	14.8	21.8	16.8	13.8	13.8	12.8	3.8	6.8	1.8
Salix 5	–	–	–	–	–	–	–	–	4.8	7.8	8.8
Salix 6	–	–	–	–	–	–	–	–	11.8	10.8	15.8
Salix 7	–	–	–	–	–	–	–	–	13.8	10.8	15.8
Saxifraga 1	–	20.7	10.8	11.8	13.8	9.8	8.8	4.8	7.8	23.7	18.7
Saxifraga 2	–	23.7	16.8	24.8	15.8	15.8	14.8	1.8	11.8	27.7	1.8
Saxifraga 3	–	7.8	9.8	23.8	16.8	7.8	13.8	12.8	9.8	23.7	1.8

	Area	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cassiope 1	2	1321	1386	1855	322	312	28	1711	1510	851	2080	1392
Cassiope 2	3		1759	550	19	16	8	1353	952	1001	1745	1203
Cassiope 3	2	256	844	789	35	18	0	771	449	817	791	862
Cassiope 4	3	456	1789	391	24	6	3	578	164	1189	1274	1857
Cassiope 5	2.5	–	–	1224	455	474	50	3214	3208	2708	2006	2648
Cassiope 6	2	–	–	>350	16	3	1	544	736	134	2796	3938
Dryas 1	4	(936)	(797)	138	223	852	607	1016	627	744	444	391
Dryas 2	60	534	1073	230	42	49	46	172	290	552	1174	519
Dryas 3	2	603	522	123	255	437	266	577	235	294	273	198
Dryas 4	6	(325)	(164)	155	69	356	55	301	187	224	218	143
Dryas 5	6	(654)	(504)	123	191	655	312	506	268	589	351	233
Dryas 6	91	809	1406	691	10	25	140	550	430	627	1854	878
Dryas 7	12	–	–	787	581	1355	574	1340	1483	1543	1026	599
Dryas 8	12	–	–	391	240	798	170	403	486	545	229	243
Papaver 1	105	302	337	265	190	220	197	237	277	278	286	207
Papaver 2	150	814	545	848	316	315	236	466	456	564	402	682
Papaver 3	90	334	238	289	266	183	240	259	301	351	221	316
Papaver 4	91	196	169	192	80	30	35	65	59	56	37	68
Salix 1 mm.	60	–	807	959	63	954	681	536	1454	1931	1127	375
Salix 1 ff.	–	520	1096	1349	149	1207	900	1047	1498	2159	1606	386
Salix 2 mm.	300	–	790	1082	132	416	55	803	1206	967	1276	737
Salix 2 ff.	–	617	1376	1909	455	418	95	1304	1816	1638	1862	1089
Salix 3 mm.	36	239	479	412	32	52	330	1196	344	621	693	285
Salix 3 ff.	–	253	268	237	38	68	137	1009	315	333	476	188
Salix 4 mm.	150	–	1314	831	509	718	965	680	1589	1751	1984	1317
Salix 4 ff.		1073	1145	642	709	880	796	858	1308	1418	1755	1038
Salix 5 mm.	–	–	–	–	–	–	–	–	–	494	844	945
Salix 5 ff.	–	–	–	–	–	–	–	–	–	371	1314	1333
Salix 6 mm.	–	–	–	–	–	–	–	–	–	–	2162	2445
Salix 6 ff.	–	–	–	–	–	–	–	–	–	1145	2736	2010
Salix 7 mm.	–	–	–	–	–	–	–	–	–	612	621	746
Salix 7 ff.	–	–	–	–	–	–	–	–	–	839	512	705
Saxifraga 1	7	–	(1010)	141	163	584	1552	558	542	1213	463	159
Saxifraga 2	6	–	513	387	432	158	387	515	617	561	584	522
Saxifraga 3	10	–	529	322	288	707	403	558	318	509	609	241
Silene 1	7	–	(251)	403	437	993	1327	674	766	1191	1187	312
Silene 2	6	–	493	524	440	400	692	568	1094	917	1406	740
Silene 3	10	–	348	211	127	313	274	348	480	1000	719	503
Silene 4	1	466	270	493	312	275	358	462	470	794	509	483
E. scheuz. 1	10	–	395	423	257	309	229	111	582	843	780	201
E. scheuz. 2	6	–	537	344	172	184	201	358	581	339	956	597
E. scheuz. 3	10	–	392	545	482	587	38	367	260	237	359	67
E. scheuz. 4	8	–	260	755	179	515	117	121	590	445	176	57
E. triste 1	10	–	0	3	1	1	1	0	3	11	12	0
E. triste 2	6	–	98	59	21	16	43	56	67	39	117	44
E. triste 3	10	–	0	0	0	0	0	0	0	0	0	0
E. triste 4	8	–	0	0	0	0	0	0	0	0	0	0
Arctostaphylos 1	–	–	–	–	–	–	–	–	1865	3035	285	1775
Arctostaphylos 2	–	–	–	–	–	–	–	–	215	272	>10	103
Arctostaphylos 3	–	–	–	–	–	–	–	–	387	375	>68	291
Arctostaphylos 4	–	–	–	–	–	–	–	–	996	1216	563	1197
Vaccinium 1	–	–	–	–	–	–	–	–	2521	9271	6067	6571

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 and 'dark cotton-grass' Eriophorum triste in flower plots in 1995-2005. Numbers in brackets have been extrapolated from 1995 and 1996 data to make up for enlarged plots (see Meltofte and Rasch 1998).

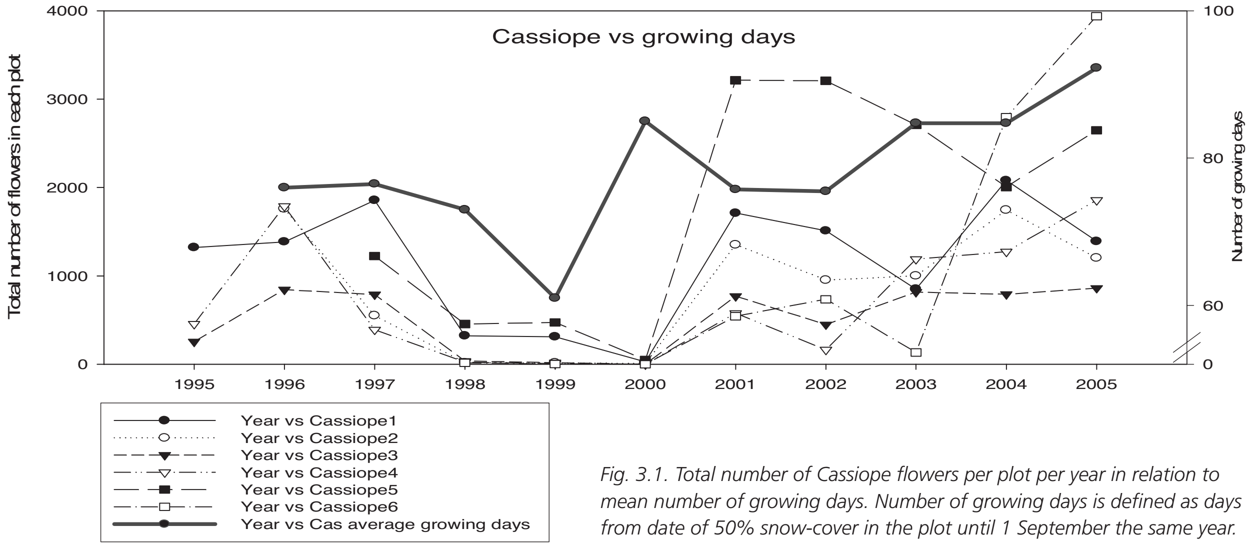


Fig. 3.1. Total number of Cassiope flowers per plot per year in relation to mean number of growing days. Number of growing days is defined as days from date of 50% snow-cover in the plot until 1 September the same year.

species despite a prolonged growing season unless in conjunction with increased summer precipitation. For species depending on a protective snow-cover, and therefore experiencing late snowmelt such as white arctic bell-heather *Cassiope tetragona*, there has been a positive correlation between length of growing season the previous year and amount of flowers the following year, respectively, since 1999/2000 (Fig. 3.1). For late snow-free plots sun rather than water seems to be the limiting factor for plant growth since the late snowmelt prevents the soil from drying up early. However, temperature and nutrients also form part of the explanation.

The peak ratio of *Salix arctica* infested with fungi was below 4% in all plots (Table 3.5). This low percentage is in accordance with previous years. The year with greatest infestation rate was 1999, which had a very late snowmelt and normal amount of precipitation resulting in a wet season, which could be conditions favouring fungi.

In accordance with the past five years, berry production in relation to number of flowers was very low, *i.e.* 7.6% for alpine bearberry *Arctostaphylos alpina* and 0.23% for arctic blueberry *Vaccinium uliginosum* (numbers of flowers have only been counted since 2002; Tables 3.4 and 3.6.). The years of greatest berry production were 1998 and 1999 for both species. Ripe alpine bearberries and arctic blueberries contain a lot of water, and the years of top production are concurrent with the years of greatest precipitation in July (1997-

Table 3.5. Peak ratio (per cent) of female Salix pods infested by fungi in Salix plots in 1996-2005.

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

Table 3.6. Area size (m^2) and numbers of berries recorded in alpine bearberry Arctostaphylos alpina, arctic blueberry Vaccinium uliginosum and crowberry Empetrum nigrum plots in 1998-2005.

	Area	1998	1999	2000	2001	2002	2003	2004	2005
Arctostaphylos 1	1.5	148	240	30	99	33	122	22	53
Arctostaphylos 2	1.5	50	17	2	36	18	55	1	1
Arctostaphylos 3	1.5	28	91	4	100	32	21	16	16
Arctostaphylos 4	1.5	139	107	0	14	44	106	201	187
Vaccinium 1	4	240	532	9	0	1	14	3	15
Empetrum 1	4	27	1	17	3081	1034	4568	1084	1955

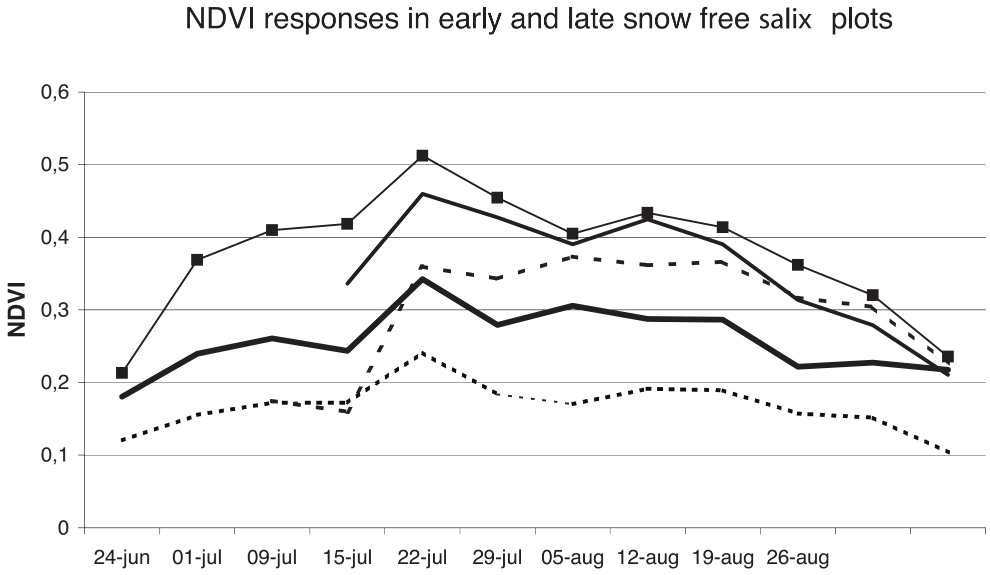


Fig. 3.2. NDVI response in early and late snow free Salix *and* Dryas *plots. Unbroken lines with increasing thickness are* Salix *1, 2 and 3, respectively. Broken lines with increasing thickness are* Dryas *1 and 2, respectively.* Salix *1 and 3 and* Dryas *1 are early snow free and* Salix *2 and* Dryas *2 are late snow free.*

1999). The amount of precipitation over summer has been decreasing since then, and in some years many small dry and unripe berries were observed in the arctic blueberry plot. As for the last four years, the arctic blueberry production has generally been high at other sites in the valley (pers. obs. and Rasch and Canning 2004) where irrigation could take place during all summer. The crowberrie *Empetrum nigrum* plot is situated on a dry and sandy ridge and is generally early snow-free and might therefore not be as water dependant as the two other monitored berry species. Hence a high berry production has been observed each year since 2001.

Vegetation greening in mammal, bird and flower study plots

Greening index data (NDVI) from an ASTER satellite image from 25 July 2005 is presented in Table 3.7, and in Table 3.8 they are compared with previous years after extrapolation to simulate 31 July each year (see Fig. 4.1 in Caning and Rasch 2003 for location of sections in Zackenbergdalen).

In general the values were lower than average for the 1995 to 2005 period, but still higher than the lowest values that occurred in 1999. The 2005 season values are similar to the values for 2001 and 2002 although they in some areas are slightly lower.

The culmination of greening in the plant plots occurred extremely early this year and was followed by a second peak two to three weeks later during the normal time span and of approximately the same order as the early peak (Fig. 3.2). Both peaks are given in Table 3.9. In return for the early peak, the mean NDVI values of the late peak were lower or equal to previous years. A reasonable explanation for the early NDVI peak is the very early snowmelt giving rise to an extended growth period in the beginning of the season. However, the early snow clearance may have caused water depletion, since a heavy rain fall of 22.6mm during 5-8 July gave rise to a sudden rise in NDVI on 9 July.

The turgor pressure in leaves of water depleted plants drop and hence also effective leaf area. In water depleted plants, leaf area index (LAI) increase when water is again supplied. LAI and reflection of light is positively correlated (H. Ro-

Table 3.7. Area size (km²) and Normalised Difference Vegetation Index (NDVI) values for 12 sections of the bird and musk ox monitoring areas in Zackenbergdalen together with the lemming monitoring area (part of Section 2) based on an ASTER satellite image from 25 July 2005 (see Fig. 4.1 in Caning and Rasch 2003 for position of sections). The image has been corrected for atmospheric and terrain influence (humidity, aerosols, solar angle and terrain effects). All negative NDVI values have been changed to 0, so that water and snow-covered areas are given similar values from year to year.

	Area	Min.	Max.	Mean	Std.Dev.
1 (0-50 m)	3.52	0.00	0.75	0.41	0.19
2 (0-50 m)	7.97	0.00	0.85	0.49	0.19
3 (50-150 m)	3.52	0.00	0.79	0.53	0.14
4 (150-300 m)	2.62	0.00	0.73	0.40	0.15
5 (300-600 m)	2.17	0.00	0.72	0.30	0.16
6 (50-150 m)	2.15	0.00	0.73	0.45	0.17
7 (150-300 m)	3.36	0.00	0.71	0.44	0.16
8 (300-600 m)	4.56	0.00	0.74	0.32	0.19
9 (0-50 m)	5.01	0.00	0.80	0.51	0.16
10 (50-150 m)	3.84	0.00	0.92	0.54	0.13
11 (150-300 m)	3.18	0.00	0.75	0.44	0.16
12 (300-600 m)	3.82	0.00	0.80	0.40	0.19
13 (Lemmings)	2.05	0.00	0.77	0.47	0.16
Total Area	45.72	0.00	0.77	0.44	0.17

Table 3.8. Mean NDVI values for 12 sections of the bird and musk ox monitoring areas in Zackenbergdalen together with the lemming monitoring area (part of section 2) based on Landsat TM, ETM+ and SPOT 4 HRV and ASTER satellite images 1998-2005 (see Fig. 4.1 in Caning and Rasch 2003 for position of sections). The data have been corrected for differences in growth phenology between years to simulate the 31 July value. When comparing values, it should be noted that optimum of the plant communities varies between years with 31 July close to optimum of most years.

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

Poulsen pers. com.), and NDVI may therefore increase drastically, if water is supplied to water depleted plants. The measurements were taken the day after the rain when the foliage surfaces had dried up. Few plots (Salix1, 3 and 4 together with Saxifraga/Silene1 and 2) only peaked early in the season, but the highest values measured in these plots later in the season are given for comparison.

3.2 The ZERO line and northern limit species

Christian Bay

To monitor the vegetational changes in Zackenbergdalen, 10 permanent plots were established in 2000 within each of the vegetation zones along a 6 km long transect, the ZERO line, from the coast of Young Sund to the top of Aucellabjerg – *i.e.* a total of 1280 plots (Fredskild and Mogensen 1997, Caning and Rasch 2001). This work is expected to be carried out every 5th year to investigate the long term changes of the species composition and distribution of the plant communities along this landscape gradient.

The vegetation analyses were carried out during the two last weeks of July 2005 by Christian Bay assisted by Marie-Luise Øllgaard Meyhoff. Most of the markers of the permanent plots in the lowland and on the slope of Aucellabjerg up to 600 m a.s.l. were undisturbed. Frost action had disturbed some of the markers, but it was possible to re-establish them. On the other hand, most markers of the plots in the upland were pushed out of the soil, which is of a more coarse type, and it was not possible to re-establish them in the original position. Consequently, most of the upland plots above 600 m were abolished. The detailed vegetation analyses were carried out by using the frequency analysis method used five years ago (Caning and Rasch 2001). The species composition and frequency of the vascular plant species were recorded in the undisturbed plots of the 1280 permanent plots.

In all types of plant communities along the line except for salt marsh, an increase in number of species since 2000 was found. The number of species new to the plant communities varied from one to eight species with the largest increase in the plant community with high species diversity – *Salix arctica* snowbed. Nearly all new species are perennials with a short life strategy. The only woody species new to a few plots was *Salix herbacea*, a species which indicates a prolonged snow cover. Only in a few analyses there was a decrease in number of species. In the wet plant communities, the most frequent new species were *Eriophorum scheuchzeri*, *Carex bigelowii*, *Saxifraga cernua* and *Juncus biglumis*. In the moist plant communities, *Polygonum viviparum*, *Festuca hyperborea*, *Pedicularis hirsuta* and *Luzula confusa* were common new species.

There were differences in the changes of frequency among the different life strategies. Woody dwarf shrubs (*Cassiope tetragona*, *Vaccinium uliginosum* ssp. *microphyllum*, *Dryas* sp. and *Salix arctica*) with a long term life strategy, showed no or only minor changes in frequency, whereas the perennials both among herbs and grami-

	1999		2000		2001		2002		2003		2005 early		2005 late	
	NDVI	Date	NDVI	Date	NDVI	Date	NDVI	Date	NDVI	Date	NDVI	Date	NDVI	Date
Cassiope 1	0.40	29.7	0.41	29.7	0.37	5.8	0.35	29.7	0.36	5.8	0.34	9.7	0.30	22.7
Cassiope 2	0.41	29.7	0.46	22.7	0.38	22.7	0.38	26.8	0.43	5.8	0.37	9.7	0.39	22.7
Cassiope 3	0.41	19.8	0.36	19.8	0.33	5.8	0.31	26.8	0.34	12.8	0.30	9.7	0.34	29.7
Cassiope 4	0.38	26.8	0.41	22.7	0.35	29.7	0.33	26.8	0.39	5.8	0.34	9.7	0.39	29.7
Mean	0.40		0.41		0.36		0.34		0.38		0.34		0.36	
Dryas 1	0.43	22.7	0.41	22.7	0.37	22.7	0.35	25.7	0.40	22.7	0.32	9.7	0.25	29.7
Dryas 2/Salix 7	0.39	19.8	0.42	22.7	0.39	29.7	0.43	5.8	0.42	5.8	0.36	9.7	0.37	22.7
Dryas 3	0.45	29.7	0.45	22.7	0.42	26.7	0.41	29.7	0.46	22.7	0.33	9.7	0.31	29.7
Dryas 4	0.34	19.8	0.32	22.7	0.33	22.7	0.28	29.7	0.29	22.7	0.25	9.7	0.29	29.7
Dryas 5	0.34	29.7	0.33	22.7	0.31	22.7	0.28	29.7	0.31	15.7	0.20	9.7	0.23	29.7
Dryas 6/Papaver 4	0.35	26.8	0.41	22.7	0.34	26.7	0.37	5.8	0.38	22.7	0.33	9.7	0.36	29.7
Mean	0.38		0.39		0.36		0.35		0.38		0.30		0.30	
Papaver 1	0.41	19.8	0.41	22.7	0.38	29.7	0.39	29.7	0.41	22.7	0.35	9.7	0.37	22.9
Papaver 2/Salix 5	0.44	19.8	0.45	22.7	0.41	29.7	0.40	5.8	0.42	29.7	0.37	9.7	0.43	29.7
Papaver 3	0.37	26.8	0.41	22.7	0.35	29.7	0.34	5.8	0.39	22.7	0.33	9.7	0.39	29.7
Mean	0.39		0.42		0.37		0.37		0.40		0.345		0.3875	
Salix 1	0.57	29.7	0.59	22.7	0.54	8.7	0.54	22.7	0.60	15.7	0.51	9.7	0.43	29.7
Salix 2	0.52	29.7	0.52	22.7	0.49	29.7	0.51	22.7	0.50	22.7	0.46	9.7	0.42	29.7
Salix 3	0.41	29.7	0.44	22.7	0.39	29.7	0.38	29.7	0.38	22.7	0.34	9.7	0.31	22.7
Salix 4	0.46	29.7	0.47	22.7	0.43	2.8	0.45	29.7	0.47	15.7	0.40	9.7	0.38	29.7
Salix 6	–	–	–	–	–	–	–	–	0.39	31.7	0.33	9.7	0.43	29.7
Mean	0.46		0.48		0.44		0.45		0.46		0.396		0.396	
Saxifraga/Silene 1	0.28	29.7	0.34	7.8	0.27	8.7	0.19	22.7	0.27	15.7	0.19	9.7	0.15	29.7
Saxifraga/Silene 2	0.36	29.7	0.38	22.7	0.34	19.7	0.31	22.7	0.38	15.7	0.34	9.7	0.27	15.7
Saxifraga/Silene 3	0.23	29.7	0.26	22.7	0.27	15.7	0.20	29.7	0.24	22.7	0.17	9.7	0.15	29.7
Silene 4	0.32	26.8	0.36	22.7	0.27	29.7	0.26	5.8	0.28	29.7	0.26	9.7	0.30	29.7
Mean	0.30		0.34		0.29		0.24		0.29		0.24		0.22	
Eriophorum 1	0.57	5.8	0.60	14.7	0.60	29.7	0.57	29.7	0.61	15.7	–	–	0.54	15.7
Eriophorum 2	0.58	29.7	0.58	22.7	0.53	26.7	0.50	29.7	0.45	15.7	0.44	9.7	0.44	15.7
Eriophorum 3	0.54	19.8	0.56	22.7	0.47	29.7	0.47	29.7	0.48	22.7	0.37	9.7	0.35	22.7
Eriophorum 4	0.73	5.8	0.72	22.7	0.68	29.7	0.64	5.8	0.67	22.7	–	–	0.70	29.7
Mean	0.61		0.62		0.57		0.54		0.55		0.41		0.51	
Mean of all	0.43		0.44		0.40		0.39		0.41		0.33		0.36	

Table 3.9. Peak NDVI recorded in 26 flower plots 1999-2005 together with date of maximum record using a hand held Skye 110 instrument with a 660-730 nm sensor. NDVI values presented are transformed averages of eight (four in very small plots) hand held RVI 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 minor part. Mean of e.g. Salix plots also involve Salix plots 5 to 7. NOTE: In 2005 two peaks, a very early and a normal, are given. 2004 data is not included due to instrumental error that season.

noids (*i.e.* grasses, sedges and rushes) showed many increases or decreases in frequency. In plots with major changes, up to 55% of the recordings from year 2000 have changed either by an increase or a decrease in frequency of the species.

In several of the plots, the plants had changed their reproductive status either by flowering or by having been sterile after the flowering season five years ago.

It is expected that the border between *Cassiope tetragona* heath and *Salix arctica* snow bed is a good marker for changes of the distribution of the snow cover and changes in the duration of the snow free period. But there were no signs in 2005 of changes in the distribution of these plant communities.

The disappearance within the last years of a large snow bank at an altitude of approximately 600 m on the ZERO line is expected to have a major impact on the vegetation below, because the early melt off of the snow bank will lead to reduced water supply to the vegetation during the later parts of growing season. However, the results of 2005 did not show any distinct signs of floristical changes in the plant communities below the snow bank.

Monitoring of northern limit species

The reproduction of selected vascular plant species with their northern distribution limit in the study area were checked in the plots established in 2000 (Caning and Rasch 2001). For almost all the species and in nearly all the plots there was a marked reduction in the number of flowers or inflorescences of plants growing in moist, wet or dry soils. *Campanula gieseckiana* in dry south exposed habitats showed a marked decrease from 155 buds five years ago to none this year in the plot with the biggest decrease.

As the only species, the snowbed species *Carex lachenalii* showed a marked increase in numbers of inflorescens in all the plots.

A new northern limit species was included in the monitoring programme. A viable population of *Pyrola grandiflora* growing just south of the air strip in a dwarf shrub community was included. This site is at the northern distribution limit of the species (Bay 1992), and it is the only site in the study area, where the species has been found.

3.3 Lichens

Eric Steen Hansen

All plots and permanent stations established in 1994 and 2000 were re-inspected by Eric Steen Hansen from 20 to 28 July. The plots (L1 to L19) were marked with green metal plates placed on the ground in front of them. Records from plots and stations that were surveyed in 1994, 2000 and 2005 are presented in Table 3.10.

I. Permanent plots L1- L19

A. Epilithic lichens

The lichen vegetation in L1 at about 1000 m a.s.l. near the top of Aucellabjerg seems fairly constant at present, as no important chances of the lichens were found in this plot between 1994 and 2005.

L6, at 600 m a.s.l., showed a marked increase in the number of thalli of *Umbilicaria virginis*, while the maximum thallus diameter remained unchanged, contrary to *Lecidea atrobrunnea*, which had increased its size. The basaltic rocks and their nitrophilous lichen flora are presumably influenced by musk ox dung or guano from birds resting on the boulders. However, the harsh climatic conditions prevailing at this level prevent a quick growth of the lichens.

A significant growth was observed by the following lichens in L2-L5 situated on four gneissic boulders near the ZERO-line just above Oksebakkerne: *Lecidea atrobrunnea*, *Pseudephebe minuscula*, *Rhizocarpon* sp. (grey thallus), *Sporastatia testudinea*, *Umbilicaria decussata*, *U. lyngei* and *Xanthoria candelaria*. Most of these species are distinctly nitrophilous just as *Dimelaena oreina* and *Physcia caesia*, which again were recorded as the dominant lichens both in L4 and L5. Both birds and musk oxen influence all these lichens via their excrements resulting in a rich growth of their thalli contrary to the slowly growing microlichens, *Acarospora* sp., *Candelariella vitellina*, *Rhizocarpon geographicum* and *Rhizoplaca melanophthalma*, where no or only minor chances were observed.

Since 2000, new thalli of *Rhizocarpon* sp. had colonized L7 situated on a gneissic boulder near the old trapping station, but as expected no increase as regards the total covering of this slow-growing lichen was found. This also applies to the other species recorded in L7. These nitrophilous lichens probably have been influenced only slightly by excrements from birds and mammals in the last 5 year period.

In L8, situated on a big gneissic boulder west of Zackenbergelven, it was observed that a part of the thallus of *Parmelia saxatilis* was teared off by birds or by strong winds. *P. saxatilis* occurs on a small ledge on the boulder. The two thalli of *Umbilicaria decussata*, which were overgrown by *P. saxatilis* during the period 1994-2000, now appeared to be exposed again. However, *Pseudephebe minuscula* was not recorded in the plot in 2005. The same applies to the thallus of *P. minuscula* on L10 located on a flat gneissic boulder at the northern end of Ulvehøj. The lichen had disappeared since 2000 probably because of frost erosion distinctly indicated by marks on the surface of the boulder. Contrary to the microlichens *Rhizocarpon* sp.

Table 3.10. Degree of covering (A), number of thalli (B), maximum thallus diameter in cm (C), presence of lichens (D) in plots in 1994, 2000 and 2005, respectively. L1-L8, L10 & L15-L16: epilithic lichen communities. L11-L14 & L17-L19: epigaeic communities. The degree of covering was estimated using the following, modified scale of Hult-Sernander: 5=>1/2; 4=1/2-1/4; 3=1/4-1/8; 2=1/8-1/16; 1=<1/16; +=just present; ++=dominating. In L1, a star marks presence.

L1	**1994**	**2000**	**2005**
Xanthoria elegans	*	*	*
Xanthoria sorediata	*	*	*
Umbilicaria virginis	*	*	*
Umbilicaria lyngei	*	*	*
Usnea sphacelata	*	*	*
Physconia muscigena	*	*	*
Pseudephebe minuscula	*	*	*
Sporastatia testudinea	*	*	*
Rhizocarpon geographicum	*	*	*
Lecanora polytropa	*	*	*
Lecidea atrobrunnea	*	*	*
Rhizoplaca melanophthalma	*	*	*
Aspicilia	*	*	*
Rock	*	*	*

L2		**1994**			**2000**			**2005**	
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Umbilicaria lyngei	2	100	2	2	100	2	2	100	2.7
Pseudephebe minuscula	+	1		1	2		1	2	4.2
Sporastatia testudinea	+	1		1	2	4.5	1	2	5.5
Rhizoplaca melanophthalma	+	1		+	2		+	2	1.5
Rock	5			5			5		

L3		**1994**			**2000**			**2005**	
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Rhizocarpon geographicum	4			4		7	4		
Sporastatia testudinea	3			3			3		
Umbilicaria lyngei	+	10		1	13	1.5	1	16	1.5
Pseudephebe minuscula	+			+	6	1.5	+	9	2.2
Rock	2			2			2		

L4		**1994**			**2000**			**2005**	
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Physcia caesia	D			D			D		
Umbilicaria decussata	13			40			48		
Xanthoria candelaria	12			22		0.5	32		1
Miriquidia garovaglii	4			6		1	6		2.2
Candelariella vitellina	2			7		0.5	7		0.5
Sporastatia testudinea	–			2		2	2		2.5
Acarospora	–			1		1.5	1		
Rhizoplaca melanopthalma								1	

L5		**1994**			**2000**			**2005**	
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Dimelaena oreina	3			3			3		
Umbilicaria lyngei	1	15		1	15	1.5	1	20	2
Sporastatia testudinea	1	6		1	6		1	6	
Rhizoplaca melanophthalma	1	7		1	7	3	1	7	4
Rhizocarpon geographicum	1	5		1	6	1	1	6	2
Rhizocarpon (gray thallus)	1	2		1	2		1	2	9.5
Pseudephebe minuscula	+	1		1	7	2	1	7	2

L5	1994			2000			2005		
	A	B	C	A	B	C	A	B	C
Umbilicaria decussata				+	2	2	+	2	2.7
Lecidea atrobrunnea				+	2	1	+	2	2
Rock	5			5			5		

L6	1994			2000			2005		
	A	B	C	A	B	C	A	B	C
Umbilicaria virginis		29			31	1.5		41	1.5
Lecidea atrobrunnea						3.2			3.7

L7	1994			2000			2005		
	A	B	C	A	B	C	A	B	C
Miriquidica garovaglii	4			5		7	5		7
Umbilicaria decussata	2	12		2	20	2	2	20	
Rhizocarpon geographicum	1			1	32		1	40	
Candelariella vitellina	+			1			1		
Rock	4			4			4		

L8	1994			2000			2005		
	A	B	C	A	B	C	A	B	C
Parmelia saxatilis	4			5			4		
Umbilicaria decussata	+			–			+	2	1.5
Pseudephebe minuscula	–			+			–		
Rock	4			4			5		

L10	1994			2000			2005		
	A	B	C	A	B	C	A	B	C
Umbilicaria lyngei	3		1.2	3		1.5	3		1.7
Sporastia testudinea	2			2					
Rhizocarpon cf. superficiale	1			1			1	20	2.2
Pseudephebe minuscula	+			1			–		
Rock	4			4			4		

L11	1994		2000		2005	
	A	B	A	B	A	B
Cassiope	5		5		5	
Salix arctica	1		1		1	
Cetraria delisei	1	7	1	5	1	5
Cetraria islandica	1	5	1	5	1	3
Stereocaulon alpinum	1	4	1	4	1	6
Peltigera malacea	+	2	+	2	+	2
Flavocetraria nivalis	+	1	+	2	+	1
Solorina crocea	+	1	–		–	
Cladonia pyxidata	+		+		+	
Cladonia borealis	+		+		+	
Ochrolechia frigida	+		–		+	1
Psoroma tenue	+		+		+	
Peltigera rufescens	–		1	4	1	4
Peltigera leucophlebia	–		+	1	+	2
Flavocetraria cucullata	–		+	1	+	1
Moss	1		1		1	

Table 3.10. Continued.

Table 3.10. Continued.

L12	1994		2000		2005	
	A	B	A	B	A	B
Dryas	4		4		4	
Carex rupestris	3		3		3	
Hierochloë alpina	+		+		+	
Salix arctica	+		+		+	
Potentilla	+		+		+	
Silene acaulis					+	
Stellaria longipes	+		+		+	
Cerastium	–		–		–	
Flavocetraria nivalis	1	25	1	30	1	30
Cetraria islandica	1	20	1	20	1	20
Stereocaulon alpinum	1	10	1	10	1	30
Peltigera rufescens	1	10	1	<5	1	6
Candelariella placodizans	1	10	+	5	+	5
Ochrolechia frigida	1		1		1	
Cetraria muricata	+	10	+	4	+	5
Cladonia borealis	+	5	+	<5	+	5
Cladonia pyxidata	+		+	5	+	5
Baeomyces	+		+		+	
Arthrorhaphis alpina	–		+	5	+	7
Candelariella terrigena	–		+	2	+	2
Peltigera didactyla	–		+		+	
Psoroma tenue	–		+		+	

L13	1994		2000		2005	
	A	B	A	B	A	B
Kobresia myosuroides	5		5		5	
Carex bigelowii	+		+		+	
Luzula confusa	+		+		1	
Hierochloe alpina					+	
Polygonum viviparum	+		+		+	
Dryas	+		+		+	
Cladonia pocillum	+	25	+	25	+	25
Physconia muscigena	+		+		+	
Cladonia borealis	+		+		–	
Rinodina turfacea	+		+		–	
Peltigera rufescens					+	3
Cladonia pyxidata					+	

L14	1994		2000		2005	
	A	B	A	B	A	B
Dryas	4		5		5	
Carex rupestris	3		3		3	
Cladonia pocillum	1		1		1	
Thamnolia vermicularis	+		1	36	1	>100
Flavocetraria nivalis	+	10	+	10	+	10
Hypogymnia subobscura	+	4	+	3	+	9
Alectoria nigricans	+	2	+		+	3
Bryoria chalybeiformis	+	2	+	3	+	1
Ochrolechia upsaliensis	+	2	+		+	2
Peltigera rufescens	+	1	–		–	
Rinodina venosa	–		+	2	+	2
Rinodina turfacea	+	1	+		+	
Baeomyces	+	1	+		+	

Table 3.10. Continued.

L14	1994		2000		2005	
	A	B	A	B	A	B
Catapyrenium cinereum	+		+		+	
Cladonia pyxidata	+		+		+	
Lecanora epibryon	+		+		+	
Phaeorrhiza nimbosa	+		–		+	
Ochrolechia frigida	+				+	
Physconia muscigena	+		–		+	1
Solorina bispora	+		–		+	
Flavocetraria cucullata	–		+	3	+	3
Cetraria muricata	–	10	+		+	1
Caloplaca cerina			+		+	
Caloplaca tiroliensis			+		+	
Lecanora behringii					+	
Moss	+	5	+			

L15	1994		2000		2005	
	A	B	A	B	A	B
Dimelaena oreina	3			3		
Lecidea atrobrunnea	2			2		
Rhizoplaca melanophthalma	1			1		
Sporastatia testudinea	1			1		
Umbilicaria decussata	1	45	1.3	1	50	1.7
Physcia caesia	+	6		+	6	
Melanelia infumata	+	3		+	3	
Rhizocarpon geographicum	+			+		
Rock	4			4		

L16	1994		2000		2005	
	A	B	A	B	A	B
Umbilicaria lyngei	3	>100	2.5	3	>100	3.7
Pseudephebe minuscula	1			1		
Rhizocarpon (yellow thallus)	1			1		
Sporastatia testudinea[1]	1			1		3.4
Umbilicaria hyperborea	+	3		+	3	
Melanelia disjuncta	+	1		+	1	
Rock	4			4		

1. Infested by Rhizocarpon pusillum

L17	2000	2005
	A	A
Cassiope tetragona	5	5
Carex bigelowii	2	2
Salix arctica	2	2
Polygonum viviparum	1	1
Stellaria longipes	1	+
Cladonia amaurocraea	2	2
Stereocaulon alpinum	2	2
Cetrariella delisei	1	1
Cladonia mitis	1	+
Cladonia borealis	+	+
Cladonia pyxidata	+	+
Cetraria islandica	+	+

and *Sporastatia testudinea*, *Umbilicaria lyngei* had increased its size on the boulder.

In two plots established in 2000, L15 and L16, the first on a gneissic boulder manured by birds just northwest of the old trapping station, the second on a big gneissic boulder at an altitude of 170 m a.s.l. on Zackenberg, the only observed change was an increase in the size and number of thalli of the nitrophilous lichen, *Umbilicaria decussata*, in L15, and a similar increase of the maximum thallus diameter of *Umbilicaria lyngei* in L16.

B. Epigaeic lichens

An increase in the number of thalli of *Stereocaulon alpinum* between 2000 and 2005 was the most important change in L11 and L12 on Ulvehøj. *S. alpinum* prefers a protective snow cover during winter. *Peltigera leucophlebia* and *Cladonia borealis*, which both avoid constantly dry soil, also have expanded their populations with more thalli in L11 and L12. *Peltigera rufescens* had developed more thalli in L12 and L13, *i.e.* the two dry heath types, but was constant on the *Cassiope* heath in L11.

The number of thalli of *Thamnolia vermicularis* had increased considerably in L14 since 2000. New thalli of this species have probably been transported to the plot by wind just as the new thalli of *Hypogymnia subobscura*. The thallus of *T. vermicularis* is usually rather loosely attached to the soil, and its interior is hollow. L14 is evidently almost free of snow during winter and therefore strongly exposed to winds.

In L17, L18 and L19 only few changes of minor importance were found between 2000 and 2005 in these *Cassiope* heath plots. Even the brown colouring of the tips of the podetia of *Cladonia amaurocraea* and *C. mitis* appeared to have been fairly constant. The colouring is considered to be caused by UV-radiation. The *Cassiope* community appears very stable at present.

II. Permanent stations along the ZERO-line 0-155

Station 83 is given as an example (Table 3.11).

A. *Dryas-Carex rupestris* heaths

Since 2000 four lichens, viz. *Candelariella placodizans*, *Peltigera rufescens*, *Psoroma tenue* and *Solorina bispora*, had disappeared from one Raunkiær plot at station 51. All

L17	**2000**	**2005**
	A	**A**
Ochrolechia frigida	+	+
Peltigera leucophlebia	+	+
Peltigera malacea	+	+
Psoroma tenue	+	+
Sphaerophorus globosus	+	+
Cladonia trassii	–	+

L18	**2000**		**2005**	
	A	**B**	**A**	**B**
Cassiope tetragona	4		4	
Dryas	2		2	
Salix arctica	2		2	
Carex rupestris	1		1	
Saxifraga oppositifolia	+		+	
Cladonia mitis	1		1	
Stereocaulon alpinum	1		1	
Cetrariella delisei	+	15	+	
Flavocetraria cucullata	+	<10	+	
Arthrorhaphis alpinum	+	5	+	
Candelariella placodizans	+	3	+	4
Cladonia trassii	+	2	+	
Baeomyces	+		+	
Cladonia phyllophora	+		+	
Cladonia pocillum	+		+	
Cladonia pyxidata	+		+	
Peltigera didactyla	+		+	
Psoroma tenue	+		+	
Solorina bispora	+		+	
Caloplaca	–		+	
Moss	2		2	
Bare soil	3		3	

L19	**2000**		**2005**	
	A	**B**	**A**	**B**
Cassiope tetragona	5		5	
Carex bigelowii	2		2	
Salix arctica	2		2	
Polygonum viviparum	–		+	
Stellaria longipes	+		+	
Cladonia mitis	2		2	
Cladonia phyllophora	1		1	
Stereocaulon alpinum	1		1	
Thamnolia vermicularis	+	20	+	
Cetrariella delisei	+		+	
Cladonia amaurocrea	+		+	
Cladonia borealis	+		+	
Cladonia pyxidata	+		+	
Peltigera scabrosa	+		+	
Psoroma tenue	+		+	
Moss	2		2	

Table 3.10. Continued.

	1		2		3		4		5		6		7		8		9		10		%	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Dryas	3	3	2	2			3	3	2	2	1	1	3	–			1	1	2	2	80	80
Carex nardina							1	1	2	2	1	1	1	1	3	3			1	1	60	60
Carex rupestris	3	3	3	3					2	2							3	3			40	40
Polygonum viviparum				1	1	1			2	1											20	40
Draba			1	–																	10	10
Minuartia rubella					3	3															10	10
Salix arctica																1	1	1		1	10	30
Ochrolechia upsaliensis	1	–	1	1			3	2			1	1			1	1	1	1		1	60	70
Thamnolia vermicularis	1	3			1	1			3	3					1	1	1	–			50	50
Brodoa oroarctica								1			1	1							1	1	30	40
Cetraria muricata	1	1	1	1				1													20	30
Cladonia pocillum	1	1			1	1		1								1					20	40
Candelariella placodizans					1	1											1	1		1	20	30
Phaeorrhiza nimbosa											1	1			1	–					20	20
Flavocetraria nivalis		2	2	2																	10	20
Cladonia borealis					1	–															10	10
Lecanora epibryon		1			1	1						1									10	30
Flavocetraria cucullata							1	1													10	10
Diploschistes muscorum									2	2						1					10	20
Hypogymnia subobscura															2	2		1			10	20
Psoroma tenue																1	1	1		1	10	30
Baeomyces																		2			0	10
Arthrorhaphis alpina		1								1						1					0	30
Cladonia chlorophaea				1																	0	10
Buellia papillata						1				1						1					0	30
Caloplaca tiroliensis						1															0	10
Solorina bispora						1				1											0	20
Rinodina turfacea						1															0	10
Leproloma vouauxii												1									0	10
Peltigera rufescens												1									0	10
Stereocaulon alpinum														1		1					0	20
Physconia muscigena																1					0	10
Mosses		1	3	3			1	1	3	3											30	40

»a=2000; b=2005«

Table 3.11. Frequency in per cent of plants inclusive of lichens occurring at station 83 at the ZERO-line. 1 = species situated in the 1/10 m² Raunkiær circle; 2 = species situated in the 1/100 m² circle; 3 = species situated in the 1/1000 m² circle.

of these species prefer rather moist habitat conditions. The more or less calciphilous lichens, *Cladonia pocillum*, *Lecanora epibryon* and *Physconia muscigena*, were recorded as new in one plot.

Four lichens with relatively high nutrient demands, viz. *Caloplaca cerina*, *C. tiroliensis*, *Cladonia pocillum* and *Physconia muscigena*, had colonized some plots at station 47. *Cetraria muricata*, *Hypogymnia subobscura* and *Thamnolia vermicularis*, which are easily detached from their substrate by strong winds, had disappeared from some plots and appeared in others. Some pioneer-species such as *Arthrorhaphis alpina*, *Buellia papillata* and *Lecanora geophila*, were not recorded in their plots in 2005, possibly because they were overgrown by other plants. The macrolichens, *Bryoria chalybeiformis* and *Stereocaulon alpinum,* were recorded in new plots in 2005.

In total, 17 species of lichens had disappeared from one or more plots at station 36 between 2000 and 2005. Microlichens such as *Arthrorhaphis alpina*, *Caloplaca cerina*, *Candelariella placodizans*, *Lecanora geophila*, *Megaspora verrucosa* and *Pertusaria panyrga* had presumably been overgrown by faster growing macrolichens and other plants. The macrolichens, *Cetraria muricata*, *Flavocetraria cucullata* and *F. nivalis*, were presumably blown away from the plots by strong winds, which on the other hand had transported, for example, *Alectoria nigricans*, *Bryoria chalybeiformis* and *Cetraria muricata*, to the station. The fact that the calciphilous lichens, *Cladonia pocillum*, *Lecanora epibryon* and *Peltigera venosa*, were recorded as new at the station in 2005, possibly indicates an indirect influence (nutritious dust, dung) of musk oxen. It is remarkable that the calciphilous and moisture dependent species *Solorina bispora* had disappeared from all of its four plots since 2000. It indicates that the microclimate has become drier in the last years.

Six lichens had disappeared and six could be recorded as new in one or more plots at station 2 in 2005. *Arthrorhaphis alpina*, *Baeomyces placophyllus* and *Peltigera lepidophora*, all pioneers on bare soil, had possibly been overgrown by other plants. However, the appearance of *Peltigera didactyla* in two plots indicates a mechanical disturbance of this *Dryas* heath caused by tramping by musk oxen and/or influence of wind. Hence, *Flavocetraria nivalis* had probably been transported to the plots by wind.

Two lichen species, viz. *Brodoa oroarctica* and *Caloplaca ammiospila*, had disappeared and nine had appeared in one or more plots at station 81. Most of the new lichens, for example *Cladonia pocillum*, *Megaspora verrucosa* and *Psora rubiformis*, are among the first colonizers on bare, more or less alkaline soil. *Leproloma vouauxii* and *Solorina spongiosa* both prefer moist soil. Part of the community is apparently moistened by melt water during early summer, but the invasion of the many 'fell-field species' shows that the soil conditions were drier in 2005 than in 2000.

Four lichen species, viz. *Cladonia borealis*, *Ochrolechia upsaliensis*, *Phaeophyscia nimbosa* and *Thamnolia vermicularis*, had all disappeared from one plot at station 83. However, more than twenty lichen species could be recorded as new in one or more plots in 2005. The extensive colonization is caused by typical 'fell-field'-species such as, for example, *Cetraria muricata* and *Flavocetraria nivalis*, the pioneer species, *Arthrorhaphis alpina*, *Candelariella placodizans* and *Baeomyces* sp., and species growing on plant remains and mosses, for example, *Lecanora epibryon*, *Buellia papillata*, *Psoroma tenue* and *Rinodina turfacea*. The new occurrence of species such as *Leproloma vouauxii*, *Solorina bispora* and *Stereocaulon bispora* indicates that the soil at this station was moister in 2005 than in 2000.

Since 2000, *Solorina bispora* had disappeared from one plot at station 92a, and four lichen species, viz. *Buellia papillata*, *Lecanora epibryon*, *Megaspora verrucosa* and *Stereocaulon alpinum*, had colonized one plot at this otherwise fairly constant station.

Three lichen species, viz. *Catapyrenium cinereum*, *Physconia muscigena* and *Stereocaulon alpinum*, had disappeared from one plot at station 92b, and three could be recorded as new, among them *Fulgensia bracteata*, which prefers comparatively moist soil conditions (cf. station 92a).

Peltigera rufescens had disappeared from one plot at station 94, and *Fulgensia bracteata* and *Pertusaria coriacea* both had immigrated to one plot. The soil is probably slightly moister now than in 2000, but otherwise the vegetation was constant at this station.

B. *Cassiope* heaths

Station 38 is situated in a previously fairly moist *Cassiope* heath. Since 2000 five species of lichens with a distinct preference for moist soil conditions, viz. *Cladonia borealis*, *Leproloma vouauxii*, *Peltigera leucophlebia*, *Psoroma tenue* and *Stereocaulon alpinum*, had disappeared from one or more plots. The microclimate is evidently drier now than five or eleven years ago. However, *Flavocetraria cucullata*, which is often associated with *Vaccinium uliginosum* in moist heath types in other parts of Greenland, has been constant in its occurrence in the whole period. Only two lichens, viz. *Alectoria nigricans* and *Cetraria islandica*, could be recorded as new at this station in 2005.

Station 34 appears to be very rich in lichens. It is a characteristic feature that many lichens that had disappeared from the station and also those that were recorded as new in 2005 usually are loosely attached to the soil substrate. This applies to species such as *Alectoria nigricans*, *Bryoria chalybeiformis*, *Cetraria islandica*, *C. muricata* (this lichen had disappeared from five plots!), *Flavocetraria cucullata*, *F. nivalis*, *Hypogymnia subobscura* and *Thamnolia vermicularis*. The soil in the station has evidently been strongly desiccated since 2000.

Station 32 is a fairly moist *Cassiope-Salix arctica* snow-patch heath. Some snow-patch lichens such as *Cetrariella delisei*, *Cladonia mitis*, *C. phyllophora* and *Peltigera malacea* had disappeared from one or more plots since 2000, but other species belonging to the same group of lichens, for example *Cladonia trassii*, had immigrated to the station, which possibly has become drier with lesser snow during winter.

The two species, *Flavocetraria cucullata* and *Stereocaulon alpinum*, were constant at station 20, situated in a *Cassiope* heath rich in *Vaccinium uliginosum*. However, many changes had taken place since 2000 in the vegetation of this station. Lichen species such as *Cladonia amaurocraea*, *C. mitis*, *Peltigera malacea*, *P. malacea* and *Psoroma tenue* had disappeared, while for example *Cetrariella delisei*, *Cladonia trassii* and *Pannaria pezizoides* had appeared since 2000. The changes seem to indicate that the vegetation moves from snow-patch-like conditions to a more heath-like state.

Like at station 20, *Flavocetraria cucullata* was very constant at station14, while many other lichens had disappeared from this station, *i.e. Psoroma tenue* from all five plots! Just as, for example *Cladonia phyllophora* and *Peltigera malacea*, *Psoroma tenue* prefers comparatively moist habitats. Its absence indicates that the microclimate at station 14 had become drier since 2000.

A comprehensive invasion of lichens including pioneer species such as *Arthrorhaphis alpina*, *Candelariella placodizans* and *Megaspora verrucosa* had taken place at station 82 since 2000. Wind erosion is a possible explanation for the observed vegetation changes, but although the microclimate presumably had become drier, the soil was still moist enough to allow colonization of species such as *Peltigera leucophlebia* and *Solorina bispora*, which both prefers slightly alkaline soil conditions.

C. *Salix arctica* snow-patch heaths

Station 60 is situated in a mixed *Salix arctica-Carex rupestris-Dryas* heath very rich in lichens and other plants. In view of the high species diversity, remarkable few changes had taken place since 2000. Three lichens, viz. *Alectoria nigricans*, *Arthrorhaphis alpina* and *Cladonia borealis*, had disappeared from one or more plots, while six species, for example *Peltigera rufescens*, had immigrated. A slight mechanical erosion of the soil caused by wind or animals seems to have given room for lichens such as *Arthrorhaphis alpina* and *Peltigera rufescens*.

Cetrariella delisei and *Peltigera malacea*, both of which prefer moist habitats with a moderate snow-cover during winter, are among the five lichen species that had disappeared from one or more plots at station 31 since 2000. Apart from, for example *Cladonia trassii*, the lichen species, which could be recorded as new at the station in 2005, usually occur on more dry soil. The habitat has apparently become drier and windier at station 31 since 2000.

Like at station 31, the occurrence and frequency of *Stereocaulon alpinum* was fairly constant at station 28, which is situated in a *Salix arctica-Dryas* community. Most of the six lichen species, which had disappeared from plots at this station, usually grow on moist soil and mosses, while most of the seven new colonizing lichens are restricted to more dry substrates. The changes found are presumably due to a slightly drier microclimate (*Stereocaulon alpinum* needs to be protected by a moderate snow-cover during winter).

Stereocaulon alpinum was recorded in one new plot at station 13, situated in a mixed *Salix arctica-Dryas-Carex bigelowii* community, but otherwise this lichen was constant here. Three more or less calciphilous lichen species, viz. *Cladonia pocillum*, *Peltigera rufescens* and *Physconia muscigena*, had disappeared from one or more plots at the station, while seven lichens could be recorded as new in one or more plots. Among the new ones some, for example *Cladonia amaurocraea* and *Peltigera leucophlebia*, prefer relatively moist soil. There were no indications of generally drier conditions at this station.

Very few changes of the lichen vegetation were recorded in the *Dryas-Salix arctica* community at station 96 in 2005: *Peltigera leucophlebia* had disappeared from one plot and *Peltigera rufescens* and *Solorina bispora* were found as new, each in one plot. Accordingly, the vegetation had been fairly constant since 2000.

D. Mixed *Vaccinium uliginosum* heaths

Station 57 is situated in a *Vaccinium-Cassiope-Dryas* heath, which apparently had remained fairly constant. Since 2000 *Cetraria islandica* had disappeared from two plots, while *Caloplaca tiroliensis* and *Cladonia borealis* had immigrated each to one plot.

Many changes had taken place at station 10, which is situated in a *Vaccinium-Cassiope* heath rich in lichens. Nine lichen species had disappeared from one or more plots since 2000, most of them (for example, *Cladonia pocillum*, *Lecanora epibryon* and *Physconia muscigena*) with a distinct preference for neutral to slightly alkaline soil. They have probably been overgrown by dwarf shrub species. *Cladonia phyllophora* and *Pannaria pezizoides* are usually restricted to moist habitats. Eleven lichen

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

* 0% snow ** 7% ice cover

Table 3.12. Date of 50% snow-cover (ice-cover on pond at Station 1) in the arthropod plot 1996-2005.

species could be recorded as new in one or more plots in 2005. Some of them are lichens, which usually prefer moist soil (for example, *Cetrariella delisei* and *Cladonia trassii*), *Cladonia amaurocraea* needs a protecting layer of snow during winter. The soil was still somewhat moist at this station in 2005.

E. Fell-fields and epilithic community

The vegetation was almost totally constant since 2000 at station 100. Station 144 is situated in a fell field with very open vegetation. The station was re-established in 2005, because the tubes had been pushed up from the basaltic soil and gravel since 2000. Station 155, which is situated on the top of Aucellabjerg, had also been disturbed since 2000, and therefore no changes could be recorded here in 2005, where the station was re-established.

Conclusion

Lichens are very useful indicators of climatic changes as well as other, more local changes in their environment. With some exceptions the present investigation shows that the epigaeic lichens along the ZERO-line had adapted to drier soil conditions since 2000. Moisture via melt water and precipitation evidently had decreased in the lichen substrates since 2000. The distinct indications were that strong winds had influenced the lichens to a great extent since 2000, which may be associated with more limited snow cover since then (see 2.2). However, the influence of UV-radiation upon the *Cladonia thalli* appeared to have been at the same level in 2005 as in 2000. As regards the epilithic lichens it can be concluded that a significant growth had taken place by many more or less nitrophilous lichens, which may have been manured by musk oxen and/or birds.

3.4 Arthropods

Steen K. Frank and Jannik Hansen

Like the previous years, five pitfall trap stations each with eight yellow traps and one window trap station with two traps were operated during the 2005 season. Sampling procedures were concurrent with previous years. The fieldwork was conducted by Line Anker Kyhn. Steen K. Frank carried out the sorting of the specimens. The material is stored in 70% ethanol at the Zoological Museum, University of Copenhagen, and is available for further study.

Ice and snow at the trap stations melted earlier than recorded in all previous years (Table 3.12), and stations 2, 5 and 7 were opened one week earlier than usual. The total number of collected arthropods in 2005 was 47,661. This number is low compared to the previous years, even though the number of trapping days were the highest so far (Tables 3.13 and 3.14)

Window traps

This year the two window traps in Gadekæret were opened on 20 May, when the ice cover on the surrounding pond only was 35%. The trap station was completely snow free, and the traps worked continuously until 26 August. On 15 June one trap was destroyed by a musk ox and replaced.

The total number of specimens caught this season was 9444 (Table 3.13). This number is at the high end of the range for 1996-2005. Only in 2000, more specimens were caught (10,588). Like previous years, chironomids constituted the bulk of specimens caught (Table 3.13). This year the chironomids had a very distinct peak one week earlier than average for the years 1996-2004 (Fig. 3.3). A possible explanation for this could be the extraordinary early

Date	27,5	3,6	10.6	17.6	24.6	1.7	8.7	15.7	22.7	29.7	5.8	12.8	19.8	26.8	**2005**	**2004**	**2003**	**2002**	**2001**	**2000**	**1999**	**1998**
No. of trap days	**14**	**14**	**14**	**13**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**195**	**172**	**168**	**168**	**168**	**166**	**153**	**174**
COLLEMBOLA		3	6	4	14	18	21	6	7	3	16	6	4	4	**112**	175	31	191	119	102	61	5
COLEOPTERA																						
Latridius minutus															**0**	0	0	0	0	0	2	0
HEMIPTERA																						
Nysius groenlandicus									5	1					**6**	10	0	1	0	0	0	0
Aphidoidea					2		2		4						**8**	3	1	0	2	0	0	0
Coccoidea															**0**	0	0	0	0	3	0	0
THYSANOPTERA								1	1	1	1	2		1	**7**	11	0	3	1	0	0	0
LEPIDOPTERA																						
Colias hecla										1					**1**	9	2	6	0	2	0	0
Clossiana sp.										1					**1**	5	4	1	1	2	1	1
Geometridae															**0**	0	0	2	3	0	0	0
Noctuidae								1	1	3		2			**7**	1	1	0	0	0	0	0
DIPTERA																						
Nematocera larvae															**0**	0	0	2	0	0	1	0
Nematocera undet.															**0**	0	0	0	1418	0	0	0
Tipulidae								1							**0**	0	1	0	0	0	1	0
Trichoceridae															**0**	2	0	0	0	0	0	1
Culicidae				3	8	12	21	48	18	9	6	3			**128**	104	96	232	209	111	322	138
Chironomidae	5	5	858	3559	161	165	691	378	273	89	96	97	63	30	**6470**	5203	7792	6378	3876	8522	5787	3743
Ceratopogonidae				1	3	3	1		1						**9**	21	66	1598	168	*	1799	*
Mycetophiliidae			1				1		1	1	5	9			**18**	21	2	6	23	22	16	624
Sciaridae			4	665	20	5	11	41	3					1	**749**	53	12	56	33	2	171	*
Cecidomyiidae				1											**0**	0	0	3	4	32	6	0
Empididae						3	1	1	2						**7**	7	8	1	8	10	9	9
Phoridae															**0**	0	0	1	1	2	3	0
Syrphidae		1		1	1		1	1	1		4				**10**	12	6	10	4	5	1	8
Heleomyzidae															**0**	0	0	1	2	0	1	0
Piophilidae															**0**	3	0	0	0	0	0	0
Agromyzidae	46	20	13	7	2	1		3	1		1	1		4	**99**	34	2	3	0	0	0	0
Tachinidae						1	1	4			1			1	**7**	10	7	0	2	6	1	0
Calliphoridae	7	2													**9**	4	1	1	1	4	5	7
Scatophagidae	1	1	17	5	2	1		1	1		1		1		**31**	11	3	7	0	2	10	0
Anthomyiidae	2		9	9					2		1	3	1	1	**28**	12	10	8	2	*	3	26
Muscidae				63	105	127	104	141	93	67	89	109	22	15	**935**	1423	866	554	1312	1455	754	745
HYMENOPTERA																						
Bombus sp.							1			1	1	4			**7**	5	3	1	0	0	1	2
Ichneumonidae					1	11	14	34	3	3	2				**68**	47	70	24	34	48	24	18
Braconidae															**0**	1	0	0	0	0	0	1
Chalcidoidea									1						**1**	1	1	2	14	0	0	0
Ceraphronoidea															**0**	0	2	0	0	0	0	0
ARANEA																						
Lycosidae								2	1	3	3	1			**10**	1	1	1	0	2	0	0
Linyphiidae		4	5		1			1				1		4	**12**	4	8	8	15	10	6	1
ACARINA			39	54	45	63	55	56	16	6	5	229	102	34	**704**	524	54	347	358	246	191	826
Total	61	36	952	4372	365	410	925	720	435	189	232	467	193	95	**9444**	7717	9050	9448	7610	10588	9177	6155

Table 3.13. Weekly totals of arthropods etc. caught in the window trap station in 2005. 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 1998-2004 are given for comparison. An asterisk marks that the group was not separated from a related group in that year.

ice melt on the pond around the traps (Table 3.12).

Apart from the chironomids, an extremely high number of sciarids were caught this year, constituting the highest number ever recorded (Table 3.13). The same apply to agromyzids, and high numbers were also caught in Noctuidae, Aphidoidea, Acari, Lycosidae and Anthomyiidae.

Like in 2004 ceratopogonids were found in low numbers, and only half the number of specimens found in 2004 were caught this year (Table 3.13).

Last year's catch of the cycclorrhaph dipteran family Piophilidae, was not followed up this year.

Pitfall traps

The first pitfall traps were established on 20 May, and all traps were in use from 3 June and until 26 August. Due to damage by foxes, fox urine and *Bombus* mould, some of the traps were replaced during the season. On one occasion also a musk ox defecated in a trap.

The number of trapping days in 2005 was 3686, which is the highest number so

Date	**27.5**	**3.6**	**10.6**	**17.6**	**24.6**	**1.7**	**8.7**	**15.7**	**22.7**	**29.7**	**5.8**	**12.8**	**19.8**	**26.8**	**2005**	**2004**	**2003**	**2002**
No. of active stations	**3**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**
No. of trap days	**168**	**184**	**258**	**280**	**280**	**280**	**280**	**276**	**280**	**280**	**280**	**280**	**280**	**280**	**3686**	**3437**	**3101**	**3059**
COLLEMBOLA	17	258	243	573	1194	517	1514	612	227	2811	1391	130	60	39	**9586**	13277	17510	20312
HETEROPTERA																		
Nysius groenlandicus		1	3	4	16	17	23	79	84	43	35	48	29	89	**471**	96	3	0
Aphidoidea	6	2	2	9	48	22	58	66	77	84	55	41	20	34	524	277	1624	157
Coccoidea			5	24	32	39	33	114	268	296	117	127	25	12	**1092**	1288	42	634
THYSANOPTERA					2		2	2	4	3	2	1	1	2	**19**	4	0	5
LEPIDOPTERA																		
Lepidoptera larvae	3		2	16	6	2	5	6	17	11	3	6	3	2	**82**	280	37	63
Colias hecla						1		3	8	2	1				**15**	38	156	29
Clossiana sp.				2	3	4	4	9	57	22	60	13			**174**	240	468	381
Lycaenidae															**0**	0	0	0
Plebeius franklinii										1					**1**	1	0	7
Geometridae											2				**2**	2	0	6
Noctuidae				2	9	9	18	21	38	16	29	31	5	5	**183**	14	110	1
DIPTERA																		
Nematocera larvae				4	2	1		3							**10**	18	29	46
Tipulidae larvae									1						**1**	6	3	3
Tipulidae					1	2	1		1						**5**	1	7	4
Trichoceridae															**0**	1	1	1
Culicidae				1	1	5	5				1				**13**	19	23	86
Chironomidae	1	2	24	340	183	155	229	388	84	53	14	8	5	6	**1492**	1596	4768	5982
Ceratopogonidae				1		2			1					2	**6**	16	107	102
Mycetophiliidae		10	12	1	1	4	17	25	13	6	5	7	3		**104**	63	70	48
Sciaridae		2	29	158	94	140	132	187	42	13	18	2	2		**819**	912	1101	762
Cecidomyiidae		2	3	1		2									**8**	13	8	6
Brachycera larvae															**0**	0	3	0
Empididae							3								**3**	5	8	24
Cyclorrhapha larvae						1	8	44	5	6	1	4	1	7	**77**	60	23	22
Phoridae		1	1	3	2	1	6	149	38	10	106	36	21	12	**386**	461	665	489
Syrphidae		2	7	2	3	8	10	8	12	4	16	17	3	1	**93**	45	35	30
Heleomyzidae															**0**	1	1	5
Agromyzidae	76	12	19	5	4		1	1	2		1	9	4	17	**151**	60	10	6
Tachinidae				1	3	9	4	5	8		3	5	1		**39**	42	60	23
Calliphoridae	44	22	3	4				1		1	2	12	5	2	**96**	31	17	44
Scatophagidae		47	31	5	3	2			1		3	7	1	6	**106**	7	42	24
Fannidae															**0**	0	0	0
Anthomyiidae	49	99	54	43	6	4	7	9	8	5	100	94	29	28	**535**	124	108	238
Muscidae			11	307	641	1061	1209	1051	372	232	319	212	27	22	**5464**	5623	8385	7499
SIPHONAPTERA															**0**	0	0	0
HYMENOPTERA																		
Tenthredinidae	1														**1**			
Hymenoptera larvae							1	1		1					**3**	4	8	0
Bombus sp.			3	4	4	2	2				2	1			**18**	40	15	7
Ichneumonidae		1	9	38	34	71	60	154	88	53	78	74	16	41	**717**	720	974	436
Braconidae			1	9	16	15	15	5	5	1	3	3	2	5	**80**	61	52	11
Chalcidoidea			1	7	9	17	15	51	66	71	149	296	40	25	**747**	746	120	190
Scelionidae															**0**	0	310	5
Ceraphronoidea						3		6	2		3	2	1		**17**	13	3	8
Cynipoidae						1		4	9	6	3	1			**24**	3	0	0
ARANEA																		
Thomisidae	7	8	1	10	3	1	1	9	15	9	10	15	4	5	**98**	90	164	219
Lycosidae	52	56	153	571	221	159	123	226	547	383	413	240	109	63	**3316**	3428	3438	1760
Lycosidae egg sac				2	1	4	3	14	3		2	7	7	2	**45**	69	85	12
Dictynidae	20	10	8	12	4		5	2	2	2	6		4	9	**84**	40	18	107
Linyphiidae	146	93	94	100	50	57	41	72	125	70	115	84	120	244	**1411**	1483	2526	1438
ACARINA	17	45	387	2249	1831	640	450	967	1313	776	487	546	217	171	**10096**	17616	18602	21282
OSTRACODA								1							**1**	0	12	9
NEMATODA			1												**1**	1	4	0
ENCHYTRAEIDAE				1											**1**	0	0	1
Unidentified															**0**	0	0	0
Total	439	673	1107	4509	4427	2978	4005	4295	3543	4991	3555	2079	765	851	**38217**	48935	61756	62523

Table 3.14. Weekly totals of arthropods etc. caught at the five pitfall trap stations in 2005. Each station holds eight yellow pitfall traps measuring 10 cm in diameter. Values from each date represent catches from the previous week. Totals from 2002-2004 are given for comparison. Asterisks mark groups that were not separated from closely related groups in that year.

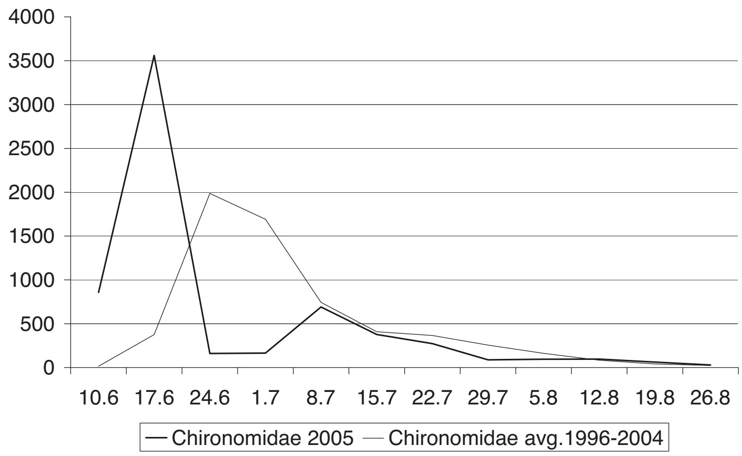


Fig. 3.3. Numbers of chironimid midges Chironomidae caught per week in the window traps 2005 compared with the mean for 1996-2004.

far. This was due to an exceptionally early thaw at all trap stations (Table 3.12), and to the fact that three trap stations were opened one week earlier than in all previous years. Weekly totals were pooled for all five plots and presented in Table 3.14 with totals from 2002-2004 for comparison.

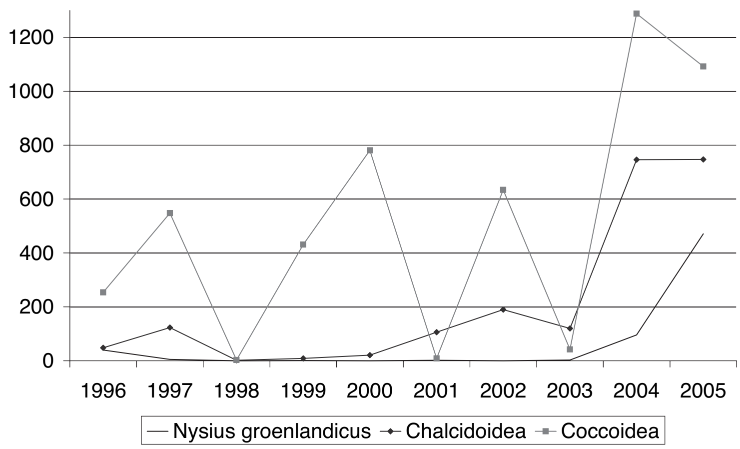


Fig. 3.4. Numbers of Coccoidea, Calcidoidea and Nysius groenlandicus caught during 1996-2005.

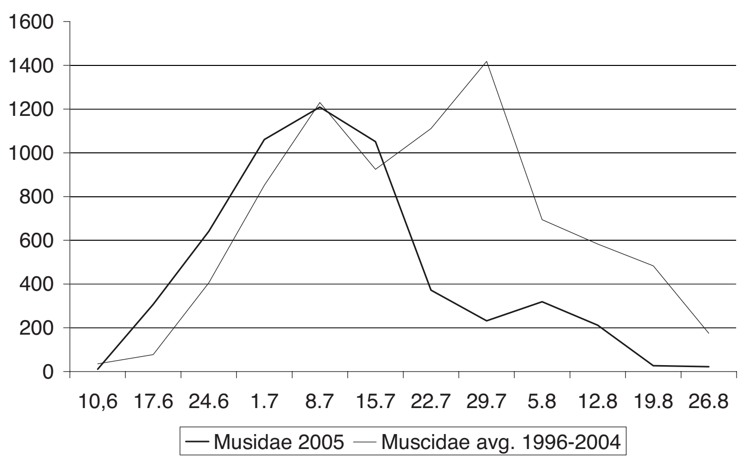


Fig. 3.5. Numbers of houseflies Muscidae caught per week in the pitfall traps in 2005 compared with means 1996-2004.

In the 2005 season 38,217 arthropods were collected. This number is low compared to other years, and was due to a major reduction in number of mites (Acari) and springtails (Collombola). These two groups normally constitute the major part of arthropods caught (Table 3.14).

Most other groups were either caught in equal or higher numbers than in recent years.

Two groups of flies Syrphidae and Agromyzidae were caught in higher numbers than in all previous years and the amount caught of another fly, Anthomyiidae, was only equalled in 1997. The anthomyiids and the agromyzids showed a pronounced peak in the beginning of the season (Table 3.14). Larvae from both families are plant-parasites, and their early occurrence and high numbers this year could be explained by an early emergence of the plants, in which the adults lay their eggs, due to the extraordinary early thaw.

Like last year, the catch of coccoids, calcidoids and the heteropteran *Nysius groenlandicus* were remarkably high. With 471 individuals, *Nysius groenlandicus* showed the highest number ever recorded (Table 3.14). The fluctuations of all three families in the years 1996-2005 are presented in Fig. 3.4, the calcidoids and *Nysius groenlandicus* showing a minor drop in numbers during the first couple of years and a major increase in the recent years. The coccoids fluctuate with high and low values within cycles of two or tree years.

Also the number of thysanopterans caught this year (19), highly exceeded the previous maximum of four in the years 1996-2004.

Among the parasitic wasps, Ichneumonidae, Braconidae, Ceraphronoidea and Cynipoidae, were found in high numbers. Especially noticeable was the gallwasps Cynipoidae, which were found with 24 individuals, compared to a maximum of three in the years 1996-2004. Like in 2004 no Scelionidae were found this year (Table 3.14).

The total number of adult lepidopterans was in the order of magnitude as last year. The noctuidaes though, were found in the highest numbers ever recorded (183).

The Muscidae peaked at the same time as the average for the years 1996-2004. The period was short and only a minor second peak occurred (Fig. 3.5).

This year a new family was added to the fauna list. One adult sawfly, Tenthredinidae, was caught in a pitfall trap already in late May, but Hymenoptera larvae have been caught in small numbers in some years.

No Tricoceridae or Heleomyzidae were found this year.

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

Since 2003, sawfly larvae (Table 3.15) have not preyed on *Salix* catkins in the study plots.

In 2005, the percentage of *Dryas* flowers depredated by "black moth" *Sympistris zetterstedtii* larvae was lower than the record-breaking numbers of 2004, but similar to several other seasons (Table 3.16). Only once, on 17 June, a larvae was encountered in a plot.

Woolly-bear *Gynaephora groenlandica* caterpillars were only encountered in June by the bird observer (J. Hansen), *i.e.* a total of 16 individuals (Table 3.17).

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

Table 3.15. Peak ratio (per cent) of female arctic willow Salix arctica pods infested by sawfly larvae in 1996-2005. + indicates that numbers were not quantified.

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

Table 3.16. Peak ratio (per cent) of mountain avens Dryas integrifolia/octopetala flowers depredated by larvae of "black moth" Sympistris zetterstedtii in mountain avens plots in 1996-2005.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
June	1	2	7	7	10	2	4	25	24	16
July	0	1	4	17	2	2	3	2	9	0
Total	1	3	11	24	12	4	7	27	33	16

Table 3.17. Number of woolly-bear Gynaephora groenlandica caterpillars recorded by one observer in study area 1A (the bird monitoring area) in June and July 1996-2005. Please note that the numbers given for 2004 differ from the ones published in Rasch and Caning (2005). The numbers given here are the numbers observed by one observer (O. Thorup) in 2004, and not the halved total of both observers in 2004, as previously published.

Bumble bees

The earliest record of a bumble bee *Bombus polaris/hyberboreus* was 25 May. 307 bumble bees were observed by one ornithologist (J. Hansen) in June and July. This is the second highest number of records, and is likely to be explained by periods of very warm weather, as well as the high number of observing hours (see Table 3.18). Most likely, this type of recording is highly observer dependent (cf. Rasch and Caning 2005).

	1999	2000	2001	2002	2003	2004	2005
June	–	59	12	48	95	243	238
July	35	34	15	31	16	107	69
Total	–	93	27	79	111	350	307

Table 3.18. Number of bumble bees Bombus polaris/hyperboreus recorded by the two bird observers in June and July 1999-2005. The numbers given for 2004 are the numbers observed by one observer (O. Thorup) in 2004, and not the halved total of both observers, as previously published.

3.5 Birds

Jannik Hansen and Hans Meltofte

Bird observations were made by Niels Martin Schmidt 19 May – 1 June, by Hans Meltofte 31 May – 14 June, by Jannik Hansen 1 June – 1 August and by Line Anker Kyhn 1-29 August. Other researchers and staff provided much valued information throughout the season.

For scientific names in this chapter, see section on Other observations. Local site names can be found in Meltofte and Berg (2005).

Breeding populations

A complete initial census was performed between 10 and 17 June by two observers. The 68 'man-hours' required for completion of the survey, are markedly above average, mainly due to the double manning. The two observers spent 44 and 24 hours, respectively, completing the census. Most parts of the 19.3 km^2 census area were snow free, and all but one of the

Month	West of river	East of river	Total
June	8; 37	19; 103	27; 140
July	6; 31	16; 90	22; 121
Total	14; 68	35; 193	49; 261

Table 3.19. 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 2005, respectively.

Table 3.20. Estimated numbers of pairs/territories in five sectors of the 19.3 km² census area in Zackenbergdalen, 2005.

	West of river <50 m a.s.l. 3.47 km²	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	0	4-5	0	0	0	4-5
Pink-footed goose	0	0	0	0	0	0
Common eider	0	0	0	0	0	0
King eider	0	1-2	0	0	0	1-2
Long-tailed duck	1	5-7	0	0	0	6-8
Rock ptarmigan	0	0	0	0	0	0
Common ringed plover	2	6-8	0	3	6-7	17-20
Red knot	2-3	12-14	6-9	8	2	30-36
Sanderling	6-7	19-27	4-5	8-9	1	38-49
Dunlin	19-20	58-66	12-13	3	0	92-102
Ruddy turnstone	5-7	28-32	25-27	6-7	1	65-74
Red-necked phalarope	0	1	0	0	0	1
Red phalarope	0	1	0	0	0	1
Long-tailed skua	7-8	12-15	7-9	2	0	28-34
Glaucous gull	1	0	0	0	0	1
Arctic redpoll	1	0	0	0	0	1
Snow bunting	33-40	33-34	28-29	13	7	114-123

long-tailed skua nests were initiated prior to the census period. The entire census was performed in good weather conditions.

In addition, large parts of the census area were covered regularly during June and July, 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 three occasions, due to fog (see below).

As in 2004, the total effort in June and July 2005 (Table 3.19) was larger than in previous years, although the number of trips was fairly close to previous seasons. A prolonged period of fog (26 June – 6 July) meant that fieldwork was obstructed several entire and half days. Extensive glacier snowmelt resulting in surge flooding in Zackenbergelven, practically prevented access to the census area west of the river between 24 and 29 July.

The results of the initial census, supplemented with records during the rest of the season (see Meltofte and Berg 2005), are presented in Table 3.20, and in Table 3.21, these are compared with the estimates of previous seasons.

The population size of a number of species changed markedly as compared to previous years. Sanderlings and common ringed plovers were recorded in the lowest numbers since the beginning of the monitoring programme. Also, dunlin numbers were lower than the last four years, and the peak seen during 2001-2003 could be coming down. Ruddy turnstones were more numerous than previously, and red knot numbers were in the high end of the range measured in the programme (Tables 3.21 and 3.22).

The season had slightly higher numbers of long-tailed skua territories than previously, but this may be related to the fact that many of the birds were not breeding and therefore moved around a lot (Table 3.21).

For the second consecutive year, the number of mapped snow bunting territories was extraordinarily high. Just as in 2004, the snow free areas of the census area were very extensive, and the mean

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Red-throated diver	1-2	3	3	2-3	2-3	2	3	2	3	4-5
Pink-footed goose	0	1	0-1	2	1	1	1	0	0	0
Common eider	0	0	0	0	1	1	1	0	1	0
King eider	2-3	2	1	2-3	2-4	3-4	4-6	1	1-2	1-2
Long-tailed duck	5-8	4-6	6-8	7-8	5-8	5-7	6-7	7-9	6	6-8
Rock ptarmigan	3	11-15	4-6	7-8	1-3	2-4	3	0-1	0	0
Common ringed plover	54-56	40-48	38-45	51-65	41-43	51-54	37-41	29	46	17-20
European golden plover	0	0	0	0	0	1	0	0	0	0
Red knot	33-43	35-44	27-32	25-33	24-27	27-30	24-27	24-25	19	30-36
Sanderling	50-63	55-70	62-70	60-67	58-66	58-72	49-55	67-74	62	38-49
Dunlin	69-81	75-91	75-94	80-94	98-103	104-111	120-132	105-114	122	92-102
Ruddy turnstone	41-51	49-58	56-63	43-49	48-50	45-51	31-37	33-34	50	65-74
Red-necked phalarope	0-1	0-2	1-2	1-2	1-2	1-2	1-2	1-2	1	1
Red phalarope	0	0	0-1	0	0	1	0	0	0	1
Long-tailed skua	25-29	22-25	21-24	19-24	21-28	22-25	23-26	25-29	21	28-34
Glaucous gull	0	0	0	0	0	0	0	0	1	1
Snowy owl	0	0	0	0	0	1	0	0	0	0
Northern wheatear	0	0	1	0	0	0	0	0	0	0-2
Arctic redpoll	0	0	0	0	0	0	0	1	3	1
Snow bunting	45-55	45-56	41-46	52-64	42-47	48-58	58-61	59-61	90-103	114-123

Table 3.21. Estimated numbers of pairs/territories in the 19.3 km² census area in Zackenbergdalen, 1996-2005.

temperature between 21 May and 10 June the 2nd highest since the start of BioBasis (see section 2.1). This could be part of the explanation for the high numbers.

Reproductive phenology in waders

The snow-cover on 10 June 2005 (27.9%) was by far the lowest recorded since measurements began in 1995, and nest initiation was early to average (Tables 3.23 and 3.24). Nearly 70% of all wader nests were initiated before 15 June, but median first egg dates were later than in 2004, except for dunlin, which had the same median date.

Reproductive success in waders

Nest success was very low in 2005 (Table 3.25). For the first time, the all-wader predation rate was above 80%. Seven nests of the 15 found were depredated, with only dunlin nests having predation rates lower than 60%. The fates of four nests were unknown.

Since no shell fragment was found in any nest, it is unlikely that glaucous gulls or long-tailed skuas were the main predators, whereas arctic foxes were encountered more often than usual (Table 3.25, and section 3.6). A fair amount of ruddy turnstone nests hatched (4 of 7), but with

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Common ringed plover	69	61	62	104	70	105	83	50	44	30
Red knot	54	60	38	44	30	63	38	26	19	47
Sanderling	94	103	98	109	89	109	64	108	106	78
Dunlin	74	102	120	100	93	167	164	131	127	125
Ruddy turnstone	66	87	83	69	73	84	57	66	67	106

Table 3.22. Total number of waders (individuals) recorded during the initial census, 10-17 June 2005, compared to numbers of previous seasons.

	Median date	Range	N
Common ringed plover	–	–	0
Red knot	–	–	0
Sanderling	15.6	7.6 - 27.6	6
Dunlin	12.6	2.6 - 28.6	11
Ruddy turnstone	11.6	2.6 - 17.6	13
Red-necked phalarope	27.6	–	1

Table 3.23. Median first egg dates for waders at Zackenberg 2005 as estimated from incomplete clutches, egg floating, hatching dates, as well as weights and observed sizes of pulli.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Snow cover on 10 June	84	82	76	80	91	53	84	79	83	48	28
Sanderling		(16 June)	18 June	18 June	23.5 June	16 June	22.5 June	17 June	13 June	8 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
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

Table 3.24. Snow cover on 10 June together with median first egg dates for waders at Zackenberg 1995-2005. Data based on less than 10 nests/broods are in brackets, less than five are omitted. The snow cover is pooled (weighted means) from section 1, 2, 3 and 4 (see section 2.2), from where the vast majority of the egg laying phenology data originate.

the Mayfield method, the rate is high due to the low number of nest days. The relatively low number of nests found and the late dates of finding in relation to hatching makes these predation rates somewhat dubious, however.

The norm in wader nests is 4 eggs, and in dunlin all nests found held 4 eggs, whereas 1 of 5 sanderling nests and 1 of 8 turnstone nests held only 3 eggs (Table 3.26).

During July and early August alarming parents, and later juveniles, were found in fens and marshes (dunlins), on the slopes of Aucellabjerg and in the dry lowlands (sanderlings, dunlins and ruddy turnstones), although in lower numbers than in recent years.

From mid July, several flocks of up to 20 long-tailed skuas roamed the lower slopes of Aucellabjerg and the lowlands. This probably had a negative impact on survival of young waders.

The number of juvenile waders in the deltas at low tide was by far the lowest recorded at Zackenberg to date (Table 3.27). Ruddy turnstone and common ringed plover numbers have previously been lower or equal to this year's numbers, but dunlin and, in particular, sanderling numbers were well below other years' figures. The somewhat reduced breeding

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	1996-2005
Common ringed plover				(40)		(62)				–	42-48
Red knot	–	–			–		–			–	(79)
Sanderling	(28)	(0-67)	(22)	60	(54)	81	(77)	55	15-29		49-54
Dunlin			(53-72)	35	32	(25)		37	7	(57)	29-35
Ruddy turnstone	(32-79)	0-33	84	72-77	71	(40)	(48)	73-79	17		59-66
Red-necked phalarope	–	–	–		–	–	–	–	–		
All waders	37-67	0-48	63-68	61-62	56	57	57	56-58	10-13	82	48-53
N nests	17	27	44	44	47	32	21	47	54	15	357
N nest days	163	274	334	521	375	328	179	552	700	104	3527.6
Fox encounters	14	5	7	13	11	14	21	11	16	18	
Fox dens with pups	2	0	1	0	2	2	0-1	2	3	0	

Table 3.25. Mean nest predation (%) 1996-2005 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 below 50 nest days have been omitted (-: no nests at all). 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.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean
Common ringed plover	(4.00)	(4.00)	(3.50)	(4.00)	(3.50)	(4.00)	(3.50)	(4.00)	(4.00)	(4.00)		3.85
Red knot				(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	3.87
Dunlin		(4.00)	(3.75)	3.90	3.70	3.93	3.63	(4.00)	4.00	3.92	4.00	3.88
Ruddy turnstone		3.71	3.79	3.82	3.58	3.80	3.75	4.00	3.77	3.92	3.86	3.80

Table 3.26. Mean clutch sizes in waders at Zackenberg 1995-2005. Samples of fewer than five clutches are given in brackets.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Common ringed plover	96	126	249	42	44	142	320	140	170	253	176
Sanderling	304	726	149	333	445	366	540	156	242	346	78
Dunlin	325	360	323	232	509	273	326	554	309	308	173
Ruddy turnstone	80	108	82	109	23	73	162	183	75	19	52
Waders total	810	1342	803	722	1021	854	1351	1040	803	928	479

Table 3.27. Total numbers of juvenile waders recorded at low tide in the former and the present deltas of Zackenbergelven during 15 counts performed every third day in the period 18 July – 28 August 1995-2005. Data from missing counts have been substituted by medians from previous and following counts. Please note that the total numbers also include numbers of juvenile red knots, which do not otherwise feature in this table.

populations of these species together with the low hatching success and possibly low fledging success in waders may account for the low numbers. However, the considerable amounts of sediment washed out from Zackenbergelven during the days of surge flooding in late July (see Breeding populations) is also likely to have reduced the food availability in the deltas. The first low tide count following the flooding hardly found any birds in the present delta, which was visibly changed with a sandy layer covering the usual mudflats. The washing out of material quite possibly limited the waders' access to prey in the silt.

Reproductive phenology and success in long-tailed skuas

Yet again, this was an early breeding year for the long-tailed skuas (Table 3.28). Nests were initiated between 7 June and 20 June, but only a minor proportion of the population attempted to breed.

This season, the bird observer did not see any lemmings in the valley. In fact, no lemming was seen by any member of staff at the research station in 2005. The number of winter nests within the 2 km^2 lemming census area was 234 (an intermediate number), down from 431 in 2004 (Table 3.28 and section 3.6). Despite a high number of foxes (Table 3.25) the skuas' nest success was around average, but most young were taken very early. This resulted in very few fledged young (Table 3.28). Only one chick was still alive at the last check (25 July, aged 18 days), and this chick may have survived.

Only one flying juvenile was observed together with two adults on 30 July, assumed to be a bird from a territory outside the census area.

Breeding barnacle geese

This year, we were able to locate one of the barnacle goose colonies suspected of using Zackenbergdalen for chick rearing. On 6 June, a colony of at least 3 pairs was located at the southern face of Zackenbergfjeldet – below the peak, Orienteringsspids. The three pairs seen were apparent non-breeders, but the birds were so high up on the mountain (500-600 m a.s.l.) that it would have been very difficult to spot any incubating birds.

A colony "near" Zackenberg in 1932 has been described by Pedersen (1934), and one specifically on the slopes of Zackenberg itself in 1947 (Johnsen 1953). Nevertheless, since Rosenberg *et al*. (1970) were not able to confirm this in 1964, the colony was thought to have been abandoned.

The first two families with goslings were seen on 26 June. On 15 July, 11 families with a total of 35 pulli were seen (the maximum of the year), and on 19 July, 10 families with 16 pulli were present. In addition to these, a pair with 1 pullus was seen at the trapping station on 14 July.

Away from the coast, a family with three goslings was seen at Vesterport Sø on 17 July, and one family with two goslings were encountered at the lake at

Table 3.28. Egg-laying phenology, breeding effort and success in long-tailed skuas at Zackenberg 1996-2005. Median egg laying date is the date, when half the supposed first clutches were laid. 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 numbers of lemming winter nests within the 2 km^2 lemming census area (see section 3.6).

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Median 1st egg date		7.6	12.6	17.6	18.6	15.6	9.6	15.6	8.6	8.6
No. of clutches found	8	17	23	8	5	21	14	7	21	8
No. of young hatched	1	25	16	2	2	18	14	5	36	5-7
Nest success % (Mayfield)		(80.6)	24.1	(18.1)	(17.5)	39.5	44.1	(76.2)	(100)	(37-61.2)
Estimated no. of young fledged	0	5	6	1	0	5	4	2	22	1
Lemming winter nests	161	366	721	331	192	326	287	95	431	234

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Primo July		(3.0)	3.1	(2.9)	1.9	(3.2)	(1.8)	2.4	(1.8)	2.6	(1.7)
Medio July		(2.3)	2.7	2.3	1.8	(3.1)	(1.7)	2.4	(1.2)	2.3	2.7
Ultimo July	(2.0)	(3.0)	2.6	2.2	1.7	3.1		2.3	(1.1)	2.3	(2.2)
Primo August	(2.3)	(2.3)	2.4		1.8		(2.0)	2.2	(1.2)	(1.9)	
No. of broods	?7	6-7	19-21	?18	29	11	4	32	8	26	14
Scotland	2.00	2.30	1.95	2.28	1.92	2.20	1.94	2.23	1.59	2.35	1.67
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

Table 3.29. Average brood sizes of barnacle geese in Zackenbergdalen during July and early August, 1995-2005, together with the total number of broods brought to the valley. Samples of less than 10 broods are given in brackets. Data from autumn on the Isle of Islay in Scotland are given for comparison, including the percentage of juveniles in the population (Ogilvie 2004 and in litt.).

Blæsenborg on 18 July. Two families were encountered on 26 and 30 July at Langemandssø, each with one gosling. Two more families, with two goslings each, were seen on 17 July in upper Store Sødal and on 18 July in lower Store Sødal, respectively.

The mean brood size in 2005 was around average, as was the number of broods (Table 3.29). Data from Isle of Islay off the western coast of Scotland indicated a poor breeding season with only 6.3% juveniles among Greenland barnacle geese and an average brood size of only 1.67 (Table 3.29; Ogilvie 2004 and in litt.). This is as low as in 2003, when breeding success at Zackenberg also was low.

Line transects

This year, the line transects were undertaken 16-18 July through Store Sødal, and 20 July on the Daneborg – Zackenberg route.

In Store Sødal, more barnacle geese than normal were recorded (Tables 3.30 and 3.31), but for other species, the numbers were quite typical. Again this year, few pink-footed geese were sighted in upper Store Sødal.

Numbers for most species are in accordance with previous years on the Daneborg – Zackenberg transect. Also, please refer to section on other observations below.

	Store Sødal 16-18 July	Daneborg 20 July
Red throated diver	6	
Great northern diver *	2	
Pink-footed goose	36	
Barnacle goose	331; 6	
Common eider		10
Long-tailed duck	1	
Rock ptarmigan	1; 1	3
Common ringed plover	55	7
Sanderling		1
Dunlin	48	7
Ruddy turnstone		2
Arctic skua		3
Long-tailed skua	9	6
Glaucous gull	11	9
Arctic tern	7	
Common raven		2
Snow bunting	113; 1	6; 1

*Table 3.30. Birds recorded (adults; young) during line transect surveys through Store Sødal and from Daneborg to Zackenberg (see map in Meltofte and Berg 2005) in mid July 2005. * Only identified to genus in the field, but see Other observations.*

Sandøen

No bird monitoring was performed on Sandøen this season.

Other observations

This section deals with bird observations not reported in the previous sections. When nothing else is stated, observations refer to the census area in Zackenbergdalen.

Red-throated diver *Gavia stellata*

The first observation on 29 May was the earliest so far (Table 3.32).

Four to five pairs made breeding attempts in the study area this season. Three nests with eggs were recorded inside the census area, plus one outside (see below). None of the nests were successful. The two first nests were initiated in mid June, while the third was initiated in mid July, and hence most likely a relay. Arctic foxes are thought to be the most likely predators on diver nests (cf. Rasch and Caning 2003).

In adjacent areas, one pair was found: A pair with a nest at Vesterport Sø in Morænebakkerne. The nest was found on 13 July, and is regarded a relay. Three pairs were seen in Store Sødal between 16 and 18 July.

Among the initial clutches, data from this and previous years showed that the clutch in Ryledammene was the earliest so far at that particular site. The clutches at

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Red-throated diver	3	2		2	3	5; 1	6; 1	3	6
Great northern diver				2; 1					2
Pink-footed goose	263	123	27	56	85	37	38	20	36
Barnacle goose	182	250; 23	227; 23	261; ≥14	260; 1	138	201; 36	12; 6	331; 6
Goose sp.	25								
Common eider	390	119; 5	55; 6	10	11; 6	7	15; 7	22	10
Long-tailed duck	13		2				1	3	1
Rock ptarmigan	2	1				1; 2		2	4;1
Common ringed plover	71	70	(78)	(105; 4)	63; 1	54	54	45	62
Red knot	1			3			1	3; ?2	
Sanderling	14; 1	10	33	11; 6	12	25; 4	9	12; 3	1
Dunlin	64; 1	62; 1	(56)	48	62	33; 8	60	28; ?10	55
Ruddy turnstone	6	8	8	6	2	5; 2	8	5; 1	2
Arctic skua						2		3	3
Long-tailed skua	13	9	14	4	21	12	6	30	15
Glaucous gull	11	11; 2	8	(7)	10	101	12	13	20
Arctic tern	3	9	1	3	8	6	2	3	7
Snowy owl					1; 3				
Northern weathear							3		
Common raven	10	9	2	(5)	4	7	9	15	2
Arctic redpoll								1	
Snow bunting	104	64; 2	(54)	(30; 6)	110; 1	48; 10	116; 47	44; 43	119; 2

Table 3.31. Total number of birds recorded (adults; young) during line transect surveys through Store Sødal and from Daneborg to Zackenberg, mid-late July 1997-2005.

Tørvedammen and Vesterport Sø were later than previous years, strengthening the presumption that both were relays.

No juveniles were recorded this season.

In late August, up to two pairs were foraging in the delta of Zackenbergelven and adjacent waters.

Great northern diver *Gavia immer*

On the line transect through upper Store Sødal on 17 July, a pair of divers apparently different from red-throated divers were seen in back light, assumed to be great northern divers. They were seen in a lake south of Valhal mountain, west of the watershed, in upper Store Sødal, where great northern divers have been recorded in earlier years.

On 29 July, a team from Nanok visited the same area and recorded a pair of great northern divers (Rasmus Gregersen in litt.).

Pink-footed goose *Anser brachyrhynchus*

Sixteen pink-footed geese were present at the arrival of the first observer (N. M. Schmidt) on 19 May.

From the first waves of pink-footed geese flying north over the area, only two pairs stayed in the area for a few days in early June, and no nests or young of this species were seen.

Immature pink-footed geese from Iceland were seen migrating northwards between 11 June and 2 July, when a total of 1319 migrating geese were recorded, although not followed systematically. The peak record was 435 on 22 June.

14 moulting immatures were seen with two barnacle geese at Halvøen on 15 July, while four birds rested at Lomsø on 19 July. In total, only 53 moulting immature pink-footed geese were recorded in the

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Red-throated diver	≤3.6	30.5	3.6	4.6	6.6	3.6	1.6	≤4.6	≤1.6	29.5
King eider	12.6	4.6	15.6	16.6	≤22.6	9.6	11.6	≤13.6	14.6	21.6
Long-tailed duck	≤1.6	30.5	2.6	6.6	6.6	7.6	3.6	7.6	2.6	1.6
Red-necked phalarope	5.6	30.5	5.6	10.6	7.6	4.6	5.6	11.6	≤1.6	27.5

Table 3.32. Dates of first observation of selected species at Zackenberg 1996-2005.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Pink-footed Goose											
Closed moulting area and further east	310	246	247	5	127	35	0	30	41	11	17
Transect Daneborg - Zackenberg	0	0	0	0	0	0	0	0	0	20	0
Coast west of closed area	230	40	60?	0	29	0	0	0	0	10	0
Upper Zackenbergdalen	0	0	15	0	0	0	0	0	0	0	0
Lower Store Sødal	20	12	21	0	5	0	16	8	11	0	2
Upper Store Sødal	20	55	144	123	21	56	69	28	27	–	34
Pink-footed Goose total	>580	>353	<487	128	182	91	85	66	79	>41	53
Barnacle Goose											
Closed area at Lomsø and Kystkærene	21	0	29	21	60	84	137	86	120	81	87
Coast east of closed area	>120	150?	96	55	66	0	109	80	45	0	2
Coast west of closed area	0	0	0	0	0	30	0	0	0	0	29
Upper Zackenbergdalen	41	85	2	75	<57	27	60	0	14	0	25
Lower Store Sødal	114	46	97	114	117	150	150	81	78	81	161
Upper Store Sødal	>19	61	63	184	87	78	46	57	71	–	108
Barnacle Goose total	>315	<342	287	449	<387	369	502	304	328	<162	412

Table 3.33. The number of immature pink-footed geese and barnacle geese moulting in the study area at Zackenberg 1995-2005. The close area is zone 1c (see http://www.zackenberg.dk/grafik/MapZoner.jpg).

study area this year (Table 3.33). This is the lowest figure so far.

Southward migration of birds from northern areas was not observed over Zackenberg this season. Local birds were seen congregating in August: 21 in the present delta on 4 August and 25 on Langemandssø on 16 August.

Barnacle goose *Branta leucopsis*

72 barnacle geese were present at Zackenberg at the opening of the station, on 19 May, mainly in the present delta.

Up to 94 barnacle geese were seen from the opening of the station through June, primarily concentrated in Sydkærene in late May, in Kystkærene in early June, and Lomsø in mid to late June.

Unsuccessful breeders joined the breeding birds (section above) at Lomsø and Kystkærene. From 30 June, 87 moulting immatures were congregated at Lomsø and Kystkærene, remaining in similar numbers until mid-July, when numbers fell. A further two with a small flock of pink-footed geese were found at Halvøen on 15 July, up to 29 were seen in western Zackenberg Bugt during 18-23 July, and 25 stayed at lakes in Morænebakkerne on 1 August and 50 on 11 August. In Store Sødal, 18 moulting barnacle geese were observed in a lake north of Valhal on 11 August (Table 3.33). Both the birds from Morænebakkerne and Store Sødal are likely to be the late birds of the flocks seen during the line transect (see below).

The line transect revealed approximately 300 moulting barnacle geese in Store Sødal and Morænebakkerne, which together with the birds at the coast of Zackenbergdalen etc. adds up to an estimated total of 412 for the entire study area (Table 3.33).

On 8 August, a flock of 233 were feeding in Rylekærene. During the following 13 days, flocks ranging from 3 to 71 were seen in the census area. From 24 August to 28 August 124 barnacle geese were recorded, unsystematically, on south bound migration.

Common eider *Somateria mollissima*

On 14 June, the first common eiders arrived at the old delta of Zackenbergelven: two females and a male. In the later half of June, common eiders were seen regularly in the open water areas that appeared as the fjord ice melted off Zackenbergelven's present delta. Most regularly, two males and six females were present, and at no time were there more than 10 common eiders in total. On 20 June, the first pair was seen flying up Zackenbergelven.

The first single female inland was seen on 30 June west of Zackenbergelven. No nests were found this year.

At Daneborg, the Sirius Dogsled Patrol reported the first arrival of common eiders on 4 June, and the colony held 2302 nests on 29 June. The first eider ducklings at Daneborg were seen 16 July, two families each with two ducklings, and pulli from this colony appeared in the old delta of Zackenbergelven from 20 July. Here, up to 15 females and 16 pulli were recorded regularly during the rest of July and August.

The last four males were seen on 20 July.

King eider *Somateria spectabilis*

On 21 June, the first king eiders were seen in the study area (Table 3.32): two females and a male. On 23 June, a pair was courting at Lomsø, but no breeding was recorded.

Neither king eider nests nor pulli have been found at Zackenberg since 2001 (Caning and Rasch 2003).

Long-tailed duck *Clangula hyemalis*

The first long-tailed ducks to arrive at Zackenberg was a pair in the ponds just north of the research station on 1 June (Table 3.32). Neither nests nor broods were encountered this season, but one abandoned egg was found at Langemandssø in Morænebakkerne on 12 July.

From mid July, long-tailed ducks congregated along the shore in Young Sund. The largest flock numbered 18 on Lomsø on 20 July.

Gyr falcon *Falco rusticolus*

Two were seen at the research station on 23 August. Later, on 29 and 30 August, single birds were seen in the census area and at the research station. The bird from the 29 August was together with ravens at a musk ox carcass near Kamelen.

Before 2002, adult gyr falcons were also seen in June or July, but since then birds have only visited Zackenberg in August – most of them probably juveniles.

Rock ptarmigan *Lagopus mutus*

A pair was regularly seen near Nansenblokken, 500 m a.s.l. on the east face of Zackenbergfjeldet between 30 May and 30 June. On 23 July a female was seen at the foot of Zackenbergfjeldet with a minimum of five chicks. These could very well be from the pair at Nansenblokken.

In adjacent areas, a pair was seen in Morænebakkerne on 13 July. Possibly the same pair was encountered at Vesterport on 23 August, and another pair on Dombjerg 17 July. Furthermore, on 29 July, a female with six chicks was seen in upper Store Sødal (Nanok pers. comm.).

Common ringed plover *Charadrius hiaticula*

Common ringed plovers were present at the opening of the station on 19 May. Prebreeding flocks were seen between 26 and 31 May. On the latter date, the largest flock of seven passed the research station.

Post-breeding flocks of adults were seen between 25 July and 19 August, with single individuals encountered as late as 29 August. Inland, the maximum was 14 on 4 August, whereas 26 was the largest number encountered in the deltas, on 13 August. Juvenile numbers at low tide in the deltas were encountered from 4 to 22 August, peaking at 72 juveniles on 13 August.

Eurasian golden plover *Pluvialis apricaria*

One individual appeared west of Zackenbergelven on 13 July.

Since the start of the BioBasis programme in 1995, only three seasons went without any sightings of this species. All sightings over the years were of single individuals, except for a pair in 1996. Observations were spread over the whole season, and on 26 June 2001 an individual was even giving alarm calls on the slopes of Aucellabjerg. It is probably fair to assume that Eurasian golden plovers breed scarcely north of the known breeding area in Jameson Land, 400 km south of Zackenberg (cf. Boertmann 1994).

Red knot *Calidris canutus*

On 25 May, the first red knot was heard singing in the census area. On the following days, red knots were heard singing both in the lowland and on the slopes of Aucellabjerg.

The first pre-breeding flock of eight red knots was recorded 1 June, marking the start of the period where flocks of red knots were feeding in the lowland fens. Here, the last flock of 11 was feeding in a mixed wader flock on 11 June.

A Dutch team of scientists colour ringed seven adult red knots breeding at Zackenberg in 2003: Five males and two females. One of these males was re-sighted in 2005: first, on 4 July it was alarming on the slopes of Aucellabjerg (400 m a.s.l.), and on 11 July, it was guarding at least one chick near the first observation site. Finally, on 15 July, it was at the same site again.

Post-breeding flocks of up to 13 red knots appeared between 11 and 25 July. No red knots were encountered at the low tide counts in the deltas.

Sanderling *Calidris alba*

Seven sanderlings feeding in the fens just north of the research station on 30 May made up the first record of the species in 2005, and also the first pre-breeding flock of the season. Mixed flocks of waders with up to 12 sanderlings were feeding in the fen areas both north and south of the research station until 12 June.

At least 4 different birds with metal rings were seen during June.

On 5 July, two small post-breding flocks each of three individuals were seen, and only a few very small flocks of post-breeding sanderlings were recorded during the rest of the season.

During low tide counts in the deltas, the peak of adult sanderlings was 44 on 20 July. Here, the maximum number of juveniles was 26 on 22 August.

White-rumped sandpiper *Calidris fuscicollis*

One adult was seen with a sanderling at the climate station on 25 June. This is the second record at Zackenberg and in East Greenland in general (Caning and Rasch 2003). Both in 2001 and this season, the birds were not visibly affected by our presence and could be observed at very short distances.

Dunlin *Calidris alpina*

During 1-7 June, a maximum of 13 dunlins fed in the ponds and fens of Gadekæret.

Small post-breeding flocks were seen inland between 13 July and 25 August, but the main congregations of post-breeding adults appeared at low tide in the deltas. Flocks were present between 16 July and 4 August, with a maximum of 108 on 29 July.

Also in the deltas, juveniles were seen between 29 July and 25 August, peaking with 36 on 10 August. Inland, the largest group of juveniles was eight on 12 August.

Whimbrel *Numenius phaeopus*

A whimbrel was feeding just south of the research station on 9 June. This is only the third record from Zackenberg. Both in 2000 and 2001, single whimbrels were observed in the census area. These are the northernmost records in Northeast Greenland (cf. Boertmann 1994).

Ruddy turnstone *Arenaria interpres*

On 23 May, the first two ruddy turnstones flew over the research station, marking the arrival of this species. From 26 May until 11 June up to eight ruddy turnstones were feeding in the fens around the research station.

In one nest, two newly hatched chicks were trampled by a musk ox. One of their siblings was found alive nearby, guarded by the parents.

On 2 July, a flock of 5 post-breeders was seen. In the old delta, six were seen on 20 July, together with four adults accompanying four juveniles on 29 July.

The first juvenile ruddy turnstone at low tide counts was a single bird on 23 July. This is the earliest record of a juvenile ruddy turnstone on the coast yet. Juvenile numbers at low tide peaked with 17 on 17 August.

Red-necked phalarope *Phalaropus lobatus*

The first observation was one individual foraging in Gadekæret on 27 May (Table 3.32). This is the earliest record of red-necked phalarope at Zackenberg so far.

A female was seen 12 June in Gadekæret, where she stayed for another day. On 16 June, a pair was present on the same pond, staying until 18 June, when copulation was observed.

On 29 June, a nest with three eggs was found at a pond in Sydkærene, the male was incubating, and the female was in the vicinity. This could indicate that a 4th egg was on the way.

The estimated 1st egg date was 27 June (Table. 3.23), which is the latest of the few records of 1st egg dates of red-necked phalaropes at Zackenberg 1995-2005.

The nest was found predated on 3 July, which probably means that a male seen at a pond in Gadekæret on 2 July was the male of the failed nest.

Red phalarope *Phalaropus fulicarius*

A pair was seen on Ryledammene on 1 July, and a female was still present the following day.

This is the fourth season since the beginning of BioBasis, that red phalaropes have been recorded at Zackenberg. Like this season, a pair was seen in each of the years 1998 and 2001, whereas in 2003 only a single female was sighted, but breeding has not been recorded so far.

Arctic skua *Stercorarius parasiticus*

No Arctic skuas were recorded inside the census area this season, but on the line transect between Daneborg and Zackenberg, a pair was seen at Lille Sødal on 20 July. Off Lille Sødal, a pair displaying distraction behaviour was seen both in 2002 and 2004, constituting the most northerly likely breeding record in Northeast Greenland (cf. Boertmann 1994).

One additional Arctic skua was seen on 20 July, closer to Zackenberg.

Arctic skuas have been recorded at Zackenberg in seven of the 10 years, the BioBasis programme has existed. Most birds in this part of Greenland are light morphs. Only three birds recorded over the years were dark morphs.

Long-tailed skua *Stercorarius longicaudus*

Contrary to 2004, quite a few pairs seemed to be non-breeding in 2005. Out of 28-34 pairs, only eight were found breeding. Post-breeding gatherings culminated on 30 July with a flock of 20 west of Zackenbergelven. The last flock, with eight birds, passed the research station on 7 August.

Only one immature bird was recorded during the season despite the favourable breeding season of 2004 (Rasch and Caning 2005). This is in line with the literature, which says that immature birds rarely return to the tundra until their 3rd calendar year (de Korte 1984). 2nd calendar year birds do, however, return to the tundra occasionally. At Zackenberg, a similar number of 2nd and 3rd calendar year birds have been sighted during 1995-2005: five to six 2nd calendar year and four to six 3rd calendar year immatures so far. It will be interesting to see if the high number of fledged long-tailed skuas from 2004 will reappear as 3rd calendar year immatures in 2006.

On the line transects, only few long-tailed skuas were observed (Table 3.30), although on 16 July a flock of five was seen in lower Store Sødal.

On 30 July, a juvenile long-tailed skua together with two adults passed south over the study area. The last adults were seen on 11 August.

Lesser black-backed gull *Larus fuscus*

On 14 June, a lesser black-backed gull flew along Zackenbergelven.

Before 2001, this species was never recorded at Zackenberg, but since a record on Sandøen in 2000, with breeding since 2003 (Caning and Rasch 2001, Rasch and Caning 2005), it has been sighted in the study area every year but 2002.

Glaucous gull *Larus hyperboreus*

Once again, a pair of glaucous gulls bred on a stony island in Zackenbergelven. The nest was washed away on 25 July, when the river rose dramatically. Curiously, the pair persisted in mobbing intruders until 24 August, although seemingly in a random area.

Apart from the breeding pair, up to 4-6 glaucous gulls were often seen, mainly in the deltas and along Zackenbergelven.

Two pairs with nests further up Zackenbergelven were observed both on 16 and 18 July (see Line transect, Store Sødal).

In late July and early August, flocks of 4-20 glaucous gulls were often seen in the present delta, including up to eight 2nd calendar year immatures on 23 July. In late August, fledged juveniles were seen at the last two low tide counts, *i.e.* four on 25 August.

The peak record of glaucous gulls was on 28 August, when 83 were seen in the deltas, including a few juveniles and immatures.

Arctic tern *Sterna paradisaea*

Two arctic terns were seen at Store Sødal on 16 July and two others on 17 July. A further three were seen on 17 July in lower Store Sødal (see Line transect Store Sødal).

The breeding colony on Sandøen was not visited this year.

Meadow pipit *Anthus pratensis*

On 30 may, a single individual was observed at the research station's air strip.

This is only the second record at Zackenberg, equalling the record from 1998 as the northernmost sighting in East Greenland (cf. Boertmann 1994).

Northern wheatear *Oenanthe oenanthe*

On 4 July, a single northern wheatear was seen catching insects at the eastern bank of Zackenbergelven. It was seemingly gathering food for nestlings, but a nest was never found.

In the easternmost part of the census area, a wheatear was seen on 7 July.

These are the first records of live birds in the census area sine 1999. Before then, the species was found breeding at Zackenberg every year since the beginning of BioBasis.

Common raven *Corvus corax*

Ravens were seen in the area almost daily, and it appeared that 2-3 pairs claimed parts of Zackenbergdalen. On 6 June, a possible nest was spotted on the southern rock face below Orienteringsspids, the southern peak of Zackenbergfjeldet.

Whether it was used this summer is uncertain, as no ravens were seen flying towards it. The birds seen at the trapping station from time to time could possibly belong to this nest.

Ravens were seen flying towards the easternmost parts of Aucellabjerg, or possibly towards Cardiocerasbjerg. This pair generally roamed in the south-eastern half of Zackenbergdalen.

In the western part of the valley, we believe that another pair was based on the northern rock face of Zackenbergfjeldet. On 27 June, a raven with a wader egg in its beak flew towards this part of the mountain, and both before and after that date, observations of ravens flying between that part of the mountain and the valley seem to support this.

In August, ravens were seen almost daily, and often in small flocks. These were probably family groups, peaking with seven at the trapping station on 22 August and seven feeding on a musk ox carcass on 27 August. 10 different birds were seen in the valley on that day.

Arctic redpoll *Carduelis hornemannii*

The first arctic redpoll was seen on 5 June, flying and calling over the valley. Again on 13 June, a bird passed overhead, and a male was singing west of the river on both 29 and 30 June.

Lapland bunting *Calcarius lapponicus*

On 8 June, a male was seen at the ponds around the research station.

This is only the 3rd season since 1995 in which Lapland buntings have been observed at Zackenberg. 1-2 birds were seen both in 1999 and in 2001. All observations are of males.

Snow bunting *Plectrophenax nivalis*

The first juvenile snow bunting was seen on 6 July. Since then, a growing number of juveniles were seen around the valley, culminating in late July.

In August, small flocks were seen several times, with 16 on 26 August as the largest.

3.6 Mammals

Line A. Kyhn

The mammal monitoring programme was performed by Niels Martin Schmidt 19 May – 15 June, Line A. Kyhn 16 June – 29 August and Toke Høye 28 June – 26 July. Additionally, mammals were systematically recorded by Hans Meltofte 31 May – 15 June and Jannik Hansen 31 May – 1 August. The station personnel and visiting researchers supplied casual observations during the entire field season.

The census area for collared lemmings was surveyed for winter nests during 1 July – 25 August. During the entire field season musk oxen were censused in the evening (between 20 and 23 hrs) from a fixed elevated point at the research station, provided that there was sufficient visibility. In addition seals hauled out on the fjord ice and arctic hares on the east-facing slope of the Zackenberg Mountain were censused systematically, seals until the ice became too fragmented on 3 July. Every week between 4 July and 29 August, the 40 km^2 musk ox study area was censused including records of sex and age classes of musk oxen. The yearly 170 km line transects Zackenberg – Store Sødal and Zackenberg – Daneborg was performed 16-18 and 20 July, respectively, by Toke Høye and Line A. Kyhn.

The 14 known fox dens within the 50 km^2 fox study area and one just across the eastern border (Kuhnelv) were checked regularly for occupation and breeding, and the only den known between Daneborg and Kuhn River was checked on 21 and 29 May and again on 20 July.

The collared lemming population

Following the 'missed' collared lemming *Dicrostonyx groenlandicus* winter peak of 01/02 and the low density of 02/03, a continued growth from the medium peak last winter was expected for the winter 04/05 as a result of an apparently absent stoat population in winter 03/04 (Tables 3.34 and 3.35 and Fig. 3.6). However, the growth did not continue and the 232 winter nests of 04/05 were medium low for Zackenberg.

The fox population experienced a peak in summer 2004 with at least 18 pups produced (Rasch and Caning 2005). This impact can have reduced the lemming population even before they settled under the snow, as lemmings are most exposed in their summer habitat and when moving between summer and winter habitats (Schmidt *et al*. 2002, Kyhn 2004). As the snow accumulated very late in autumn

	Winter nests category 1	Winter nests category 2	Animals seen
1995	285	821	–
1996	161	263	0
1997	342	109	1
1998	711	109	43
1999	305	57	9
2000	184	70	1
2001	318	22	11
2002	311	29	4
2003	96	31	1
2004	431	24	23
2005	232	154	1

Table 3.34. Annual numbers of lemming winter nests recorded within the 2.05 km² census area in Zackenbergdalen 1995-2005 together with the numbers of animals encountered by one person (2005: N.M. Schmidt 1-15 June and J. Hansen 16 June-31 July) with comparable effort each year within the 19 km² bird census area during June-July. Numbers from previous years have been corrected following a critical review of the data. Category 1 denotes nests from the previous winter, category 2 nests from earlier winters that were not recorded previously.

	Distance km	Winter nests No.	Winter nests No./km
Store Sødal			
1996	150	2	0.01
1997	300	11	0.07
1998	150	21	0.14
1999	130	3	0.02
2000	130	1	0.01
2001	130	13	0.10
2002	130	9	0.07
2003	130	12	0.09
2004	108	2	0.02
2005	130	2	0.02
Daneborg - Zackenberg			
1997	50	22	0.44
1998	50	17	0.34
1999	40	1	0.03
2000	40	0	0,00
2001	40	24	0.60
2002	40	5	0.13
2003	40	1	0.03
2004	40	16	0.40
2005	40	22	0.55

Table 3.35. Lemming winter nests recorded along the 170 km transects Zackenberg – Store Sødal and Daneborg – Zackenberg 1996-2005. Nests were recorded within 3 m on each side of the two observers.

2004 (data from the meteorological station and section 2.2), the summer predation may have lasted much longer than in normal years, which might have had a pronounced effect on the lemming population. However, with no predation by stoats the lemming population have been remarkably low for two consecutive winters. The stoat situation at Karup Elv, approximately 220 km south of Zackenberg, was much different, as they had record high numbers of stoat predated lemming winter nests despite a missed lemming peak in the winter of 03/04 (Fig. 3.6).

Of the 232 new nests found at Zackenberg in 2005, 190 were build in the vegetation, which is assumed to indicate that they were build in the beginning of the season, and 24% of these were breeding nests. Also 24% of the 41 nests build on top of the vegetation, *i.e.* in the snow pack, were breeding nests.

Again this year, not a single of the examined winter nests was found to have been depredated by stoats, and no stoat scats were found during the systematic study (Table 3.36). After the lemming low in 95/96 the stoat population needed two years to recover (Fig. 3.6). The lemming population has not experienced a full peak since 97/98 and this might explain the absence of stoat predated winter nests in 03/04 and 04/05. For the seasons to come the lemming population should increase dramatically in response to the relaxed stoat predation, if reacting as most described lemming populations.

This year 154 old winter nests were found. This is surprising, since the area has been monitored systematically since 1995. The most likely reason for this is that the observers this year were new to the sampling procedure and therefore very cautious and vigilant during the sampling. However, inexperience might also explain for some mis-categorization of nests, but most of the old nests recorded were very old and not just worn from the winter.

Fig. 3.6. Lemming winter nest density (right axis) and stoat predation on lemming nests (left axis) within the census area in Zackenbergdalen (2.05 km²) and at Karup Elv, Traill Ø (10km²) 220 km south of Zackenberg (kindly provided by Benoit Sittler). Data include nests built from October until May. Nests and nest predation by stoat are given as total number per km².

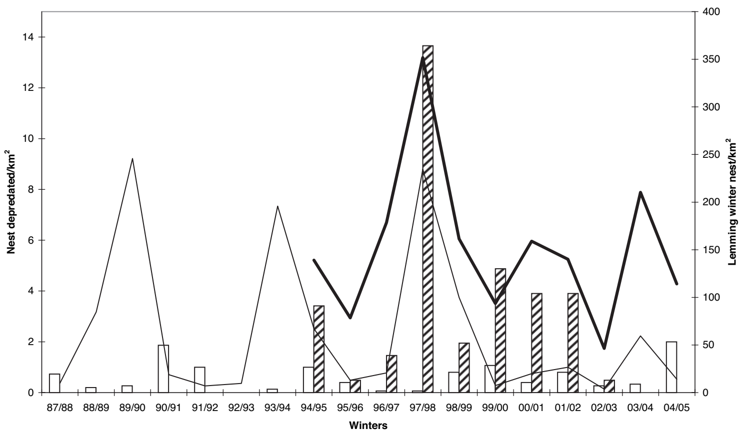


Table 3.36. Numbers of casts and scats from predators collected from 29 permanent sites within the 2.05 km² lemming census area in Zackenbergdalen. The samples represent the period from mid/late August the previous year to August in the year denoted.

	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

	May	June	July	August	Total
1996		445	445	2412	3302
1997		290	1086	1432	2807
1998		522	635	1121	2278
1999		361	392	1292	2045
2000		478	898	1543	2919
2001		923	1257	1689	3868
2002		418	448	1819	2684
2003		287	638	2247	3172
2004		1311	786	3285	5381
2005	1064	2090	1353	3449	6891

Table 3.37. Total numbers of 'musk ox days' per month, calculated as accumulated numbers of musk oxen recorded per day during the respective months within the 40 km² census area in Zackenbergdalen based on the daily counts from a fixed elevated point at the research station 1996-2005. NOTE: Data from 2004 have been recalculated. May is not included in the total.

Musk ox population biology

The pattern of musk ox *Ovibos moschatus* occurrence in Zackenbergdalen as recorded daily during counts from the research station closely matched the patterns observed in 2001, 2002 and 2004 (Fig. 4.6 in Caning and Rasch 2003, fig. 4.4 in Rasch and Caning 2003 and fig.3.5 in Rasch and Caning 2005, respectively) with high numbers in May-June, lower in July and increasing again to the highest counts in August. This pattern with many oxen in June correlates well with the early snowmelt in the beginning of June, as for last year. In 2005 the number of musk oxen per observation was extremely high and the record so far both within the 40 km² census area (Table 3.37) and in the entire visible area of 135 km² (Figs 3.7 and 3.8). There were 131 oxen per observation in 2005 and 114 in 2004 for the entire area visible during counts from the station. Until then, the record was 82 in 1995, whereas the lowest number recorded was 37 in 1999. This is quite a large variation in relation to the total musk ox population of Wollaston Forland and A.P. Olsen Land, which is estimated to encompass some 500-800 animals (Boertmann and Forchhammer 1992, Rasch and Canning 2003).

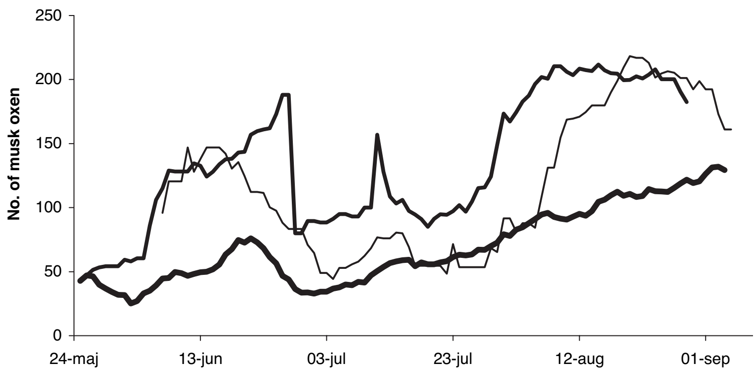


Fig. 3.7. Numbers of musk oxen (one week running means) recorded from a fixed elevated point at the research station in 2004 (thin line) and 2005 (medium line) along with average from all years (heavy line).

Looking at records of piles of faeces counted along the line transects in July, the number of winter faeces usually corresponds to the number of musk oxen counted in Zackenbergdalen during summer, but for the last two years these numbers have been decreasing despite that the numbers of musk oxen in Zackenbergdalen have increased drastically (Table 3.38). This implies that the musk oxen must have spent the winter elsewhere than in Store Sødal and along the coast towards Daneborg.

The two line transects Zackenberg –

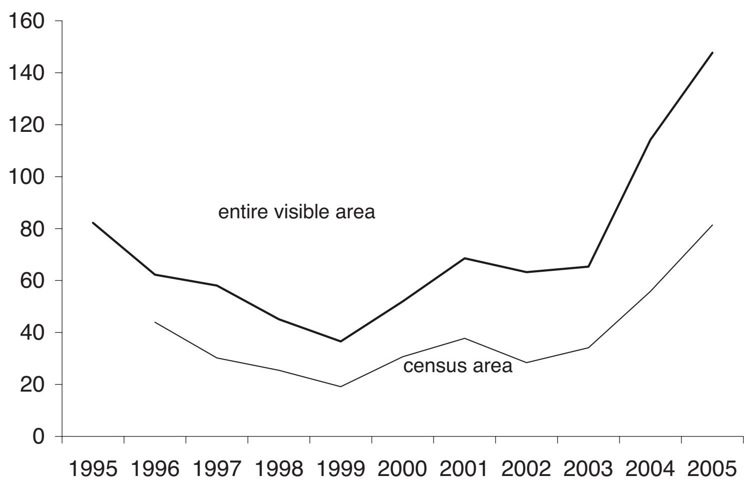


Fig. 3.8. Annual average numbers of musk oxen/observation counted from a fixed elevated point at the research station 1996-2005 in the 40 km² census area and in the entire visible area (approximately 135 km²), respectively.

	Store Sødal	Zackenberg-dalen	Daneborg-Zackenberg	Snow cover (%) Zackenberg 10 June
Musk oxen/km²				
1996	0.37	0.33	–	77
1997	0.39	1.58	0.13	81
1998	0.62	1.18	0.86	80
1999	0.78	1.20	0.70	92
2000	0.25	2.10	0.22	54
2001	0.31	3.38	0.92	82
2002	0.69	1.68	0.30	77
2003	0.26	1.70	0.22	83
2004	0.28	0.10	0.73	49
2005	0.38	1.03	2.22	28
Faeces piles/km				
1997 winter/summer	1.38 / 0.30	–	6.13 / 1.03	81
1998 winter/summer	1.49 / 0.35	–	1.25 / 0.23	80
1999 winter/summer	7.71 / 2.00	–	4.58 / 3.08	92
2000 winter/summer	2.87 / 0.46	–	1.13 / 0.28	54
2001 winter/summer	6.82 / 1.36	–	2.63 / 0.45	82
2002 winter/summer	5.12 / 1.88	–	4.73 / 0.60	77
2003 winter/summer	9.34 / 3.00	–	3.70 / 0.68	83
2004 winter/summer	2.33 / 4.13	–	4.03 / 3.45	49
2005 winter/summer	2.32 / 1.80	–	0.73 / 2.15	28

Table 3.38. Musk ox densities (animals/km²) in Store Sødal (92 km² in 1996-1998 and 125 km² in 1999 and onwards), the census area in Zackenbergdalen (40 km²) and in the coastal region between Daneborg and Zackenberg (37 km²) in mid/late July 1996-2005. Also densities of faeces piles (no. of piles/km walked) in Store Sødal (150 km in 1997-1998, 130 km in 1999-2003, 2005 and 54 km in 2004) and from Daneborg to Zackenberg (40 km) are given. Densities from earlier years have been recalculated.

Store Sødal and Zackenberg – Daneborg were walked on 16-18 and 20 July, respectively. The associated weekly musk ox census was walked on 15 July. A total of 130 animals were aged and sexed out of a total 154 animals observed. The main part of these was encountered on the Zackenberg – Daneborg transect just east of the border of the musk ox census area, *i.e.* on the slopes of Cardiocera Mountain. 26% of the aged animals were calves and 25% were reproductively active females (+4 years). This gives a mother/calf ratio of app. 1:1, which is double the expected ratio, since a cow only gives birth every second year according to the literature, and previous years with an observed mean of 2.2 cows per calf. In 2004 there were two calves per cow, and the high ratio again this year likely reflects that the last couple of years have provided good conditions for the musk oxen, since so many cows have been able to divert energy for calf production two years in a row. Secondly, since calves are born April to June the high number of calves also reflects the warm spring and early snowmelt providing optimal conditions for new born calves.

Since 1996, the ratio between males and females in the different age classes has been approximately equal until the class of 3yrs (except in 2005) (Table 3.39). For 3yrs and 4+ yrs there are more females (means of 8.4 and 40.9, respectively for the two classes) than males (means of 4.3 and 30.6, respectively). Looking at the record of carcasses, 4+ males are overrepresented making up 49% of the total sample as opposed

	Calf	F1	M1	F2	M2	F3	M3	F4+	M4+	Total
1997	13	5	6	13	14	8	2	32	10	103
1998	11	6	7	8	8	8	7	44	23	122
1999	24	0	0	9	8	13	7	58	52	171
2000	25	6	7	4	1	7	6	47	44	147
2001	27	10	7	6	7	6	1	58	38	160
2002	21	10	9	12	10	10	4	57	40	173
2003	18	6	7	3	5	3	4	34	29	109
2004	11	4		2	2	8	7	6	19	59
2005	34	5	10	5	10	13	1	32	20	154

Table 3.39. Sex and age distribution (actual numbers) of musk oxen based on total counts along the two line transects and the related total census in Zackenbergdalen 1997-2005. All counts were made within 16-30 July and covered an area of approximately 200 km². Possible double counts have been omitted. Note, 24 of the musk oxen encountered in 2005 were not aged and sexed.

Table 3.40. Fresh musk ox carcasses found during the field seasons of 1995-2005. F = female, M = male. 'Thaw hours' are numbers of hours during October-April with positive temperatures, which may have caused ice crust on the snow. Note: Two of the carcasses found in 2005 died in July.

	Snow cover 10 June (%)	Thaw hours	Total carcasses	4+ yrs F / M	3 yrs F / M	2 yrs F / M	1 yr F / M	Calf
1994-1995	76	?	2	0 / 1				1
1995-1996	77	47	13	7 / 1	0 / 1	0 / 2	1 / 1	
1996-1997	81	9	5	0 / 2		1 / 0	1 / 0	1
1997-1998	80	83	2	0 / 2				
1998-1999	92	32	1	0 / 1				
1999-2000	54	35	8	0 / 6	1 / 0			1
2000-2001	82	13	4	0 / 4				
2001-2002	77	88	5	1 / 2	1 / 0			1
2002-2003	83	178	3	0 / 2				1
2003-2004	49	50	2	1 / 1				
2004-2005	28	39	6	2 / 3				1

Table 3.41. "Total number of records" gives the number of records of all adult and those of juvenile foxes encountered in the field away from their maternal den during June-August 1996-2005. Note: 20 white fox records were made in May 2005.

	Total no.of records	Total no.colour phase	No. 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

to 22% females in the same age class (Table 3.40). The sex ratio is close to even for the younger age classes. These shifted sex ratios might rely on differences in natural causes of death, difficulties in separating 3 yrs males from 4+ yrs females or that young bulls may form bachelor groups with a different activity pattern and area use.

Arctic fox dens

2005 was not the best year for foxes *Alopex lagopus* as no pups or intense den use indicating offspring were observed over the season. However, the number of adult foxes observed was the second highest recorded (Table 3.41), which may indicate that many of the minimum of 18 pups produced in 2004 actually made it through the winter. This is in accordance with the number of musk ox carcasses observed (Table 3.40), but not with the very low number of lemming winter nests found (Table 3.34), which equalled the situation in 1996. Intense competition for food over winter and spring among the foxes might thus have hindered the allocation of energy for reproduction and hence a new generation this year.

Six dens seemed occupied over the summer (nos 1, 2, 3, 4, 10 and 12), and three were occasionally in use (nos 5, 7 and 9) (Table 3.42).

Two new dens were found this year, each consisting of one entrance and si-

Table 3.42. Numbers of known fox dens in use, numbers with pups and the total number of pups recorded at their maternal dens within the 50 km^2 fox census area in Zackenbergdalen. 'W' and 'D' denote white and dark colour phase, respectively. Dens in use are defined as dens showing signs of use over the entire summer season.

	No. of known dens inside/outside	No. of dens in use inside/outside	No. of breed. dens inside/outside	Total no. of pups recorded	No of muskox carcasses	Lemming winter population
1995	2/0	0/0	0/0	0	2	decrease
1996	5/0	4/0	2/0	5W + 4D	13	low
1997	5/0	1/0	0/0	0	5	increase
1998	5/0	2/0	1/0	8W	2	peak
1999	7/0	3/0	0/0	0	1	decrease
2000	8/0	4/0	3/0	7W	8	low
2001	10/2	6/1	3/1	12W + 1D	4	increase
2002	10/2	5/1	0-1/0	0	4	intermediate
2003	11/2	8/1	3/0	17W	2	low
2004	12/2	12/2	4/1	18+W	2	increase
2005	14/2	6/0	0/0	0	6	low

tuated under a large stone near den 4 and 12, respectively.

For all dens, the total number of entrances was counted in order to allow for analysis of development over the coming years. Especially den 1 seems to be going through some restructuring, as the roof is falling down in some places and new entrances are formed. Generally dens nos 1, 2, 3, 4, 10 and 12 appear to be very old, as they hold many entrances.

Arctic hare

This year an average of 13 hares *Lepus arcticus* per observation was recorded during the daily counts covering the east-facing slopes of Zackenberg. Observations were made from a fixed elevated point at the research station (calculated as number of hares per observation day) in conjunction with the daily counts of musk oxen. Totally, a factor 10 more hares were observed in 2005 than previous years (Table 3.43). Mech (2000) found that an early onset of winter had adverse effect on the reproductive success of arctic hares by shortening their summer replenishment period. Oppositely, a delayed onset of winter with late snow fall in the autumn of 2004 (the meteorological station and section 2.2) and early snowmelt of 2005 are the likely factors explaining the increase in number of hares observed. A delayed onset of snow may be beneficial to arctic hares, as continued access to forage during autumn likely increases hare fitness, preparing them better for the coming winter.

The number of arctic hares observed at other sites than Zackenberg Mountain was correspondingly high this season. However, 60 of these 150 hares were observed on the slopes of Aucella during the daily musk ox census.

The total numbers of arctic hares observed per day increased during the season with largest numbers occurring from mid July until late August (Fig. 3.9), and there was a tendency for the group size to increase correspondingly over summer. This probably reflects that the leverets become more active and that female hares expand their home ranges in association with a more relaxed behaviour when nursing of leverets is over in July (Hearn *et al*. 1987). In general, hares seem more active at night time, when they gather in larger groups and are more often observed in the lowlands than during the day, where they are most often observed between boulders on mountain hill sites (personal observation during three seasons).

	Sum	Average ± SD	Range	Counts	Others
2000	57	1.74 ± 2.9	0-11	16	67
2001	52	0.84 ± 1.52	0-6	22	72
2002	17	0.27 ± 0.73	0-4	16	19
2003	94	1.45 ± 2.82	0-13	20	42
2004	56	0.89 ± 1.7	0-3	23	135
2005	607	6.08 ± 8.59	0-30	48	150

Table 3.43 Numbers of arctic hares counted daily from a fixed elevated point at the research station during June-August 2000-2005. Average, SD and range are based on sum pr. observation day. "Others" are hares observed incidentally in the field. Only counts performed with good visibility are included. Note: Data has been recalculated for all years.

Other observations

Arctic wolf *Canis lupus*

Three times during the season fresh tracks were observed in Zackenbergdalen.

Stoat *Mustela erminea*

Stoats were observed at two occasions in Zackenbergdalen, one inside the station area, the other at the slopes of Aucellabjerg. No scats were found during the systematic scat and casts collection (Table 3.36), which is in accordance with the observation that no lemming winter nests had been depredated by stoats during the winter 04/05 (see the lemming population chapter for discussion).

Seals *Phoca spp.*

Seals hauled out on the ice of Young Sund are primarily ringed seals *Phoca hispida*, but also bearded seals *Erignatus barbatus* are present in the area, just as hooded seals *Cystophora cristata* and harp seals *Phoca groenlandica* can occur. The species can not be identified during the daily censuses from the research station. This year seals were censused until 3 July when the

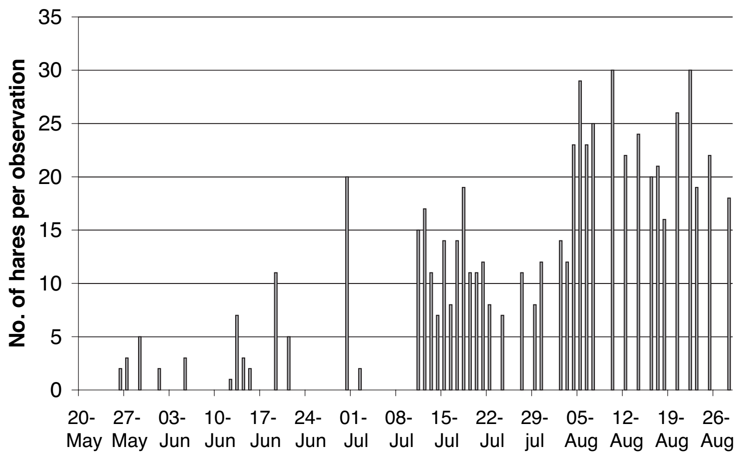


Fig. 3.9 Total number of arctic hares observed from a fixed elevated point at the research station during daily census in 2005.

Table 3.44. Numbers of seals counted daily from a fixed point at the research station from 1 June until the fjord ice became too fragmented in early/mid July 1997-2005. Only counts performed with good visibility are included.

	Average±SD	Range	Counts
1997	8.52 ± 4.98	3 - 21	23
1998	7.42 + 4.50	0 - 18	18
1999	25.05 + 12.32	2 - 61	22
2000	14.38 + 7.00	2 - 28	16
2001	22.06 + 14.22	3 - 57	16
2002	28.68 + 3.82	9 - 48	13
2003	63.58 + 32.09	14 -126	12
2004	19.00 ± 6.40	9 - 30	13
2005	13.40 ± 12.82	2 - 48	15

Lake	SS	SS	SS	LS	LS	LS
Date	26.7	6.8	16.8	26.7	6.8	16.8
Ice cover (%)	0	0	0	0	0	0
Temperature (°C)	12	11.4	6	13	11.6	7
pH	5.89	5.98	6.06	5.95	6.09	6.01
Conductivity (µS/cm)	20	19	27	13	14	15
Chlorophyll a (µg/l)	1.38	1.50	1.88	1.65	1.66	1.55
Total nitrogen (µg/l)	440	210	140	280	280	180
Total phosphorous (µg/l)	11	9	7	9	15	8

Table 3.45. Physico-chemical variables and chlorophyll a concentrations in Sommerfuglesø (SS) and Langemandssø (LS) during July and August 2005.

ice became too fragmented. There was an average of 13 seals per count, which is low compared to a mean of 24 for all years (Table 3.44).

On a visit to Sandøen on 18 August six walruses *Odobenus rosmarus* were observed hauled out.

3.7 Lakes

Kirsten Christoffersen and Erik Jeppesen

Sommerfuglesø and Langemandssø in Morænebakkerne were sampled three times during the period 26 July to 16 August following the standard BioBasis monitoring programme for lake surveys. As in the previous two years the ice cover of both lakes decreased rapidly during June and was reduced to 50% coverage as early as 18 and 22 June, respectively (Table 3.46). This is the earliest ice-out since the onset of the programme.

Water temperatures varied between 6°C and 12°C, with mean temperatures of 9.8°C and 10.5°C in Sommerfuglesø and Langemandssø, respectively, and thus belong to the upper end of the water temperature range recorded since 1997 (Tables 3.45 and 3.46). However, the average values for conductivity, total nitrogen and total phosphorus did not deviate from the average of the previous years, but remained within the normal year-to-year fluctuations (Table 3.46).

The chlorophyll *a* concentrations (equivalent to the productive phytoplankton biomass) varied between 1.38 and 1.88 µg/l. Thus, the average concentrations of 1.59 and 1.62 µg/l in Sommerfuglesø and Langemandssø, respectively, were similar to those of previous years (Tables 3.45 and 3.46). In both lakes, the phytoplankton communities were totally dominated by chrysophytes (Tables 3.47 and 3.48), with averages of 73% and 89% of the total biovolume in Sommerfuglesø and Langemandssø, respectively. Dinophytes constituted the majority of the remaining biovolume (25% in Sommerfuglesø and 7% in Langemandssø).

The composition of the zooplankton community was examined using samples taken once in mid-August. In Sommerfuglesø, the cladoceran *Daphnia pulex* was found to occur frequently (6.4 ind/l), followed by a negligible amount of copepods and rotifers. In Langemandssø, *D. pulex* was absent; instead cyclopid copepods *Cyclops abyssorum alpinus* and the rotifer *Polyarthra* sp. dominated the zooplankton community (Table 3.49). The presence and absence of *D. pulex* clearly reflect the non-occurrence of fish in Sommerfuglesø and

Table 3.46. Average physico-chemical variables in Sommerfuglesø (SS) and Langemandssø (LS) in 1999-2005 (July-August) compared to single values from mid-August 1997 and 1998. ND = no data.

Lake	SS	SS	SS	SS	SS	SS	SS	SS	SS	LS	LS	LS	LS	LS	LS	LS	LS	LS
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	1997	1998	1999	2000	2001	2002	2003	2004	2005
Date of 50% ice cover	ND	11.7	18.7	25.6	2.7	3.7	24.6	24.6	18.6	ND	23.7	21.7	30.6	8.7	6.7	2.7	26.6	22.6
Temperature (∫C)	6.3	6.5	6.1	10.1	8.4	8.3	11.0	8.7	9.8	6.8	6.4	4.0	9.5	8.4	8.1	11.1	9.1	10.5
pH	6.5	7.4	6.7	5.8	6.6	6.0	6.5	6.3	6.0	6.5	7.0	6.3	5.5	6.4	5.5	6.1	6.1	6
Conductivity (µS/cm)	15	13	10	18	18	8	12	15	22	8	9	7	9	8	6	6	8	14
Chlorophyll a (µg/l)	0.84	0.24	0.41	0.76	0.67	1.27	1.84	1.62	1.59	1.04	0.32	0.38	0.90	1.46	2.72	3.14	0.98	1.62
Total nitrogen (µg/l)	ND	130	210	510	350	338	277	267	263	ND	80	120	290	340	387	237	230	247
Total phosphorous (µg/l)	4	9	11	10	19	11	11	7	9	8	7	7	11	20	13	10	11	11

Table 3.47. Biovolume (mm^3/l) of phytoplankton species in Sommerfuglesø and Langemandssø during July-August 2005.

Lake	SS	SS	SS	LS	LS	LS
Date	26,7	6,8	16,8	26,7	6,8	16,8
Nostocophyceae	0.000	0.000	0.000	0.000	0.000	0.000
Dinophyceae	0.071	0.282	0.202	0.000	0.027	0.062
Chrysophyceae	0.162	0.768	0.733	0.177	0.336	0.376
Diatomophyceae	0.000	0.000	0.000	0.000	0.000	0.000
Chlorophyceae	0.006	0.016	0.006	0.003	0.006	0.048
Others	0.000	0.000	0.000	0.000	0.000	0.000
Total	0.239	1.066	0.941	0.180	0.369	0.486

Table 3.48. Average biovolume (mm^3/l) of phytoplankton species in Sommerfuglesø and Langemandssø from 1997 to 2005 (except for 2000 and 2004).

Lake	SS	SS	SS	SS	SS	SS	LS	LS	LS	LS	LS	LS	LS
Year	1998	1999	2001	2002	2003	2005	1997	1998	1999	2001	2002	2003	2005
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
Dinophyceae	0.034	0.044	0.015	0.006	0.027	0.185	0.291	0.185	0.305	0.040	0.156	0.123	0.030
Chrysophyceae	0.022	0.096	0.358	0.066	0.237	0.554	0.066	0.187	0.048	0.592	0.377	0.358	0.296
Diatomophyceae	0.002	0.000	0.001	0.000	0.000	0.000	0.002	0.000	0.000	0.002	0.000	0.000	0.000
Chlorophyceae	0.005	0.002	0.000	0.000	0.002	0.009	0.016	0.000	0.002	0.002	0.000	0.003	0.019
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
Total	0.063	0.147	0.377	0.073	0.266	0.749	0.375	0.372	0.354	0.637	0.533	0.484	0.345

the existence of a population of arctic char *Salvelinus alpinus* in Langemandssø.

During the initial survey in 1997, gillnet fishing demonstrated the presence of arctic char in Langemandssø. In this year's investigation, a re-survey of the char population was undertaken using a series of the so-called "Ella traps", which rely on live catches of fish; thus, the small fish population was not disturbed. A pilot-trial over a few days using Ella traps was performed in 2004; however, no fish were caught. This year three traps were set at different heights above the bottom in Langemandssø from 17 July to 4 August. A single trap was simultaneously placed in Sommerfuglesø. The traps were checked every second day. As no fish were caught during the first two days, trap openings were diminished by half. This resulted in the capture of one fish in Langemandssø on day 4. The fish was dead, it was 11 cm long and had a weight of 12 g. The trap entrance of one trap was then enlarged, while the others were kept constant. One more fish was caught alive on day 13. It was a female of 9 cm and a weight of 9 g.

Although meagre, the results show that Langemandssø still hosts a population of

Table 3.49. Density (no/l) of zooplankton in Sommerfuglesø (SS) and Langemandssø (LS) in mid-August 1997-2005.

Lake	SS	SS	SS	SS	SS	SS	SS	SS	SS	LS	LS	LS	LS	LS	LS	LS	LS	LS
Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cladocera																		
Daphnia pulex	0.3	10.5	0.3	6.7	8.2	6.8	7.7	0.7	6.4	0	0	0	0	0	0	0.1	0	0
Macrothrix hirsuiticornis	0.1	0	0	0	0	0	0	0	0.07	0	0	0.2	0	0	0	0	0	0
Chydorus sphaericus	0.05	0	0	0	0.06	0	0	0	0.13	0	0.1	0	0.5	0.1	0.07	0	0	0.13
Copepoda																		
Cyclops abyssorum alpinus (adult+copepodites)	0.8	0.5	0.5	0.3	0.5	0.2	0.9	0.3	0.07	3.3	2.9	4.1	22.0	13.4	6.8	8.6	4.9	8.0
Nauplii	5.7	1.3	6.5	1.1	1.4	2.3	0.3	0.3	0.2	5.2	3.8	6.4	3.1	4.5	4.5	4.2	0	0
Rotifera																		
Polyarthra dolicopthera	171	90	185	97	74	11	0.5	1.87	7.67	316	330	274	168	248	22	78	71	99
Keratella quadrata group	4.5	3.0	17	0	0	0.4	0.1	0	0	4.5	28	34	0	0	0.3	0	1.3	0
Conochilus sp.	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	0	0	0	0	0	0	0	0

dwarf form arctic char. Future surveillance of the fish might benefit from the use of biological multi-mesh survey gill nets (the Nordic norm), as these permit detailed examination of the composition of all age classes.

4 Zackenberg Basic
The MarineBasic Programme

Mikael K. Sejr, Tage Dalsgaard, Søren Rysgaard, Egon Frandsen and Peter B. Christensen

Introduction

This is the report from the third year of the MarineBasic monitoring programme in the Young Sund-Tyrolerfjord system. The aim of the programme is to detect possible changes in a high-arctic marine ecosystem due to climate variability and change. This is accomplished by combining an intense summer field campaign with deployment of automated moorings supplying recordings throughout the year. Physical, chemical and biological parameters are measured in the main research area, Young Sund, but also in Tyrolerfjord and the Greenland Sea when weather conditions allow it.

The overall design of the sampling programme is a combination of stations sampled once every summer, a sampling station sampled frequently every summer and a mooring system deployed in August and retrieved one year later. Density and diversity of benthic fauna were analysed from digital images recorded along 3 transects perpendicular to the coast from 20-60 m water depth. The dominant species were identified and counted. Hydrographic measurements (depth, salinity, temperature, Chlorophyll *a*) were performed along a longitudinal transect from the innermost part of Tyrolerfjord to about 40 km offshore in the Greenland Sea at intervals of 5-10 km between CTD casts (Fig. 4.1). The same measurements were performed along 2 transects across Young Sund at intervals of 1-2 km between CTD casts (Fig. 4.2).

At the frequently visited station the following parameters were measured roughly every second day: light attenuation (PAR), vertical profiles of salinity, temperature and fluorescence, and water was sampled from 9 depths and filtered for Chlorophyll *a* (Chl. *a*) determination. In addition, 3 times during the 3-week sampling period, samples were taken for vertical profiles of UV-B absorption, NO_3^- + NO_2^-, PO_4^{3-}, NH_4^+, SiO_4, dissolved inorganic carbon (DIC) and total alkalinity (TA) and vertical hauls were made from bottom to top with plankton nets for zooplankton and phytoplankton determination. At the seafloor sulfate reduction and sediment-water fluxes of O_2, DIC and nutrients were measured once at a water depth of 60 m. In addition, the vertical concentration profile of O_2 in the sediment was recorded.

The mooring system launched in 2004 was retrieved and replaced with a new system this year. The mooring system was deployed at a depth of ~80 m (74°18.93’N, 20°16.70’W) and consisted of one automatic sediment trap at a depth of 60 m and 2 CTD probes at 65 m and 50 m depth.

Sea ice

A camera system was established at Grønnedal in August 2004, which gave good coverage of the outer part of Young Sund (Fig. 4.3 a and b) until it broke down 1 February 2005. The camera system overlooking the study area from behind the weather station failed, but pictures from the camera system at the Zackenberg mountain proved fine for estimating the date of ice break-up (Fig. 4.3 c-e). The mili-

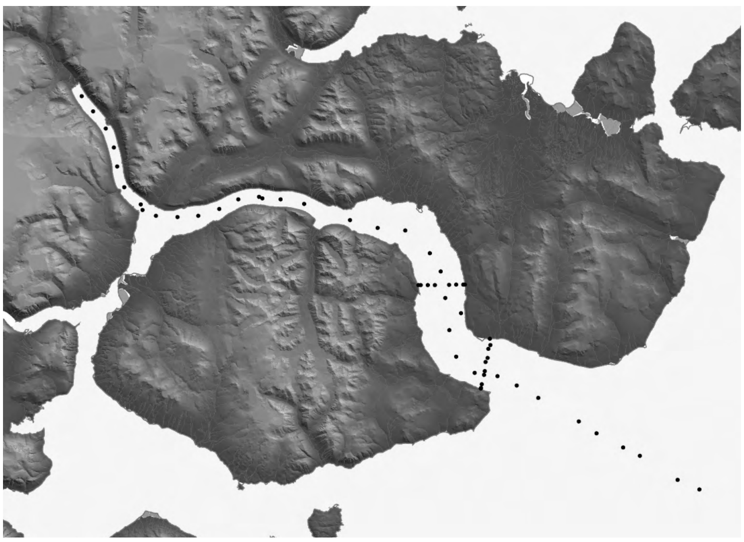


Fig. 4.1. Map of the sampling area. The dots represent the hydrographic sampling stations from the innermost Tyrolerfjord on the left to the Greenland Sea on the right.

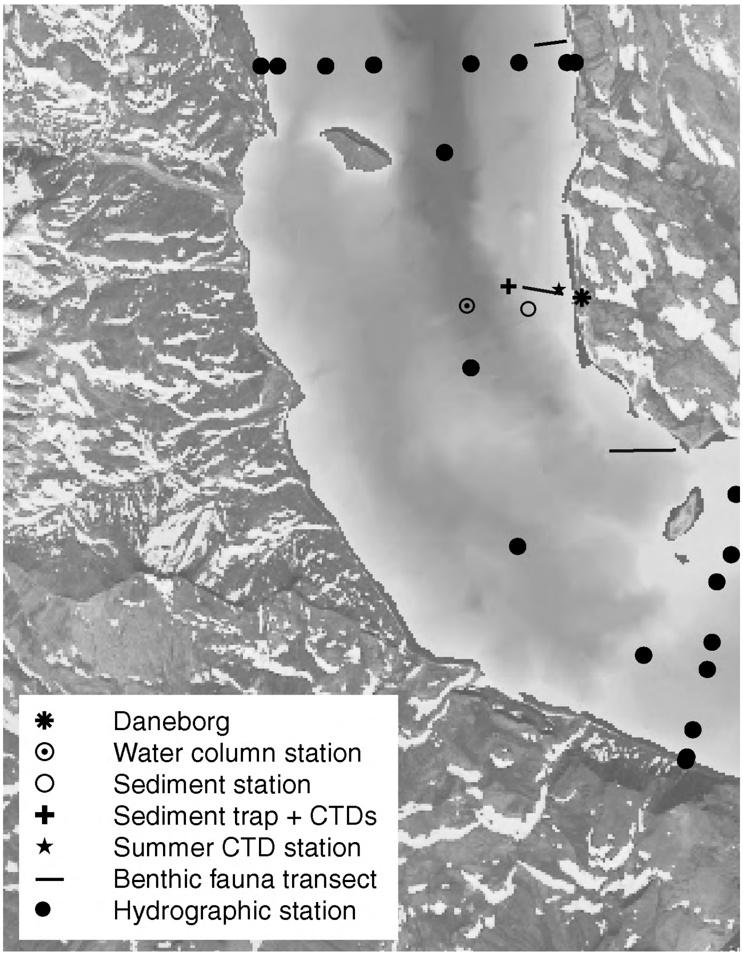


Fig. 4.2. Map showing the sampling stations in the outer part of the Young Sund in more detail.

tary patrol SIRIUS estimated that ice cover was established 1 November 2004 and ice break-up occurred on 7 July 2005. This agrees well with the dates estimated from the pictures (Fig. 4.3). There was almost no drifting ice in the fjord during the open-water period in August 2005, which was also clearly seen from the pictures from the Zackenberg mountain (Fig. 4.3 d and e).

The military patrol SIRIUS continued their measurements of sea ice and snow thickness at 74°18.59'N, 20°15.04'W during 2004-2005 (Fig. 4.4). Maximum sea ice thickness was 125 cm and maximum snow cover thickness was 80 cm during 2004-2005. Compared to 2004 this was an increase in snow cover and a decrease in ice thickness. The lower maximal ice thickness may be due to a thicker layer of snow minimizing the heat loss from the ice to the atmosphere.

The annual ice-free periods in the outer part of Young Sund during 2003, 2004 and 2005 were 128, 116 and 98 days, respectively (Fig. 4.5, Table 4.1). Based on historic military reports, in which sea ice thickness was noted for safe dogsled transport (15 cm thick ice) along with day of sea ice break-up, we constructed the past 54 years of ice-free conditions in the outer part of Young Sund (Fig. 4.5). As is evident from the figure, an ice-free period of ca. 80 d was normal from 1950 to around 1995. Hereafter, the ice-free period dramatically increased from around 1995 until 2002, when an ice-free period of up to 130 days was observed. During the last 3 years the duration of the ice free period has decreased again to 98 days in summer 2005, although this is still considerably above the average of ca. 80 days noted above.

Table 4.1. Sea ice conditions in the outer part of Young Sund.

	2003	2004	2005
Ice thickness (cm)	120	150	125
Snow thickness (cm)	20	32	85
Days with open water	128	116	98

Water column

Continuous data

The sediment trap was retrieved on 8 August. The annual vertical flow of particles was documented but due to a manufacturing programming error in the software the seasonal variation in sedimentation could not be estimated. Annual sedimentation was 1072 g dry weight m^{-2} yr^{-1} corresponding to 18.7 g C m^{-2} yr^{-1}. New software was installed in the sediment trap for the 2005-2006 season. Continuous data were recorded at two stations (Kap Ehrenberg; 22 m depth and Daneborg; 24 m depth) during the study period in August 2005 and are presented in Fig. 4.6. The tidal amplitude has a maximum of about 0.8 m during spring flood at the outer part of Young Sund and a minimum during neap tide of about 0.3 m. The long wave phase speed of the tidal wave gives a time lag of 30 minutes between the two moorings spaced 50 km apart and 48 minutes between the sill and the inner part of the fjord. Temperature varied from –1.332°C to 0.133°C at Daneborg with a mean temperature of –0.791°C (±0.003, n= 4852) and salinity from 32.15 to 33.00 with a mean of 32.73 (±0.001, n=4852). At Kap Ehrenberg, the temperature varied from –1.141°C to –0.259°C with a mean temperature of –0.803°C (±0.003, n= 2860) and salinity from 32.47 to 32.95 with a mean of 32.78 (±0.001, n=2860).

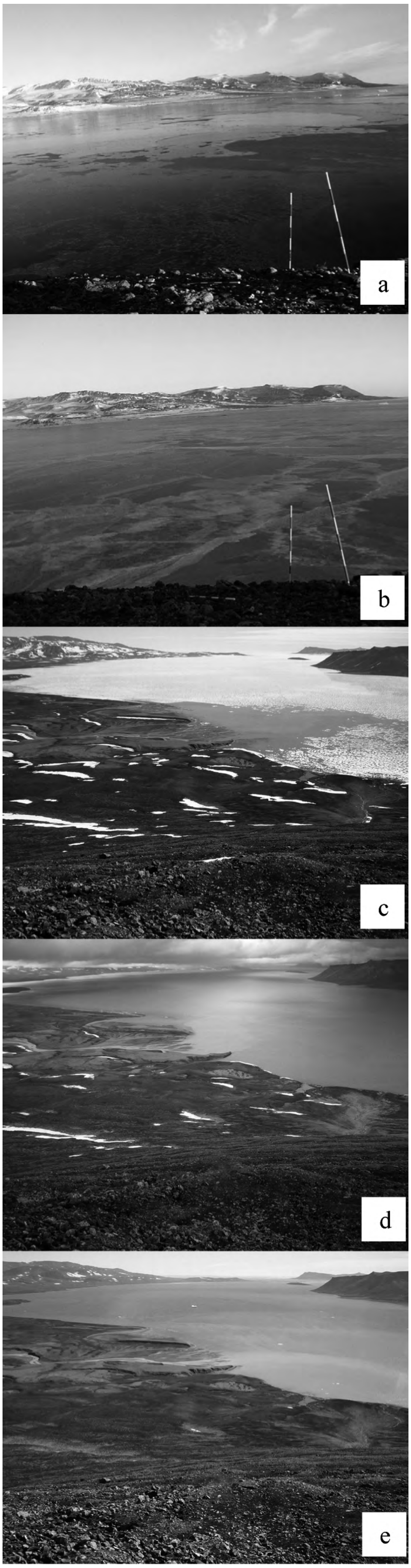


Fig.4.3. Sea ice conditions during 2004-2005 in Young Sound as seen from Grønnedal (a, b) and from the Zackenberg mountain (c, d, e). Picture a was taken 13 October 2004 when ice formation was starting and picture b was taken 1 November 2004 when ice was estimated to be established. Picture c was taken 28 June 2005 and d was taken 7 July 05, the day when the ice broke up. Picture e (31 July 05) illustrates the low amount of sea ice during summer.

Vertical profiles of temperature, salinity, density and Chlorophyll a across and along Young Sund.

Profiles across Young Sund, near the island Basaltøen, were measured two times during the study period. Distinct differences were found (Fig. 4.7). On 4 August strong easterly winds had forced the surface water towards the western shore. Here, a thin layer of low-salinity surface water was concentrated in the upper 7-8 m of the water column and was characterized by a temperature above 5° C and a salinity below 25. The disappearance of the surface water induced upwelling of nutrient-rich bottom water at the eastern shore, which resulted in increased phytoplankton production with chlorophyll a values of up to 18 µg l^{-1}. This is a good indication that primary production is limited by nutrients, primarily NO_3^- (see below) in the summer. On 16 August the surface water was reestablished uniformly across the fjord. The surface layer now extended down to about 20 m with a tem-

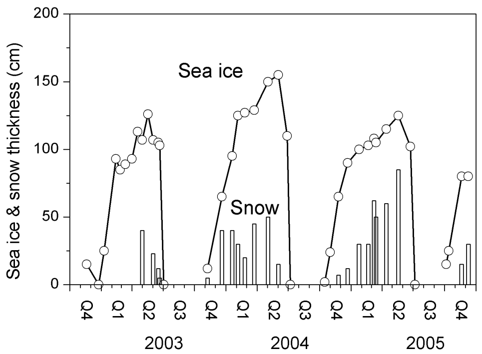


Fig. 4.4. Thickness of sea ice and snow cover on the ice in the outer part of Young Sund.

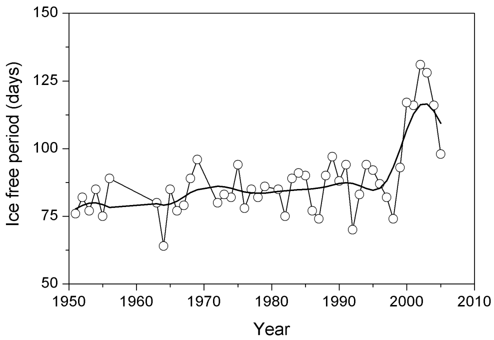


Fig. 4.5. Length of the ice free summer period in days in the outer part of Young Sund. Thick line indicates a 5 year running mean.

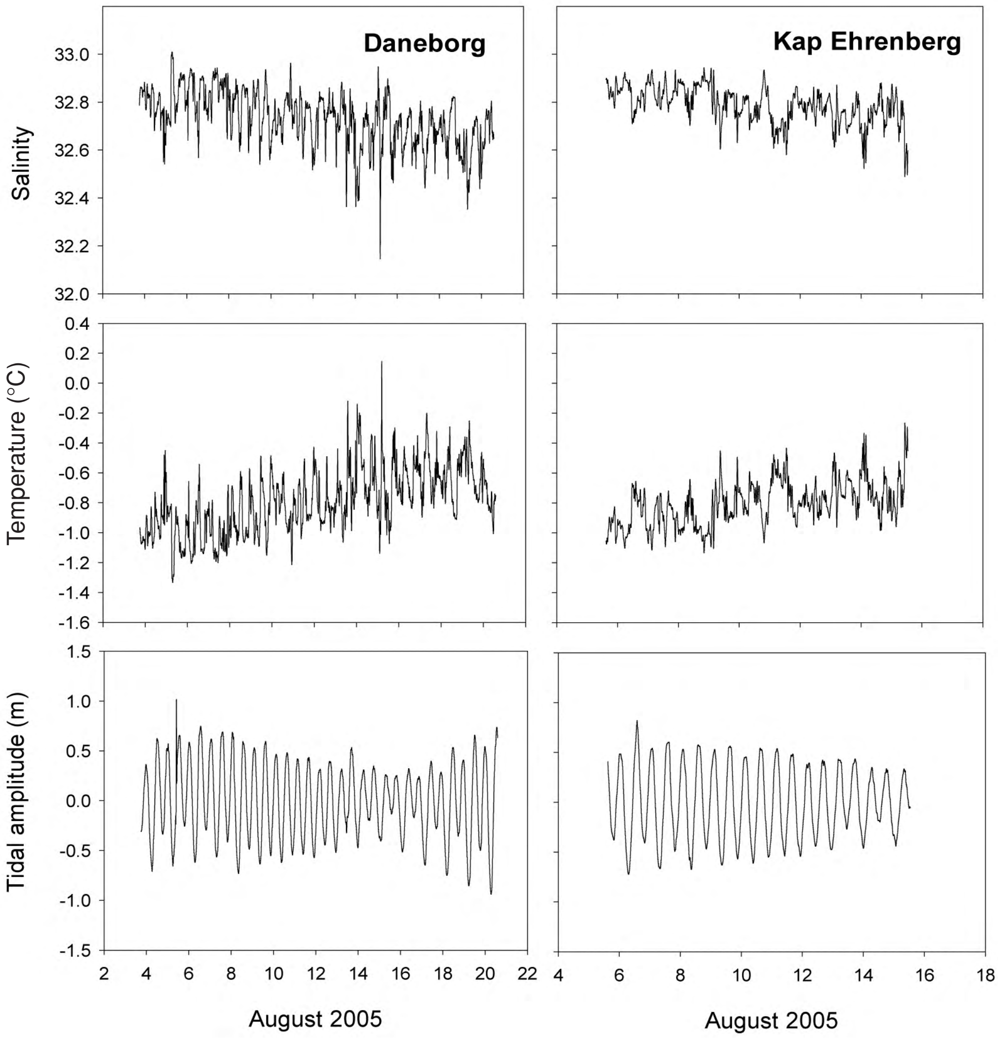


Fig. 4.6. Data from the mooring system at Kap Ehrenberg and Daneborg during the intensive study period.

perature of approximately 4 and a salinity of 27. Concentrations of chlorophyll *a* were reduced to < 1 µg l^{-1} and the bloom close to the eastern shore had disappeared.

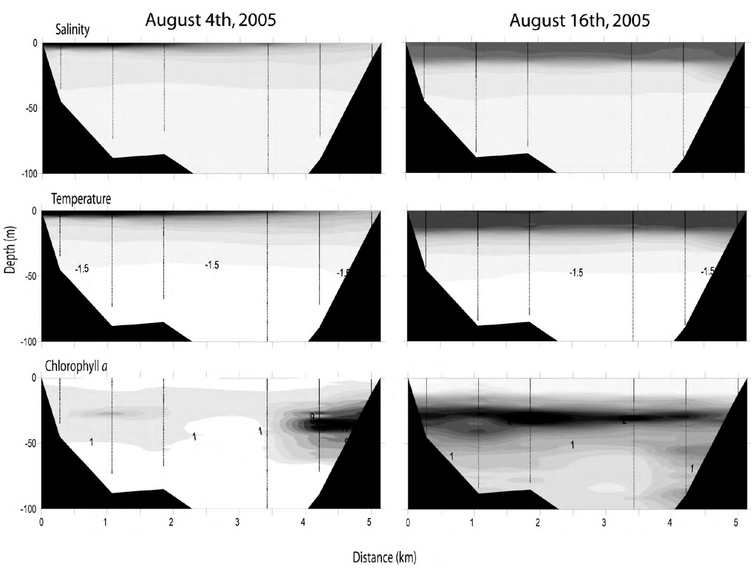


Fig. 4.7. Salinity, temperature (°C) and chlorophyll a (µg l^{-1}) along a transect across Young Sound close to the island Basalten Ø. Vertical line of dots represent sampling points. Distance (km) on the x-axis represents distance from the western shore of Young Sound (Clavering Ø).

The low amount of sea ice present during the summer of 2005 allowed a transect of vertical profiles to be made from the inner part and outwards into the Greenland Sea (Fig. 4.8). Due to input of freshwater from land and less exchange with the open sea, salinity of the surface water was lower in the inner part of the fjord. The layer of low-salinity surface water gradually decreased in thickness toward the open sea. Turbidity was also highly correlated to run-off from land with peaks in turbidity found in surface water near the glacier at the bottom of Tyrolerfjord and close to the Zackenberg River. Outside the sill of the fjord, higher chlorophyll *a* values were observed. Peak values of chlorophyll *a* were also deeper – about 50 m – outside the sill compared to about 30 m inside. This has been observed in previous years and seems to be a general feature. The presence of Upper Arctic Intermediate Water (UAIW) with high salinity (>34.5) and temperature (> 1 °C) was observed at 200-300 m depth in the Greenland Sea.

Vertical profiles at two stations, GH_7 in the Greenland Sea and YS_3.06 in Young Sund were compared from 2003 to 2005 (Fig. 4.9). At station GH_7 the warm surface water extended relatively deep in 2003 compared with 2004 and 2005 whereas the surface-water salinity was lower in 2005 due to large amounts of melting sea ice. At YS_3.06 the warmer surface water of 2003 could be traced down to about 20 m depth. The lowest surface-water salinity was found in 2004.

The temporal variability of temperature, salinity and chlorophyll *a* was investigated in the upper 150 m of the water column (Fig. 4.10) by recording vertical profiles every other day during August 2005 at a single station (74°18.58´N, 20°18.11´W). In the beginning of the period, the surface water was only 6-7 m thick but thickness increased during the study period to approximately 15 m. Chlorophyll *a* concentrations were highest in the beginning of the period, when highest values were observed below the surface layer, most likely due to nutrient limitation. Compared with August 2004 the most notable difference was that the salinity 33 contour was observed at 40 m depth in 2005 compared with 50 m depth in 2004.

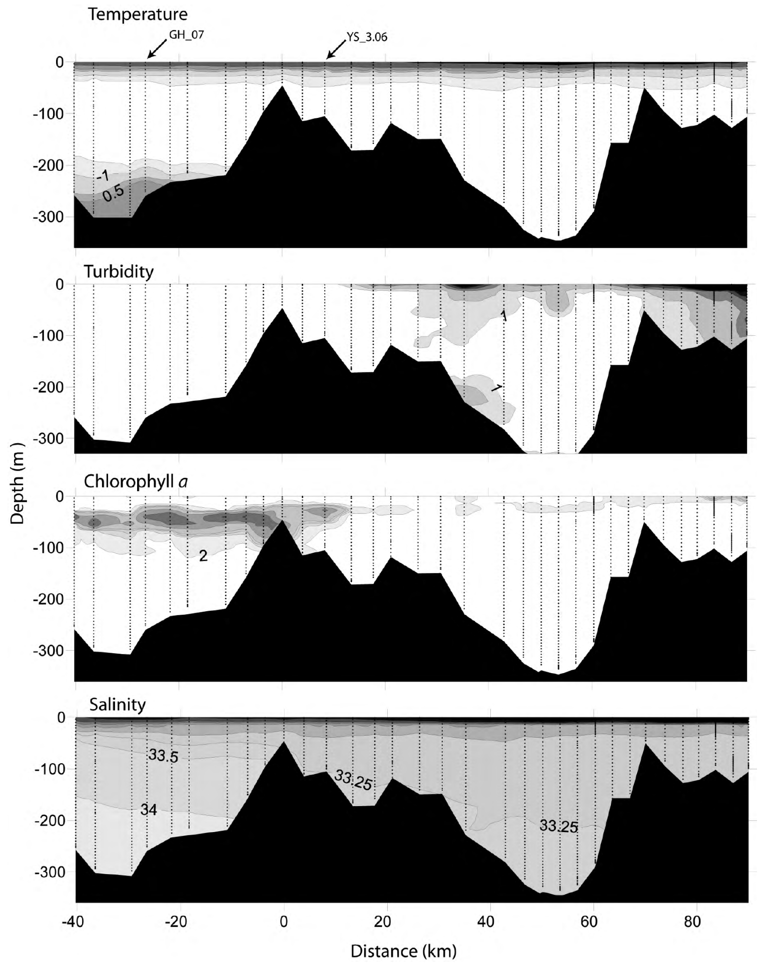


Fig. 4.8. Temperature (°C), turbidity, fluoroscence and salinity in the Young Sound – Tyrolerfjord system and in the Greenland Sea, August 2005. Vertical lines of black dots represent sampling points.

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

Nutrients, DIC and TA concentrations in the water column of the location 74°18.58’N, 20°18.00’W were measured on three occasions (4, 12 and 20 August, 2005). The nitrate concentration was very low in the surface water due to phytoplankton uptake and dilution by melt water, and increased with depth to 3-5 µM (Fig. 4.11). Phosphate was detectable in the surface water and concentrations increased to 0.5-0.6 µM in the bottom water. Silicate concentration profiles were different from those of nitrate and phosphate and showed a maximum at the surface followed by a minimum at 20 – 30 m depth and an increase towards the bottom. This could indicate that silicate is introduced to the fjord via melt water from the rivers. This difference in shape of the concentration profiles of nitrate, phosphate and silicate was also reflected in the average concentrations calculated for the intervals 0-5 m, 0-45 m and 45-150 m (Table 4.2). Phosphate and nitrate concentrations increased from the surface waters towards the

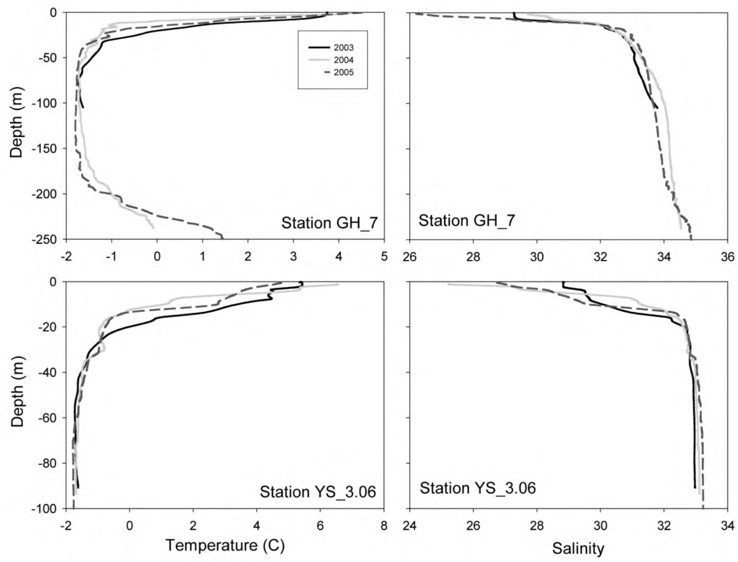


Fig. 4.9. Vertical profiles of temperature (left panels) and salinity (right panels) at two stations from 2003 to 2005. Position of profiles are indicated on Fig. 4.8.

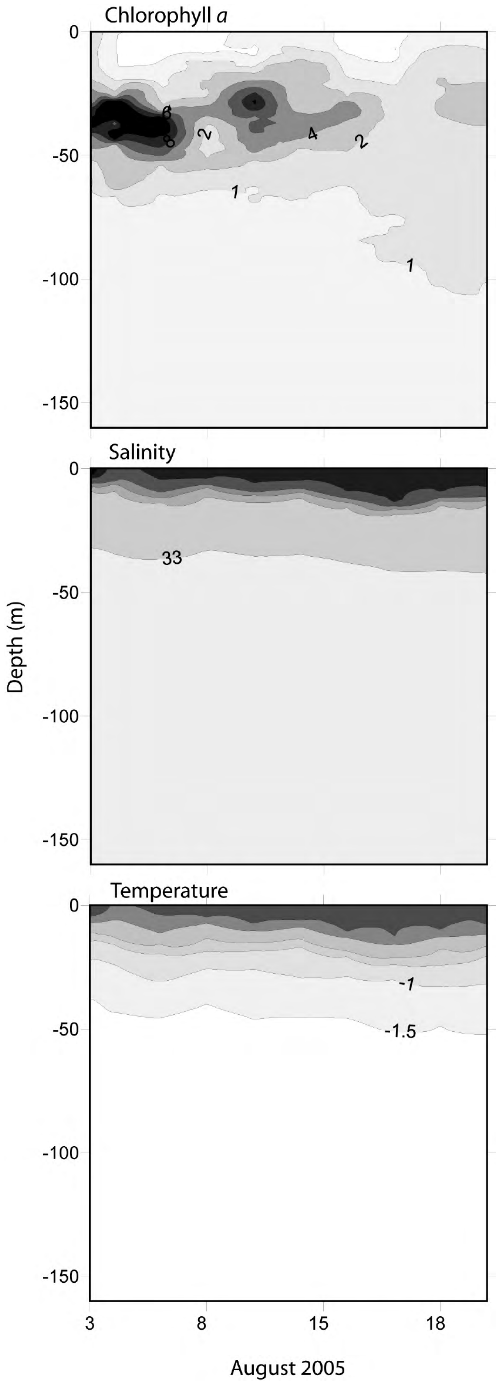


Fig. 4.10. Temporal variation of chlorophyll a (µg l⁻¹), salinity and temperature (°C) based on vertical profiles taken every 2nd day in Young Sound during August 2005.

deeper waters, whereas silicate displayed a minimum concentration in the second interval. Ammonium was not detected.

Phytoplankton is generally assumed to assimilate carbon, nitrogen and phosphorus in a ratio of 116:16:1, the so-called Redfield ratio. The ratio of inorganic nitrogen (nitrate + nitrite; ammonium was below detection level) to phosphate in the upper 30 m of the water column was below 2.5. This ratio should be close to 16 for phytoplankton growth to be non-limited. Together with the fact that NO_3^- was generally below 0.25 µM in that part of the water column this indicates that primary production was strongly nitrogen limited.

In 2005 nutrient concentrations were also measured on a longitudinal transect of Young Sund (Fig. 4.12) from the innermost part of Tyrolerfjord to the Greenland sea. As expected from the profiles measured at the standard station off the weather station NO_3^- concentrations were low in the upper 30-40 meters and increased towards the bottom. Silicate, on the other hand, displayed a maximum in the surface layer, indicating that silicate enters Young Sund with fresh water from the rivers. This is also reflected in maximum concentrations close to the glacier in the inner part of Tyrolerfjord. Phosphate was similar to silicate with maxima in the surface waters. Phosphate, too, appears to enter the fjord from the rivers, which was clearly seen as maxima close to the glacier in Tyrolerfjord and in the central part of Young Sund close to the river Zackenberg.

Dissolved inorganic carbon (DIC) ranged from 1829 µM in the upper 0-5 m of the water column to an average of 2189 µM in the bottom water of Young Sund (Fig. 4.13, Table 4.2). Total alkalinity (TA) followed the same vertical trend as DIC and ranged from 2067 to 2451 µM in the water column. The concentration profiles of DIC and TA showed similar patterns with stable high concentrations in the bottom waters and lower levels in the surface layers, probably due to consumption by primary producers and dilution by melt water. Atmospheric pCO_2 levels were significantly higher than pCO_2 levels in the surface water on all sampling dates showing that the CO_2 flux was directed from the atmosphere into the water column of Young Sund. This year's pCO_2 level was the lowest observed during the monitoring program. In Table 4.2 the mean hydrographic conditions at the locality in the outer part of Young Sund are given for the first three years of the MarineBasic program.

Light and optical properties of dissolved organic matter (DOM)

At four different dates during August the attenuation of light (PAR) in the water column was quantified and samples were taken for the determination of the optical properties of dissolved organic matter. Light attenuation coefficients were calculated for PAR based on vertical profiles.

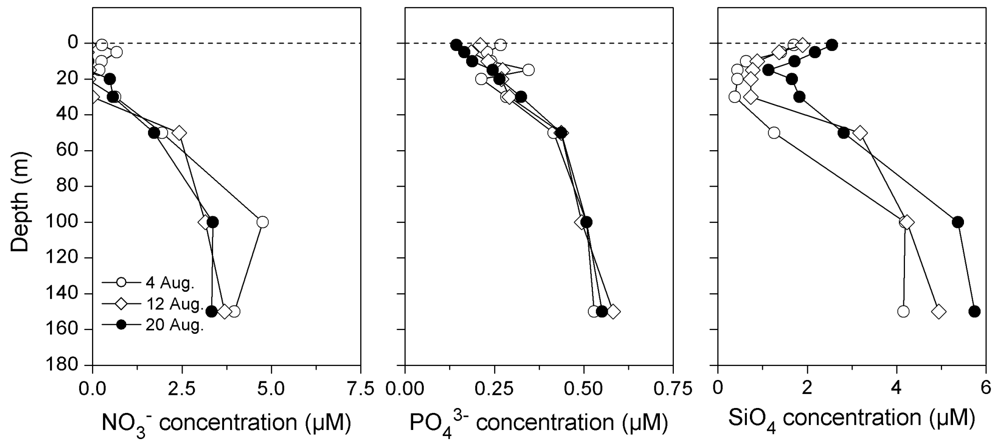


Fig. 4.11. Concentrations of NO_3^- + NO_2^-, PO_4^{3-} and SiO_4 in the water column in the outer part of Young Sund in August 2005.

The attenuation coefficients ranged between 0.0834 and 0.1241 with a mean of 0.1100 (Table 4.3). The attenuation coefficient of UV-B was 1.32 ± 0.12 which was comparable with estimates from 2003 and 2004. A research project concerning the bioavailability of dissolved organic carbon (DOM) was conducted during the MarineBasic program and is described in detail elsewhere in this report.

Phytoplankton and zooplankton

Vertical net hauls for phyto- and zooplankton were performed on 4, 12 and 20 August at the same location as in previous

0-5 m water depth	**2003**	**2004**	**2005**
Potential temperature (°C)	5.570 ± 0.175	5.515 ± 0.158	4.612 ± 0.077
Salinity	28.103 ± 0.230	26.029 ± 0.247	27.428 ± 0.089
Chlorophyll a (µg L^{-1})	0.727 ± 0.069	0.060 ± 0.004	0.945 ± 0.239
DIC (µM)	1806.2 ± 60.4	1769.0 ± 46.5	1829.5 ± 11.5
TA (µM)	1929.5 ± 65.8	1867.5 ± 52.5	2066.6 ± 11.1
pCO_2 (µatm)*	302.2 ± 32.6	197.1 ± 10.1	154.8 ± 9.0
NO_3^- (µM)	0.00 ± 0.04	0.16 ± 0.05	0.04 ± 0.08
PO_4^{3-} (µM)	0.25 ± 0.01	0.58 ± 0.17	0.20 ± 0.01
SiO_4 (µM)	2.41 ± 0.30	2.51 ± 0.59	1.85 ± 0.11
0-45 m water depth	**2003**	**2004**	**2005**
Potential temperature (°C)	2.564 ± 0.203	0.708 ± 0.095	0.998 ± 0.109
Salinity	30.449 ± 0.168	31.166 ± 0.104	31.027 ± 0.105
Chlorophyll a (µg L^{-1})	0.498 ± 0.032	0.407 ± 0.021	1.465 ± 0.292
DIC (µM)	2000.6 ± 40.4	1986.3 ± 3.6	2001.6 ± 17.6
TA (µM)	2146.0 ± 44.9	2175.5 ± 31.2	2263.8 ± 19.5
NO_3^- (µM)	0.83 ± 0.27	0.46 ± 0.15	0.08 ± 0.04
PO_4^{3-} (µM)	0.34 ± 0.03	0.62 ± 0.08	0.24 ± 0.01
SiO_4 (µM)	2.20 ± 0.2	1.45 ± 0.27	1.25 ± 0.09
45-150 m water depth	**2003**	**2004**	**2005**
Potential temperature (°C)	−1.653 ± 0.004	−1.659 ± 0.001	−1.725 ± 0.002
Salinity	32.933 ± 0.002	33.093 ± 0.001	33.217 ± 0.001
Chlorophyll a (µg L^{-1})	0.257 ± 0.011	0.117 ± 0.004	1.040 ± 0.257
DIC (µM)	2181.1 ± 7.9	2172.4 ± 0.40	2188.9 ± 3.2
TA (µM)	2318.8 ± 1.7	2347.6 ± 5.0	2450.5 ± 4.7
NO_3^- (µM)	3.95 ± 0.15	4.64 ± 0.14	3.15 ± 0.18
PO_4^{3-} (µM)	0.58 ± 0.01	0.88 ± 0.11	0.50 ± 0.01
SiO_4 (µM)	4.22 ± 0.27	4.48 ± 0.11	3.99 ± 0.26

*mean of surface layer (0-1 m)

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

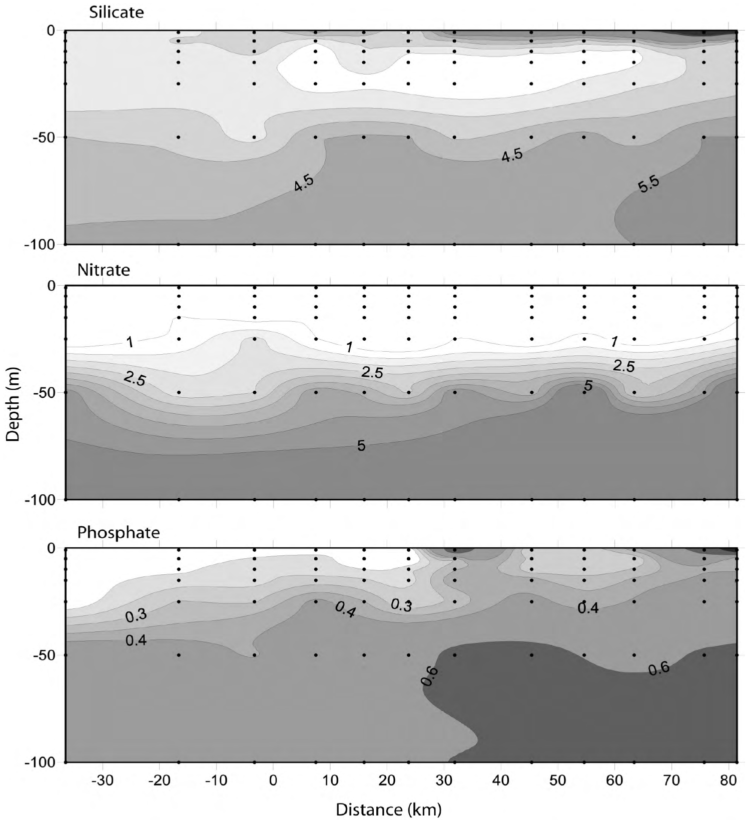


Fig. 4.12. Concentrations of silicate, nitrate and phosphate (μM) in the upper 100 m of the water column in the Young Sound – Tyrolerfjord complex and in the Greenland Sea during August 2005.

years (74°18.58´N, 20°18.00´W). For phytoplankton, relatively little change was observed during August (Table 4.4). Ten to 15 species were observed and diversity was relatively low. Compared with 2004 the phytoplankton community was dominated by the same species e.g. *Chaetoceros spp*., *Gymnodinium sp*. and *Nitzchia frigida* but diversity was generally lower in 2005 than in 2004. For zooplankton, the overall abundance of copepods was very similar to 2004 values and again dominant species were *Oithona spp*. and *Pseudocalanus spp*. nauplii (Table 4.5). A notable trend observed during the first three years of the program is found in the relative abundance of the two Calanus species *C. finmarchicus* and *C. hyperboreus*. The ratio between *C hyperboreus* and *C. finmarchicus* was 56:1 in 2003, 11:1 in 2004 and 3:1 in 2005. This is interesting since *C. finmarchicus* is generally described as belonging to warmer Atlantic water whereas *C. hyperboreus* is a typical arctic species. Although based on a very short period of time and a limited data set these results suggest an increased influence of Atlantic water in the area and it will be interesting to see if this trend continues.

The abundance of non-copepod species showed decreasing abundance during the study period (Table 4.5) from an abundance of 23.850 ind. m^{-2} on 4 August to 9.788 ind. m^{-2} on 20 August. *Fritellaria* was the dominant species together with *Radiolaria*. Compared with previous years, 2005 was characterised by a large number of gastropod larvae. Overall abundance was comparable with 2004 and 2003.

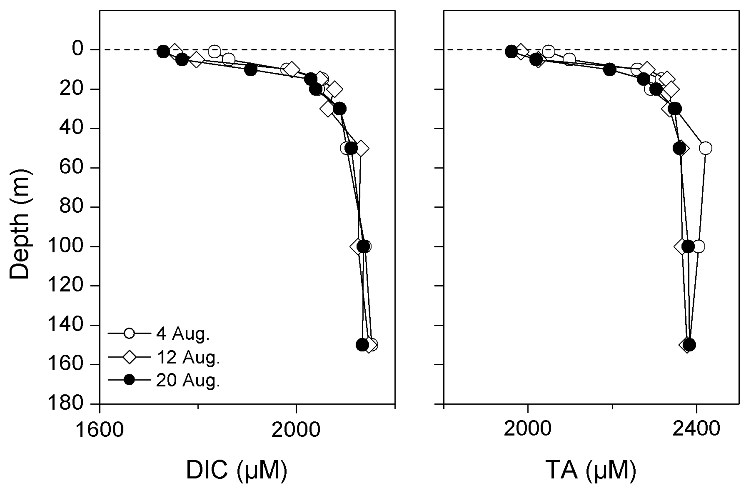


Fig. 4.13. Concentrations of dissolved inorganic carbon (DIC) and total alkalinity (TA) in the water column in the outer part of Young Sund in August 2005.

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 11 August 2004.

Of the organic carbon reaching the sediment surface 5.211 mmol C m^{-2} d^{-1} was returned to the water column as dissolved

Table 4.3. Attenuation coefficients in the water column of Young Sund. Mean ± SE (n).

	2003	2004	2005
PAR attenuation coefficient (m-1)	0.117 ± 0.007 (8)	0.136 ± 0.004 (8)	0.110 ± 0.009 (4)
UV-B attenuation coefficient (m-1)	1.27 ± 0.05 (8)	1.43 ± 0.23 (8)	1.32 ± 0.12 (4)

inorganic carbon (DIC) in 2005 (Table 4.6). The O_2 consumption by the sediment of 6.099 mmol m^{-2} d^{-1} was slightly higher than the DIC efflux. This indicates that O_2 is not only channelled into oxidation of organic matter, but part of it must be used for re-oxidation of reduced metals or sulphide. The specific O_2 consumption was highest in the upper part of the sediment (Fig. 4.14) showing that the main O_2 consumption was created by the fresh organic matter deposited on the surface of sediment. The specific O_2 consumption in the uppermost part of the sediment was dramatically higher in 2005 than in 2004, resulting in a much lower O_2 penetration in 2005. The fact that most of the O_2 consumption occurred in a narrow band (0.25 mm thick) indicates that this was created by a recent input of fresh organic matter. With time, the organic matter settling on the sediment surface will be mixed downwards by fauna-mediated reworking of the sediment. Therefore, the deeper homogenous O_2 consumption zone in 2004 indicates that the organic matter had been in the sediment for longer than in 2005. This agrees very well with the very large phytoplankton bloom in the eastern part of Young Sund in the beginning of August (Fig. 4.7), which most likely created a large pulse of organic matter to the sediment surface.

Sulphate reduction was responsible for about 40% of the mineralization of organic matter in summer 2005 (Table 4.6) which is less than in 2004 when it was 48%. As mentioned above, the O_2 profiles in the sediment indicated that a recent input of organic matter was being mineralized very close to the sediment surface (Fig. 4.13), and that this occurred with O_2 as electron acceptor. In 2004, O_2 consumption was lower and occurred deeper in the sediment. Consequently, the proportion of mineralization occurring via sulfate reduction was lower in 2005 than in 2004.

Sulphate reduction was low in the upper layers of the sediment, where other mineralization processes dominated, and increased significantly with depth (Fig. 4.15). Diffusive and whole-core O_2 uptake were identical in 2005, indicating that the role of benthic fauna in mineralization was not significant.

Benthic animals

The abundance of dominant benthic species was determined from 150 photographs of the sea floor along standard depths and transects. The overall patterns of abundance of the four most abundant groups were similar to previous years (Fig. 4.16). Brittle stars increased in abundance at increasing depth. Highest abundance at 40 m and 50 m was found at H2, while maximum abundance was found at 60 m at H3. Sea urchins were most abundant at H1 and H2 and only found at 60 m at H3. Bivalves were most abundant at shallow depths and at H2 and H3. Compared with

Table 4.4. Phytoplankton diversity (mean ± SE, n = 3) during August 2005. The ten most abundant species are shown together with their relative accumulated proportion of total cell count.

	4 August 2005		12 August 2005		20 August 2005	
No. species	10 ± 1.0		15.7 ± 0.7		12.3 ± 1.3	
Diversity	1.33 ± 0.08		1.60 ± 0.09		1.57 ± 0.12	
Equilibility	0.58 ± 0.02		0.58 ± 0.03		0.63 ± 0.07	
Dominant species	*Gymnodinium sp.*	40	*Gymnodinium articum*	30	*Nitzschia frigida*	33
	Nitzschia frigida	56	*Gymnodinium sp.*	51	*Chaetoceros eibenii*	49
	Fragilariopsis oceanica	70	*Navicula vanhofenii*	61	*Gymnodinium cf arcticum*	59
	Chaetoceros dicipiens	82	*Nitzschia frigida*	69	*Melosira sp.*	66
	Fragilariopsis cylindricus	94	*Navicula septentrionalis*	77	*Fragilariopsis cylindrus*	73
	Achnanthes taeniata	97	*Ceratium sp.*	83	*Fragilariopsis oceanica*	78
	Thalassiosira sp.	98	*Cylindrotheca closterium*	86	*Chaetoceros socialis*	83
	Pseudonitzschia delicatissima	99	*Chaetoceros decipiens*	88	*Attheya septentrionalis*	86
	Protoperidinium pellucidum	99	*Chaetoceros eibenii*	90	*Chaetoceros decipiens*	90
	Chaetoceros eibenii	99	*Thalassiosira antarctica*	91	*Gymnodinium sp.*	92

	4 August 2005			12 August 2005			20 August 2005		
	Mean	SE	%	Mean	SE	%	Mean	SE	%
	No m^{-2}	n=3	of total	No m^{-2}	n=3	of total	No m^{-2}	n=3	of total
Copepods									
Pseudocalanus spp.	4800	861	11.0	5077	612	11.0	6250	744	13.7
Pseudocalanus spp. Nauplii	9600	2033	22.0	12714	2897	27.6	6912	1409	15.1
Oithona spp.	13162	1838	30.1	11840	1293	25.7	18197	3894	39.8
Oithona spp. Nauplii	2389	984	5.5	5802	2338	12.6	4778	1230	10.5
Calanus hyperboreus	2667	1105	6.1	533	187	1.1	928	272	2.0
Calanus glacialis	384	64	0.9	576	148	1.2	746	85	1.6
Calanus finmarchicus	1003	246	2.3	939	203	2.0	874	112	1.9
Onchaea	3861	492	8.8	4821	1048	10.5	3648	608	8.0
Microcalanus	5077	1287	11.6	3029	984	6.6	2581	602	5.6
Harpacticoida	363	119	0.8	213	56	0.5	85	43	0.2
Metridia longa	405	107	0.9	544	187	1.1	704	169	1.5
Sum	43712			46091			45706		
Other Groups									
Cirripedia	171	107	2.5	27	19	0.4	43	11	0.2
Bivalvia, larvae	85	21	1.2	85	21	2.6	234	65	2.4
Gastropoda, larvae	1024	98	14.8	1941	598	1.0	1472	11	1.7
Fritellaria, bor.	3755	427	55	3264	192	75	2176	1041	61
Oikopleura	128	64	1.9	320	98	5.0	85	11	1.2
Polychaeta, larvae	170.7	56	2.5	85	43	1.7	43	65	9.7
Echinodermata, pluteus	21.3	21.3	0.3	833	315	0.1	299	115	5.1
Decapoda	1.3	1.3	0.0	0	0	0.0	0	0	0.0
Amphipoda	5.3	5.3	0.1	28	4.0	0.1	15	18	0.7
Chaetognatha	27	10.4	0.4	6.7	2.7	0.3	1.3	11	0.2
Radiolaria	1280	256	18.6	4138	1551	12.9	3422	453	15.8
Isopoda	42.7	42.7	0.6	2.7	2.7	0.0	1963	28	1.0
Ascidiacae	149	76.9	2.2	21	21	0.2	4	2.3	0.0
Hydromedusae	21.3	21.3	0.3	29	17	0.4	21	21	0.5
Sum	23850			10782			9788		

Table 4.5. Composition of zooplankton in vertical hauls taken from 160 to 0 m depth at three sampling dates in August 2005.

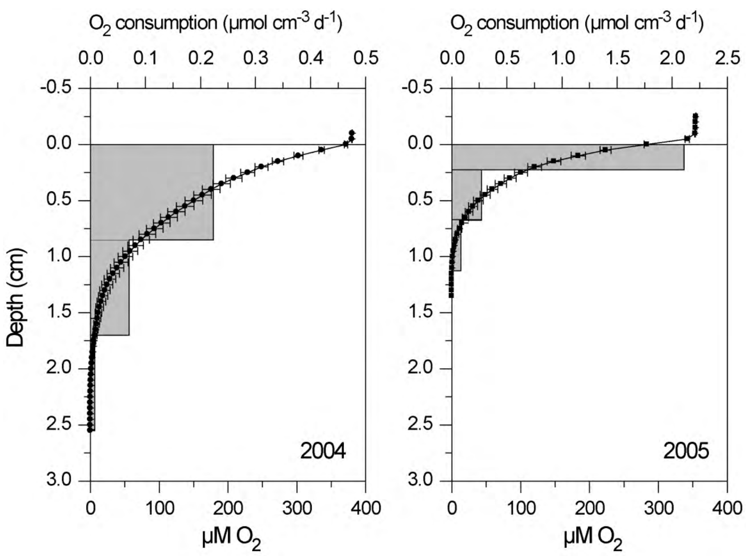


Fig. 4.14. Vertical concentration profiles of oxygen (dots) and modeled consumption rates (bars) in the sediment at 60 m water depth in outer Young Sund, August 2004 and August 2005.

2003 and 2004 a notable difference in 2005 was the exceptionally high abundance of bivalves at H3 at 30 m. Here, mean abundance had increased by a factor of 5 compared with 2003 (Table 4.7). When comparing abundance between years it is important to keep in mind the great spatial variability in benthic abundance. The abundance at a single station might vary by a factor of 2 or 3 within a few meters. Since the exact same spot can not be sampled every year, differences between year are also influenced be spatial variability. Data obtained over a longer period are necessary to identify temporal trends in the abundance of benthic fauna. In addition to tracking abundance of dominant species the purpose of the pictures is also to provide an estimate of diversity and checking for the appearance of new species.

	2003			2004			2005		
	Average	±SE	n	Average	±SE	n	Average	±SE	n
TOU	–5.191	0.523	10	–4.429	0.925	10	–6.099	0.417	10
DIC	6.955	2.298	10	3.372	0.457	10	5.211	1.478	9
NO3- + NO2-	0.221	0.087	10	0.135	0.045	10	–0.019	0.018	10
NH4+	–0.002	0.064	10	0.041	0.026	10	–0.018	0.009	10
PO43-	–0.017	0.013	10	0.249	0.076	10	–0.012	0.006	10
SiO4	0.543	0.090	10	0.474	0.118	10	0.256	0.107	10
SRR	0.430	0.084	3	0.816	0.216	3	1.033	0.584	3
DOU	–3.026			–2.909			–6.323		
TOU/DOU	1.72			1.52			0.96		
SRR/DIC flux	0.124			0.484			0.396		

Table 4.6. Sediment-water exchange rates of O_2 (TOU), 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.

Underwater plants

The annual growth of the algae *Laminaria saccharina* can be quantified by measuring the new leaf produced. The measured growth in specimens collected in August 2005 is thus a result of the physical and biological conditions experienced during the summer of 2004 and until collection in 2005. In addition to measuring the length of the new leaf, the carbon content of the leaf is also determined. Annual growth in cm and g C yr^{-1} from 2003 to 2005 is presented in Table 4.8. The length of the new leaves in 2005 was the longest yet recorded while the carbon production was intermediate from 2003 to 2004.

Other activities: Walrus, seal and arctic char

The abundance of walrus at their haul-out location Sandøen was determined on 11 occasions during August 2005. The mean number of individuals observed was 9 with a range in observations from 0 to 21 individuals. MarineBasic also collected 15 individuals of arctic char which are stored frozen in a data bank for future determination of contaminants.

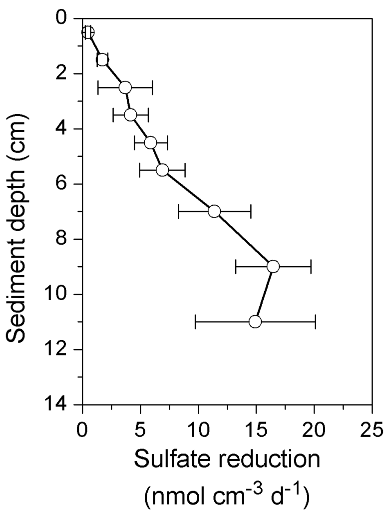


Fig. 4.15. Sulfate reduction rates in the sediment at 60 m water depth in Young Sund in August 2005.

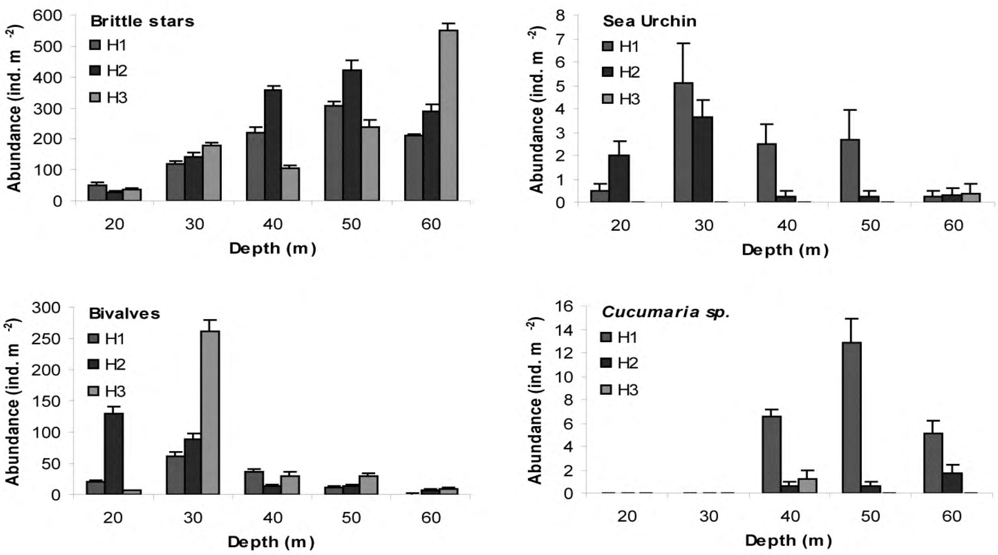


Fig. 4.16. Abundance of dominant benthic fauna in Young Sound (mean ± SE, n = 10) estimated from analysis of photos from August 2005.

(n = 10)	H1 2003 Mean ± SE (n = 10)	H1 2004 Mean ± SE (n = 10)	H1 2005 Mean ± SE (n = 10)	H2 2003 Mean ± SE (n = 10)	H2 2004 Mean ± SE (n = 10)	H2 2005 Mean ± SE (n = 10)	H3 2003 Mean ± SE (n = 10)	H3 2004 Mean ± SE (n = 10)	H3 2005 Mean ± SE
Brittle star									
20	122 ± 12	115 ± 16	52 ± 7	28 ± 4	34 ± 4	27 ± 3	4.2 ± 2.6	43 ± 5	36 ± 4
30	126 ± 8	145 ± 10	117 ± 13	242 ± 22	62 ± 7	144 ± 13	70 ± 8	142 ± 11	180 ± 8
40	245 ± 13	212 ± 18	220 ± 19	317 ± 23	247 ± 24	355 ± 16	118 ± 11	116 ± 11	107 ± 9
50	206 ± 10	298 ± 20	308 ± 11	376 ± 29	382 ± 10	423 ± 31	97 ± 8	205 ± 19	238 ± 23
60	98 ± 13	203 ± 14	210 ± 5	267 ± 17	417 ± 13	288 ± 22	362 ± 26	452 ± 28	550 ± 21
Sea urchin									
20	5.7 ± 1.4	6.2 ± 1.9	0.5 ± 0.3	0	1.1 ± 0.5	2.0 ± 0.6	0	0	0
30	2.0 ± 0.8	4.9 ± 1.0	5.1 ± 1.7	2.5 ± 0.7	4.5 ± 0.6	3.7 ± 0.7	0	0	0
40	1.7 ± 0.7	3.6 ± 0.5	2.5 ± 0.8	0	0	0.3 ± 0.3	0	0	0
50	0.3 ± 0.3	1.3 ± 0.9	2.6 ± 1.3	0.8 ± 0.7	0.2 ± 0.2	0.3 ± 0.3	0	0	0
60	0.1 ± 0.1	0.3 ± 0.3	0.2 ± 0.2	0.7 ± 0.5	0.8 ± 0.4	0.3 ± 0.3	0	0.7 ± 0.3	0.4 ± 0.4
Bivalves									
20	30 ± 3.4	35 ± 5.0	19 ± 2.8	43 ± 5.1	76 ± 14.5	129 ± 13	12 ± 3.9	38 ± 1.6	5.9 ± 1.5
30	22 ± 3.1	27 ± 2.9	62 ± 5.6	21 ± 3.7	46 ± 2.4	89 ± 10	55 ± 6.2	91± 8.4	260 ± 19
40	19 ± 3.4	22 ± 2.5	37 ± 4.7	69 ± 10.8	47 ± 8.1	14 ± 2.8	9.4 ± 2.7	22 ± 2.3	29 ± 7
50	1.0 ± 0.7	2.2 ± 1.1	10 ± 3.1	20 ± 4.1	36 ± 4.4	14 ± 2.8	6.4 ± 1.4	16 ± 2.8	28 ± 5
60	0	0	0.8 ± 0.4	2.0 ± 0.7	7.7 ± 2.3	7 ± 2	2.1 ± 1.0	6.0 ± 1.9	9 ± 3
Sea cucumber									
20	0	0	0	0	0	0	0	0	0
30	0	0.2 ± 0.2	0	0	0.2 ± 0.2	0	0	0	0
40	4.1 ± 1.0	2.3 ± 0.8	0.6 ± 0.4	0	0.6 ± 0.4	0.6 ± 0.4	0	0.6 ± 0.6	1.2 ± 0.6
50	4.9 ± 1.5	12 ± 2.0	13 ± 2.1	2.0 ± 0.7	0.4 ± 0.2	0.6 ± 0.4	0	0	0
60	3.7 ± 1.1	5.2 ± 1.3	5 ± 1.2	1.0 ± 0.5	0	1.7 ± 0.8	5.1 ± 2.7	1.7 ± 0.6	0

Table 4.7. Density of dominant benthic fauna along three transects (H1, H2, H3) in Young Sund.

Table 4.8. Annual growth of Laminaria saccharina in Young Sund.

	2003 Mean ± SE (n)	2004 Mean ± SE (n)	2005 Mean ± SE (n)
Length of new leaf blades (cm yr-1)	108.6 ± 7.6 (14)	105.7 ± 6.2 (16)	118 ± 5.5 (20)
Production of new leaf blades (g C yr-1)	15.1 ± 1.3	5.8 ± 0.8	11.0 ± 0.9 (20)

5 Research projects

5.1 Effects of climate manipulations on processes and organisms in high arctic terrestrial ecosystems

Anders Michelsen, Susanne M. König, Lotte Illeris, Marie F. Arndal, Kristian R. Albert, Mikkel P. Tamstorf and Helge Ro-Poulsen

Ecosystem manipulations are important to obtain an experimental validation of observations made in the various programmes in Zackenberg aiming at understanding causes of between-year variations, and differences between ecosystem types. In 2004 an experiment was initiated in a *Cassiope tetragona* and a *Salix arctica* heath to investigate the consequences of warming, increased cloud cover and changed growing season length on plant performance, reproduction and gross and net carbon fluxes. The experiment was continued in 2005 and is planned to be maintained at least until the end of the 2007 growing season, preferably longer if funding can be secured.

The experiment consists of 60 permanent plots each of 1m^2 placed in the two heath types. Warming during the growing season is achieved by erecting passive greenhouses which enhance the soil temperature by 1.0°C. Short and long growing season is achieved by snow addition or removal in the beginning of the season. Shading screens which simulate enhanced cloud cover are also erected which reduce incoming photosynthetic active radiation (PAR) by 60% and reduce soil temperature by 2.0°C.

The preliminary results from the *Cassiope* plots in the growing season of 2005 show that the manipulations affect both plant photosynthesis and respiration from plants and soil, measured in transparent and dark plexiglass chambers installed on permanent bases in each plot (Fig. 5.1). The gross ecosystem production was increased by 47% in warmed plots compared to un-manipulated control plots across the season, and the production was higher in warmed plots at all dates of measurement. 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 aboveground carbon storage. On ecosystem level, the increased carbon gain by plants in warmed plots is, however, offset by increased carbon loss from the ecosystem due to increased plant and soil respiration. At all times of measurement, the ecosystem respiration in warmed plots exceeded that of control plots. Conversely, in shaded plots the lower soil temperature led to reduced ecosystem respiration, and hence, reduced carbon loss. These results demonstrate a tight temperature control of soil C emission in two high arctic heath types. Preliminary analyses also suggest that plants adapt to changed conditions by altering their tissue N concentration. Future analyses will show how plant reproductive effort, and secondary metabolites which protect the plants from herbivores, are affected by experimental changes in growing season length, summer temperature and incoming light.

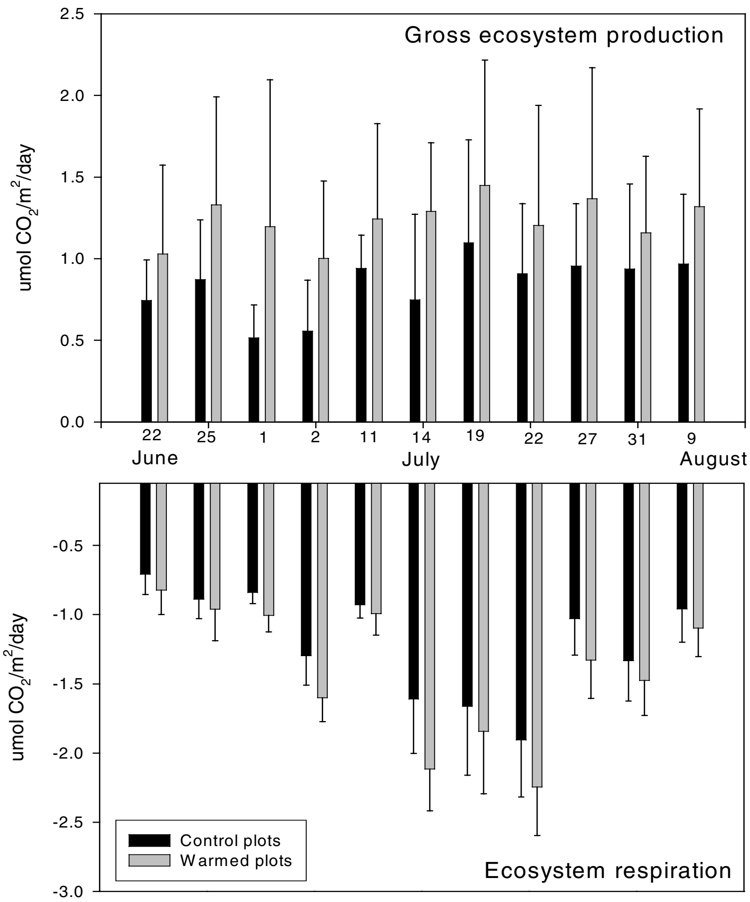


Fig. 5.1. Growing season, gross ecosystem production and ecosystem respiration in Cassiope tetragona heath at Zackenberg in 2005. Means ± standard error, n=6. By convention, C uptake by vegetation is positive while C fluxes out of the ecosystem are negative.

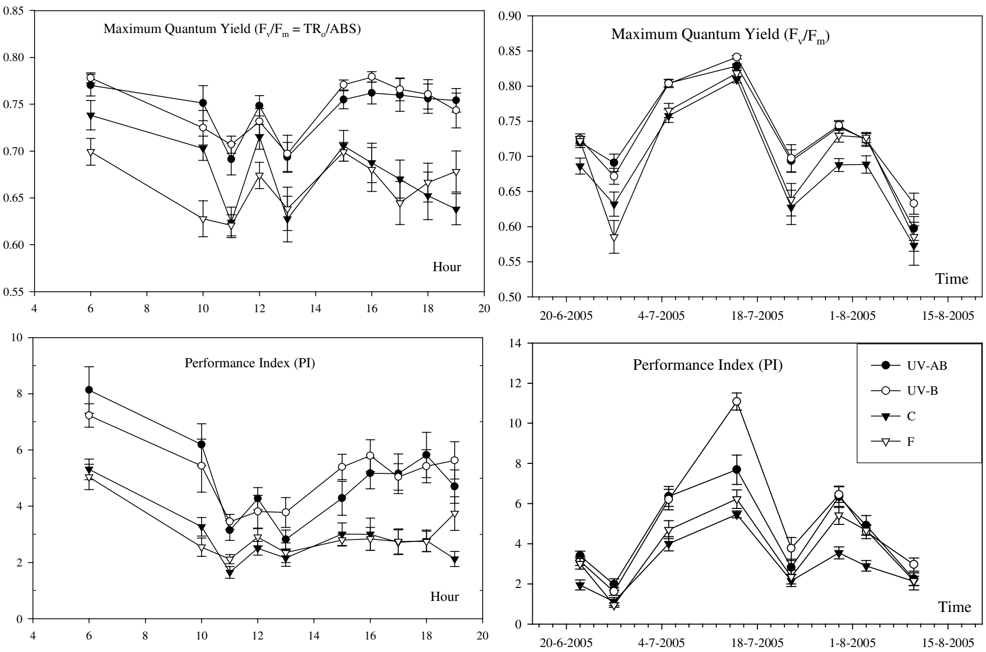


Fig. 5.2. Daily and seasonal fluctuations in Maximal quantum yield (F_V/F_M) and Performance Index (PI) during summer 2005 on Betula nana. UV-excluding treatments are depicted as circles, whereas controls receiving ambient UV-B radiation are depicted as triangles. See text for further explanations.

5.2 Studying effects of current UV-fluxes on high arctic vegetation (UV-B exclusion experiments)

Kristian R. Albert, Marie Frost Arndal, Anders Michelsen, Mikkel P. Tamstorf, Helge Ro-Poulsen and Teis N. Mikkelsen

The experiments with UV at Zackenberg are aiming at a holistic approach by studying both direct (*i.e.* on photosynthetic performance) and indirect effects (*i.e.* soil microbial community composition) of current UV-fluxes and hereby contribute to the need for new knowledge and insight in this research area. At present there are great scientific interests for UV-B studies, as motivated in the latest recommendations in the ACIA report.

Hence, several UV-exclusion experiments were initiated and reestablished in 2005 after the discontinuation of experiments in 2004. The former sites labeled 1 and 2 alias 'level 'and 'sloping' sites were reestablished as in 2001-2003. The four treatments were: Exclusion of UV-B (Mylar filter), UV-AB (Lexan filter), filter control (UV-transparent Teflon filter) and an open control organized in four blocks and treatments comprising the dominant plant species *Salix arctica* and *Vaccinium uliginosum*. In addition a third site with the same treatments was established nearby on *Betula nana*, named the '*Betula nana* site' (Fig. 5.2). In general, it is hypothesized that if the plants are affected negatively by the current level of UV-fluxes, then screening by means of UV-absorptive filters will result in a stress release and overall increase of plant photosynthetic performance. On all three species chlorophyll *a* fluorescence measurements were conducted throughout the experimental period to investigate possible UV-mediated plant stress. To study effects in the longer term, which may be accumulating, these three sites are planned to be continued in the future, if funding is obtained.

UV-doses were homogenized in the maximum irradiation experiment on *Salix arctica* as in 2002 and 2003 including the previous mentioned treatments. The previous analysis in this experiment type suggested and identified the potential for new insights by applying the newest techniques and conducting 1) seasonal measures by means of parallel PAM fluoriometry and fluorescence induction curves and 2) campaigns with simultaneous PAM fluorescence and CO_2-and H_2O- gas exchange measurements. To our knowledge, this is the first time that such techniques have ever been applied in UV manipulative studies and also no such records are reported on arctic plants. These data are being processed aiming at publication in a high rated refereed journal. Finally a UV-study on the gas exchange of canopies of *Vaccinium uliginosum* was prepared for future studies. The last measurements was in the beginning of August with final leaf harvests for determination of biomass, area and content analysis of chlorophyll, total carbon and nitrogen, UV-B absorbing compounds (qualitative and quantitative) and also leaf reflectance measurements (350-1250nm).

An additional pilot study on daily variations in a range of non-invasive parameters on un-manipulated *Salix arctica* leaves was carried out by conducting parallel measures of leaf reflectance (350-1250nm), PAM fluoriometry, recordings of chlorophyll induction curves and also simultaneous PAM fluriometry and gas-exchange. Leaves were harvested for laboratory analysis as above.

In this report are presented some of the *Betula nana* responses to treatment. During the experimental period chlorophyll *a* fluorescence induction curves were recorded and from these a range of parameters were derived and calculated, see the presentation in ZERO report of 2004 or Albert *et al*. 2005 for details. The measurements were done on randomly selected leaves. The much reported parameter, maximal quantum yield (F_V/F_M) closely relates to Photosystem II (PSII) function and are often interpreted as a proxy for plant stress, if treatment effects are significantly different. Indeed, such plant stress release were detected on *Betula nana* as F_V/F_M were significantly increased in the treatments, where large proportions of UV-B and UV-AB were excluded as compared to both filtered and open control. This response was seen throughout the experimental period. Parallel results were seen in the behavior of the Performance Index (PI-index). This parameter integrates into one parameter the proportional responses of energy fluxes related to trapping and dissipation within the PSII and also to the energy transport behind PSII. Hereby the PI-index expresses the overall effective energy processing through PSII and is believed to sum up the accumulative effects on PSII. The results clearly demonstrated that current levels of UV-fluxes induce plant stress on *Betula nana*. Moreover, the increase in both F_V/F_M and PI-Index across treatments during early summer clearly indicates the seasonal course of plant photosynthetic performance: Early build up and midseason maturation of plant photosynthetic capacity until mid July, hereafter followed by senescence processes in late July and onwards.

To assess whether the treatment response were restricted to periods during the day with high irradiance measurements, measurements throughout one day under sky clear conditions were conducted. As expected a midday depression in both F_V/F_M and PI- index were seen across treatments in parallel with irradiance doses, which are being maximal around 13:00. Surprisingly the values in UV-reduced treatments were higher during all times of the day. This demonstrates that control plants, being exposed to current levels of UV-radiation, appears to be permanently stressed and do not 'catch-up' after exposure to the midday event by finalizing repair processes. This new finding points to the importance of negative impacts of ambient UV- radiation on the photosynthetic apparatus in sensitive plant species. Moreover, the negative response in ambient UV may be linked to carbon assimilation further downstream, why future studies using specially designed chambers will try to detect whether the effects also link to decreased net photosynthesis. To sum up, *Betula nana* were demonstrated to have a higher level of stress, when exposed to current UV-fluxes than in controls and, as such, this plant species is sensitive to current UV-fluxes, at least in short term.

Further work during summer 2006 is prepared to focus on whether high arctic plants can be induced to or are capable at all to screen off UV-B by means of supplemental spaying of a chemical UV-B protectant (EDU) and thereby avoid the negative stress effects as measured by chlorophyll *a* fluorescence. Also the investigations on *Salix arctica* and *Vaccinium uliginosum* at the 'level' and 'sloping' sites plus at the *Betula nana* site will be continued with same protocol as in this year.

5.3 Habitat-dependent availability of nutrients and ground water for Arctic willow growth

Niels M. Schmidt, Claudia Baittinger, Johannes Kollmann and Mads C. Forchhammer

Our previous investigation of the Arctic willow (*Salix arctica*) in the Zackenberg valley has documented spring snow-cover extent rather than temperature during the growing season as limiting factor for an-

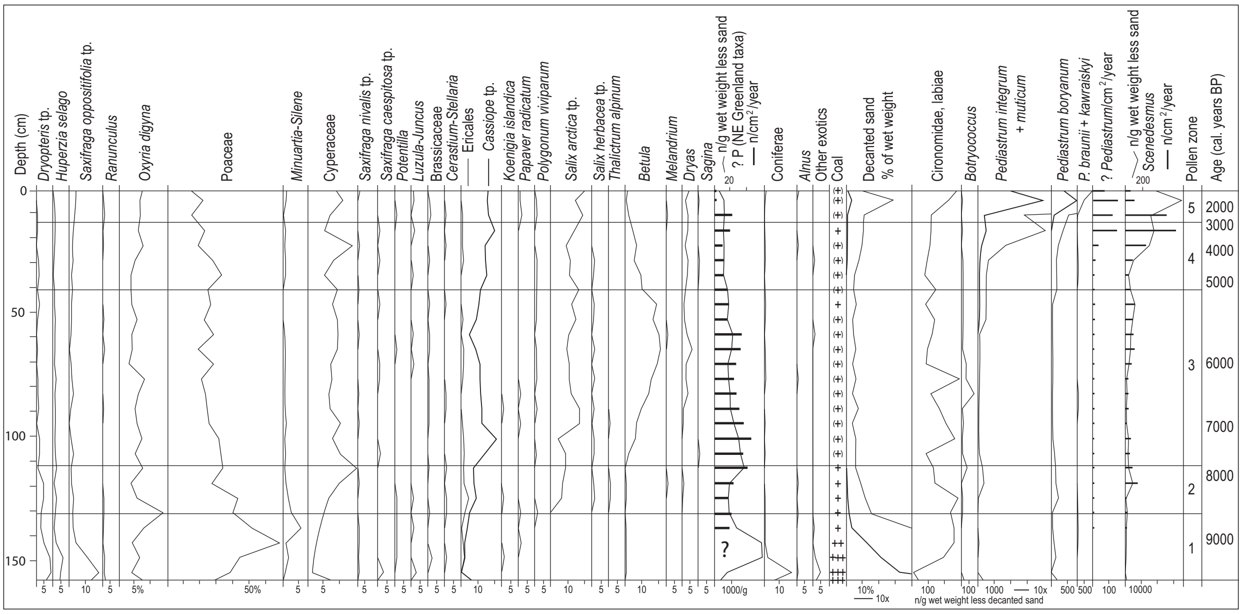


Fig. 5.3.

nual radial growth (Schmidt *et al*. 2006). Furthermore, preliminary results from the ongoing examination of the effects of the three main habitat types (*i.e. Salix* snowbed, *Cassiope* heath, abrasion plateau) and plant sex (see Schmidt and Forchhammer 2004) on annual growth show that growth differs among habitats, but also between the two sexes within habitats. In order to pursue this subject further, we estimated the availability of ground water and nutrients in the three habitats.

Seven sampling plots were established in each of the habitats, and at each plot nutrient and ground water availability were recorded. All measurements were made within 50 cm of a living individual of *Salix arctica* and within the first 15 cm of the upper soil.

At each station, nutrient availability was measured using two anion and two cation Plant Root Simulator (PRS)™-probes (http://www.westernag.ca/innov/main.html). These probes assess the availability of nutrients by continuously adsorbing ions from the soil which is believed to be a more adequate measure of plant nutrient availability than standard soil analyses. The probes were inserted into the soil in mid July and recovered in late August, and are now being processed in the laboratory.

Similarly, the ground water content was measured in mid July and again in late August using a ThetaProbe soil moisture sensor (Type ML2X; Delta-T Devices Ltd). The availability of ground water differed significantly between habitats, with the lowest water content found on the abrasion plateau, intermediate in the *Salix* snowbed, and the highest water content on the *Cassiope* heath. On the abrasion plateau, the soil water content increased significantly during the study period, whereas in the two latter habitat types the water content decreased significantly.

From each of the three habitats one male and one female plant were sampled completely, *i.e.* including roots and stems. These six individuals form the basis for refining the dendrochronological methodology applied on Arctic willow, but they are also used for the exploration of the within-individual variation in growth patterns. Finally, as in 2003, we collected five male and five female Arctic willow twigs from around *Salix* monitoring plot 4 (Schmidt and Forchhammer 2004). These twigs are now being processed, and will together with the 2003 samples be used for the analysis of a potential inter-annual trade-off between radial growth and reproduction.

5.4 Holocene vegetational and climatic changes at Zackenberg

Bent Fredskild

Pollen and macrofossil analyzes have been made on sediment cores from two lakes in Morænebakkerne in the north-western part of Zackenbergdalen, both above the

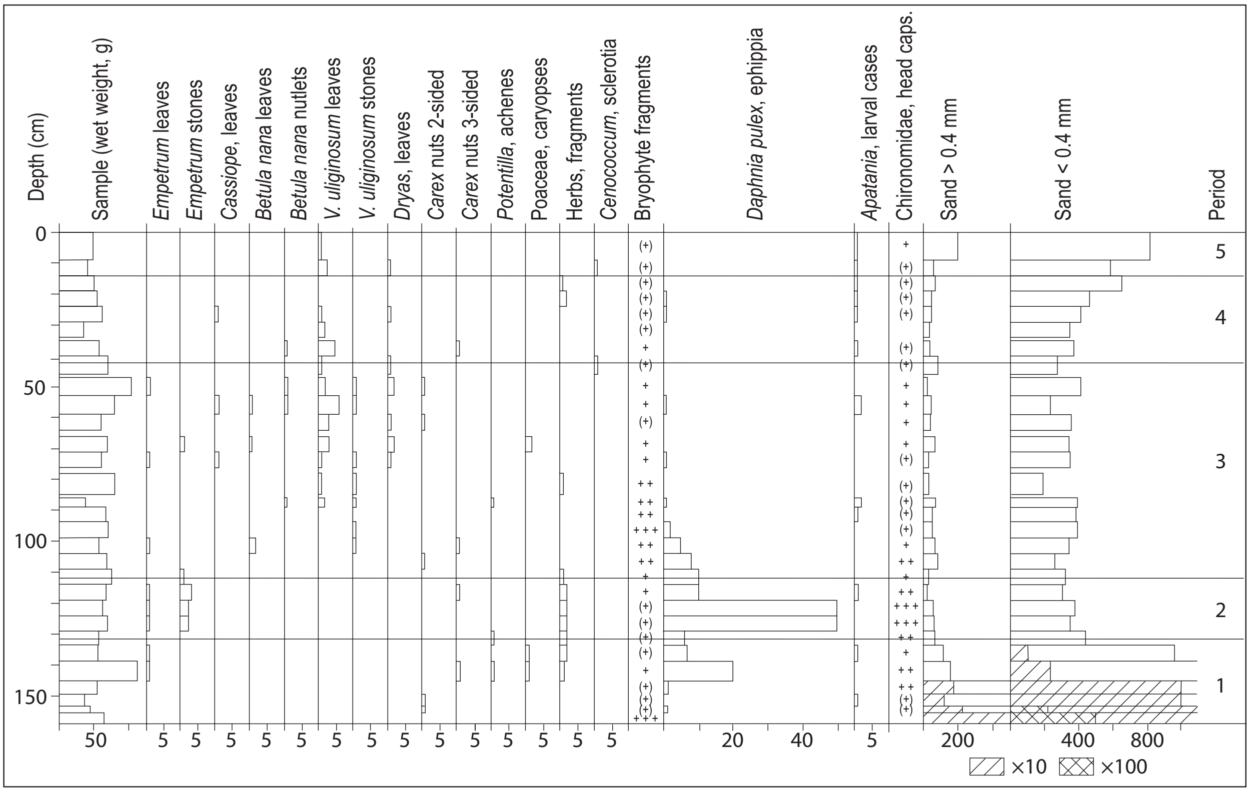


Fig. 5.4.

upper quaternary marine limit. In lake Boresø 150 cm undisturbed sediment covers the period from c. 9000 cal. years BP until today. As a result of sediment slumping only the period c. 9000-c. 5500 BP is covered by four undisturbed lumps of gyttja in the almost four meter thick sediment in lake Langemandssø. The pollen- and macrofossil diagrams (Figs. 5.3 and 5.4) from Boresø illustrate the change in vegetation on the surroundings and thereby reflects the climatic changes during Holocene. The analyses from Langemandssø confirm the results from Boresø. 18 radiocarbon datings from Boresø and four from Langemandssø have been made on either bulk samples, lacustrine mosses or terrestrial plant fragments.

Zone 1 (c. 9000-8300 cal. years BP)

The high content of sand and rebedded spores of Pteridophytes (ferns etc.), and the dominating pollen of *Saxifraga oppositifolia*, Gramineae and *Oxyria digyna* indicate an open pioneer vegetation following the deglaciation. The dwarf shrubs *Empetrum hermaphroditum* and *Cassiope tetragona* are rare.

Zone 2 (c. 8300-7250 cal. years BP)

Salix arctica, *S. herbacea*, *Thalictrum alpinum* and *Tofieldia* sp. has immigrated, and the vegetation covers most of the surroundings, yet still with fell field and pioneer vegetation types. The stone-like seeds of *Empetrum hermaphroditum* in all macrosamples indicate higher summer temperatures than during the late Holocene.

Zone 3 (c. 7250-5500 cal. years BP)

Betula nana is immigrating to reach a maximum of 22% and 29% of the pollen sum in the middle of the zone, corresponding to the present day 24% in recent gyttja from the interior part of Scoresby Sund c. 500 km to the south. Another important dwarfshrub is *Vaccinium uliginosum*, the seeds and/or leaves of which are found in nine of the 11 macro samples. Like zone 2, this zone was significantly warmer than today, but because of the late immigration to East Greenland of *Betula nana* it can not be determined exactly when the Holocene temperature maximum was reached and whether it happened during zone 2 or 3.

Zone 4 (c. 5500-4500 cal. years BP)

The lower boundary is placed at the decrease in *Betula* pollen, indicating a decrease in summer temperature supported by the lack of fruits of *Vaccinium ulignosum* and macro-remains of *Empetrum*. *Cassiope* is spreading, and pollen of *Sagina*, most

Fig. 5.5. Emergence trap placed in Sydkærene (left). Emerging arthropods are detained in the plastic cup by means of a simple lock (right).

likely *S. intermedia* indicate more *Salix arctica* snowbeds.

Zone 5 (c. 4500 cal. years BP to present day)

The zone border is defined by limnological changes in Boresø, where the production of algae increases. The decrease in pollen of *Betula* continues, whereas *Cassiope*, *Salix arctica*, *Saxifraga oppositifolia*, and *Oxyria* increase, indicating more snowbeds and snow protected heaths. A marked decrease by a factor 10 in the sedimentation rate in the upper part of the zone indicates a continued lowering of temperature until the present day and thereby a marked shortening of the ice free period of the lake.

5.5 The World Herbivory Project – Zackenberg sites

Angela Moles, Line Kyhn et al.

The idea that interactions between organisms are more intense in the tropics underpins much thinking about tropical ecology, global patterns in plant and animal traits, and latitudinal gradients in biodiversity. In the World Herbivory Project, we aim to provide the first direct and global test of this idea by quantifying the intensity of herbivory, pre-dispersal seed predation and post-dispersal seed removal at approximately 100 sites in all sorts of different ecosystems around the world (see www.bio.mq.edu.au/ecology/moles/herbivory/home.html for more detail).

In the last 15 months, we have established 70 of the 100 study sites; in ecosystems in Africa, North, Central and South America, Australia and Europe. The vegetation has included everything from tropical rainforests to savannas, deserts and arctic heath. The large herbivores have included gorillas, elephants, rhinoceroses, kangaroos, tapirs, llamas, and of course, Zackenberg's musk oxen.

The two sites we have established at Zackenberg (74°28.57'N, 20°37.75'W and 74°28.46'N; 20°32.19'W) are extremely important to the project, as they are much further from the equator than any other site. At these sites, we are studying herbivory on *Salix arctica*, *Casiope tetragona*, *Dryas octopetala*, *Pedicularis hirsuta*, *Rhododendron laponica* and *Vaccinium uliginosum.* In addition to measuring herbivory, we are quantifying leaf chemical and physical defences, and measuring their nutrient content. We will be happy to share any of the Zackenberg data, as soon as we have it.

Unfortunately, the project is still in its establishment phase, so we are unable to report any data at present. However, we can tell you that it looks like Moles' initial hypothesis (that there would be no latitudinal gradient in herbivory; based on the idea that the relative abundances of herbivores and carnivores ought to scale proportionally with net primary productivity) is wrong. It looks like everybody else might be right: herbivory probably is more intense in the tropics.

5.6 Arthroped emerging patterns in the High Arctic

Niels Martin Schmidt and Toke Thomas Høye

During the 10 years of monitoring at Zackenberg, the results of the pitfall and window traps have revealed large interannual variation in the capture numbers of arthropods. These differences in trappings may be due to variation in not only phenology but also in arthropod activity.

We examined the emergence phenology of arthropods by placing three emergence traps (Fig. 5.5) in Gadekæret and Sydkærene, respectively. Emergence traps catch arthropods as they emerge from the soil and move towards the light, thereby entering a simple lock chamber that detains the animals. Temperature data-loggers placed inside and just outside one trap yielded information on the potential heating effect of the traps.

A total of 1462 arthropods were caught

in the six traps. Arthropods were sorted to mainly family, and belonged to the Chironomidae, Ceratopogonidae, Sciaridae, Culicidae, Mycetophilidae, Hymenoptera, Linyphidae. A few Hemiptera of the species *Nysius groenlandicus* were also identified. In both fen areas, trappings were dominated by Chironomidae, but in Gadekæret Culicidae and Sciaridae constituted substantial fractions of the total catch too (Table 5.1). Though the overall pattern of arthropod emergence was similar, the total number of arthropods trapped differed markedly between fen areas (Fig. 5.6). One striking feature of the emergence traps was the complete lack of true flies, e.g. Muscidae and Anthomyiidae, which are abundantly caught in pitfall and window traps in close proximity of the emergence traps.

The phenology patterns of the various species and groups of species will be examined in relation to the climatic data available from ClimateBasic.

Table 5.1. Arthropod composition of arhtropods trapped in emergence traps in Gadekæret and Sydkærene (in percent).

	Gadekæret	Sydkærene	Total
Ceratopogonidae	0	14	9
Chironomidae	60	69	66
Culicidae	9	0	3
Hymenoptera	3	4	4
Linyphidae	1	1	1
Mycetophilidae	0	3	2
Nysius groenlandicus	7	1	3
Sciaridae	15	1	6
Undeterminable	5	6	6
Total	100	100	100

5.7 Genetics analysis of dunlin in northern Europe

Liv Wennerberg and Gunnhild Marthinsen

Arctic waders are migratory birds, adapted to breeding conditions in the cold arctic climate and amazing long-distance migrations to wintering areas further south. The dunlin, *Calidris alpina*, is one of the world's most common wader species. It breeds circumpolarly in arctic and temperate regions, and winters in costal and inland habitats. Local adaptations in morphology and phenology occur, and several subspecies have evolved in different parts of the world. Nine subspecies of dunlin are currently recognised by Clements (2000). However, the subspecies structure is debated, and especially after the introduction of molecular genetic techniques, it has become clear that the taxonomy needs revision. For this purpose, we use a range of molecular genetic tool (DNA-sequencing, microsatellite analysis and AFLP) to investigate the phylogeographic structure and validity of the currently recognised subspecies of dunlin in northern Europe. The birds in Northeast Greenland are considered a separate and endemic subspecies, *C. alpina arctica* (Schiøler 1922), in most literature. We investigate their relationship to other populations/subspecies

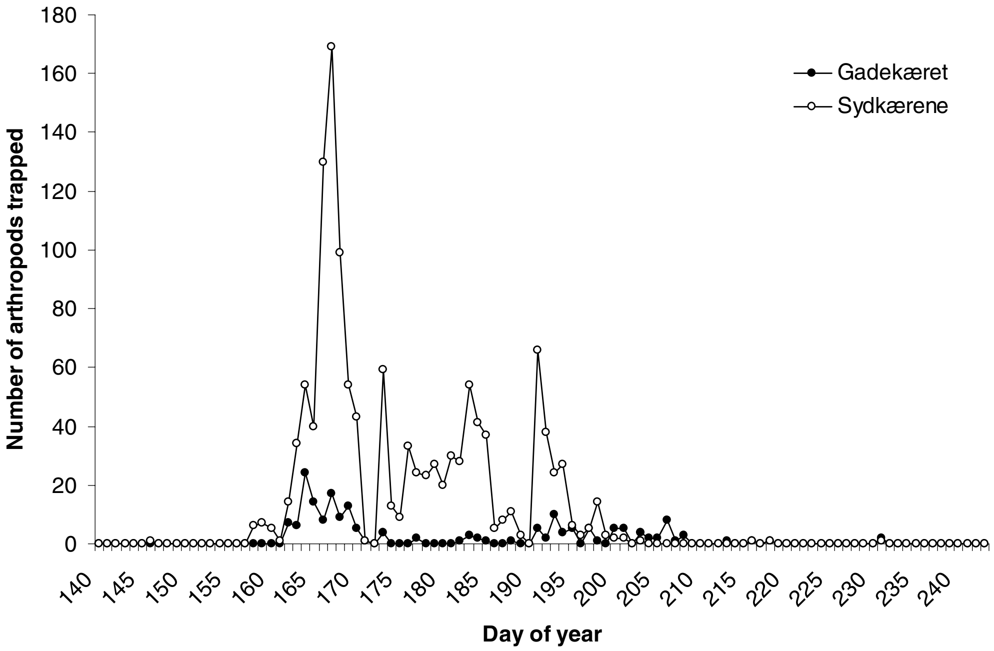


Fig. 5.6. Total catches from the emergence traps in Gadekæret (open dots) and Sydkærene (closed dots) during the entire 2005 field season.

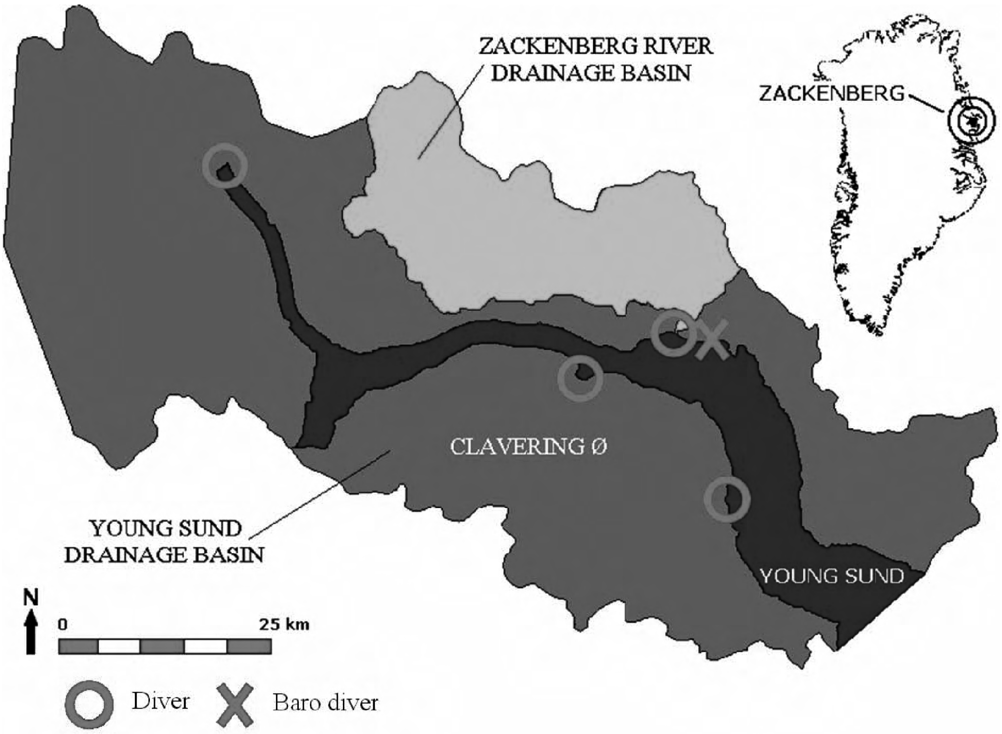


Fig. 5.7 Catchment area of the Young Sund/Tyrolerfjord system (brown + light green area) showing the drainage basin of Zackenberg (light green area). Sampling stations and deployment of divers are shown by red circles and a baro-diver collecting tidal data is shown with a red cross. All oceanographic stations have been published previously (Rysgaard et al. 2003; previous ZERO reports).

of dunlin in the northern Atlantic region, including Iceland, Spitsbergen, the Baltic Sea region, northern Scandinavia and Russia. Preliminary data analyses reveal genetic similarity to *C. alpina schinzii* on Iceland, an area which is passed by Greenlandic dunlin on their migration route towards winter areas in western Africa.

5.8 Coupling freshwater run-off from catchment area of the Young Sund/Tyrolerfjord with fjord circulation and exchange with the Greenland Sea (OPHAV)

S. Rysgaard, J. Bendtsen and S.H. Mernild

The overall goal of this OPHAV project is to increase our understanding of the coupling between freshwater run-off from land, the circulation in the fjord system and the exchange with the Greenland Sea. The project will integrate knowledge from ClimateBasic, GeoBasic and MarineBasic and form the basis for a 3D-hydrodynamic model describing this land-fjord coupling. The model will at a later stage be further developed to include a variety of biogeochemical processes that have been collected through the MarinBasic Programme and earlier marine research projects (CAMP) within the area.

Based on existing data in the Monitoring Programmes and previous research projects a topographic model will be established that will couple the catchment area of the fjord with the bathymetry. An attempt will be made, based on climate data from Zackenberg and Daneborg, to model the run-off from land and predict the freshwater input to the fjord. The model will be validated on direct measurements of the freshwater transport in the river Zackenbergelven, Lerbugten, the inner part of the fjord Tyrolerfjord, and in one of the rivers (Djævlekløften) in the outer part of the fjord (Se Fig. 5.7). These 4 rivers contributes with up to 90% of the freshwater run-off.

This summer the water level (h) in these rivers were monitored each 15 min with the use of automatic diver-systems. The period of measurement was at least 10 days. In addition, a baro-diver-system was placed in the outer part of Zackenbergelven to correct for the air pressure level variation in each of the automatic divers. At river Zackenbergelven, National Environmental Research Institute and Geographic Institute at University of Copenhagen were responsible for collection of data (See chapter 2). At each of the other three localities the amount of discharge (Q) was measured at least 3 times during the summer of 2005 to ensure that the absolute amount of freshwater from the ter-

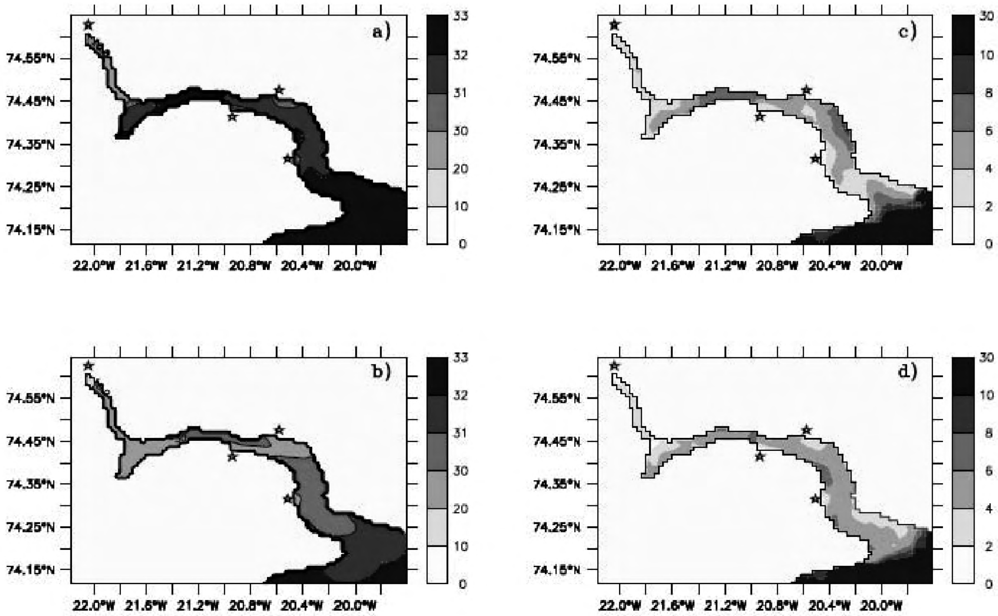


Fig. 5.8 Model solutions of monthly average surface salinity in June (a) and in August (b). The mixed layer depth [m], defined by the depth level with the steepest density gradient is shown in June (c) and August (d). Stars mark the location of the major 4 rivers.

restrial environment to the marine environment could be quantified from Q/h relations for each specific river. The Q/h estimated freshwater flux was then used in the spatial hydrodynamic model to verify the freshwater input to the fjord from all 4 rivers. Next step will be to include nutrients and suspended material and couple that to the freshwater flux. Therefore water samples were collected at Djævlekløften, Lerbugten and the inner parts of Tyrolerfjord in addition to the river Zackenbergelven. These will be analyzed for total phosphor (TP) and total nitrogen (TN)

A 3D-hydrodynamic model was set up for the fjord and an area of about 40 km outside the sill. The model has an open boundary to the East Greenland Current, and 4 rivers, corresponding to the monitored rivers mentioned above, enters the model domain. The river discharge is updated in the model with a time step of 15 minutes. In the outer part of the fjord measurements made by the MarinBasic Programme of water level, temperature- and salinity profiles describe the conditions at the open boundary. The meteorological forcing that drives the model is based on modelled fields from an operational weather forecast model supplied with measurements from Zackenberg and Daneborg. A comprehensive sensitivity study was made where the influence from an increase in river runoff was quantified. This study was used in a context of quantifying the effects from a possible future global warming.

Examples of model solutions are shown in Figs 5.8 and 5.9.

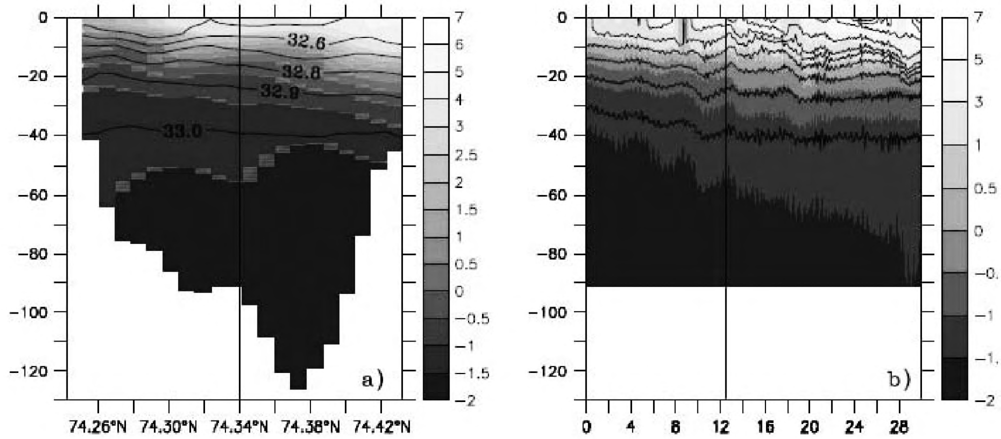


Fig. 5.9 Model solutions of temperature [°C] and salinity (contour) along a transect at 20.35°W at the 12. June, covering the central part of Young Sund. (b) Time series of the vertical distribution of temperature and salinity (contour) at 74.34°N and 20.35°W. The vertical line in (a) corresponds to the location used in (b), and the vertical line in (b) corresponds to the time for the section shown in (a).

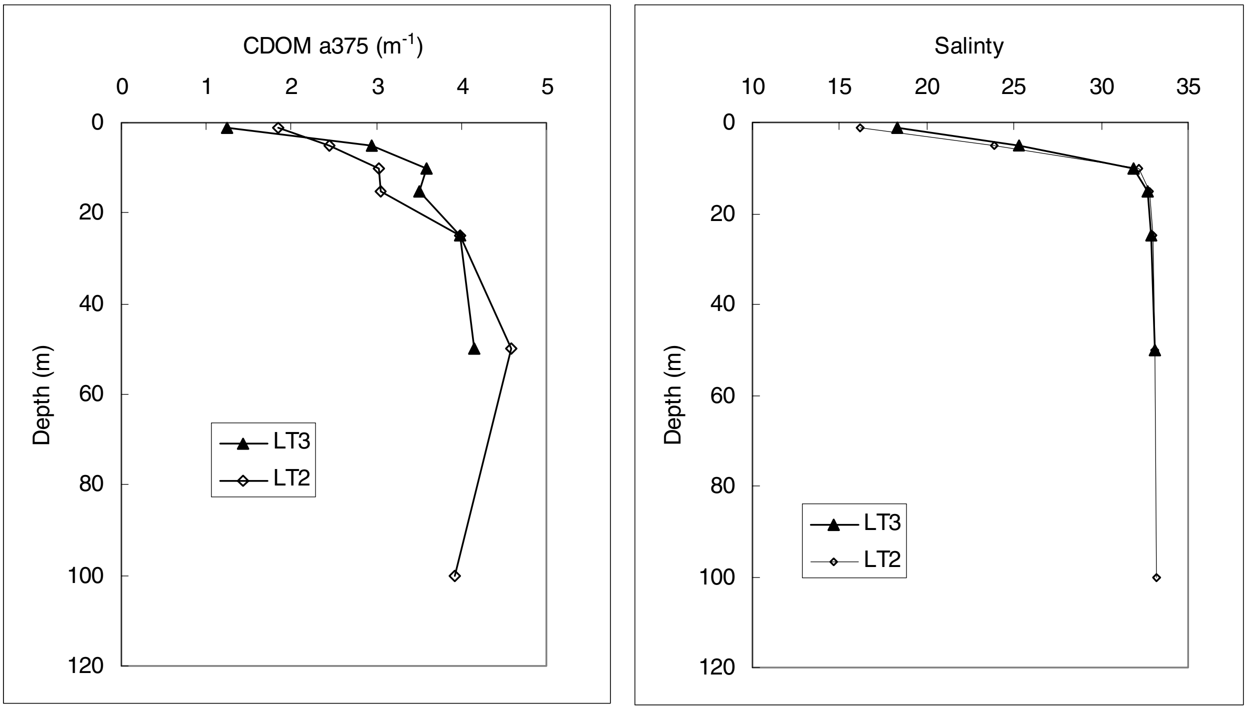


Fig. 5.10 Vertical profiles of the upper 100 m of the water column at two stations in Tyrolerfjord (LT2 and LT3) showing a quantitative measure of DOC (absorption coefficient at 375 nm) and salinity.

5.9 The origin, concentration and bioavailability of dissolved organic carbon in Young Sound.

Mikael Sejr and Colin Stedmon

The organic carbon processed by a marine ecosystem can be divided into two fractions: particulate and dissolved. The particulate fraction has been the focus of numerous studies in Young Sound whereas dissolved organic carbon (DOC) has received very little attention. DOC can constitute an important fraction of the available carbon. Furthermore, organic carbon of terrestrial origin contributes significantly to the carbon flow in Young Sound. Approximately half of the carbon input to the fjord from the Zackenberg River is in the dissolved form (Rysgaard & Sejr 2006). Carbon input from land is expected to be very sensitive to climate change due to increased run-off. It is therefore relevant to describe the role of DOC in the carbon flow in Young Sound.

To do this a study was conducted in August 2005 by members of the MarineBasis program. The aim was to describe the variation in concentrations and characteristics of DOC in the fjord along a gradient of fresh water influence. This was done by sampling in the upper 100 m of the water column along a transect from Tyrolerfjord into the Greenland Sea. Water samples from 4 different rivers including the Zackenberg River were also collected.

To characterize and quantify the DOC the optical properties was studied. The absorption coefficient at 375 nm can be used as a quantitative measure of DOC and vertical profiles from two stations in Tyroler fjord is presented in Fig. 5.10 together with data on salinity. To study qualitative differences in DOC the fluorescence was measured by using excitation emission matrices (EEM). These provide a 2-D contour of the fluorescence characteristics of DOC. The EEMs measured were subsequently analysed using parallel factor analysis (PARAFAC) which separates the combined measured fluorescence signal into that from different underlying subfractions present (Stedmon *et al*. 2003). Fig. 5.11 shows an example of the EEMs from two samples. The fluorescence contour plots show that there is both a quantitative and qualitative difference in the DOC at these two depths. Further analysis of the variability in the fluorescence signal, with respect to depth, location and water mixing will allow us to assess the dynamics of DOC from different sources (*i.e.* land or sea) and follow their mixing in the Sound. The PARAFAC analysis is currently underway.

Additionally, a long-term mineralisation study was performed to investigate the

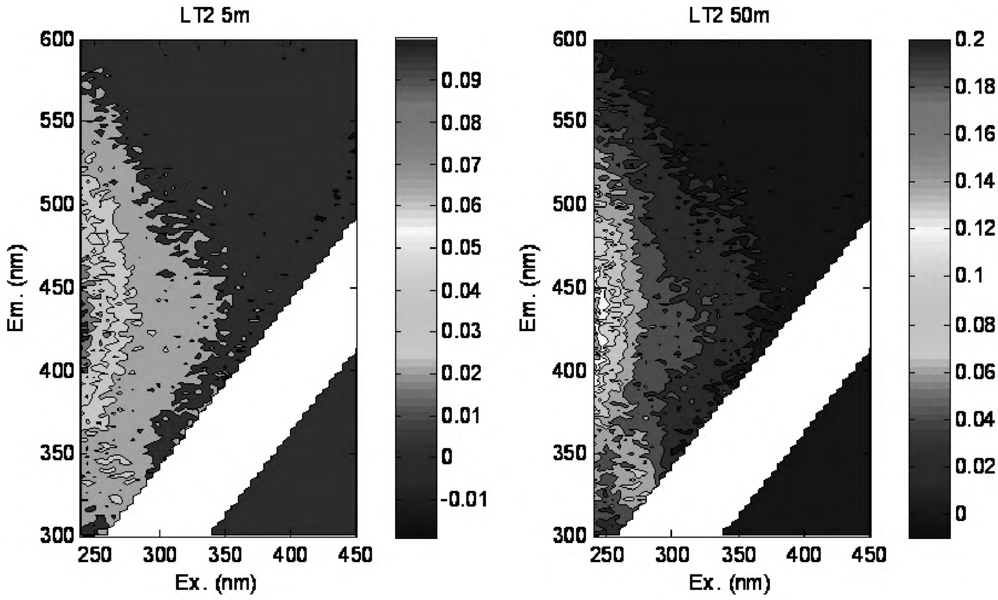


Fig. 5.11 Shows an example of the EEMs from two samples. The fluorescence contour plots show that there is both a quantitative and qualitative difference in the DOC at these two depths.

bioavailability of DOC in the surface water. Incubation of filtered water samples showed that oxygen is consumed (Fig. 5.12) indicating that part of the DOC is readily available for bacterial mineralisation within a time scale of days. A significant fraction of the DOC added to the fjord from the surrounding catchment area is thus mineralized in the area and constitute an important input of carbon at the bacterial level. As of spring 2006, samples are still being processed and final results will be published elsewhere.

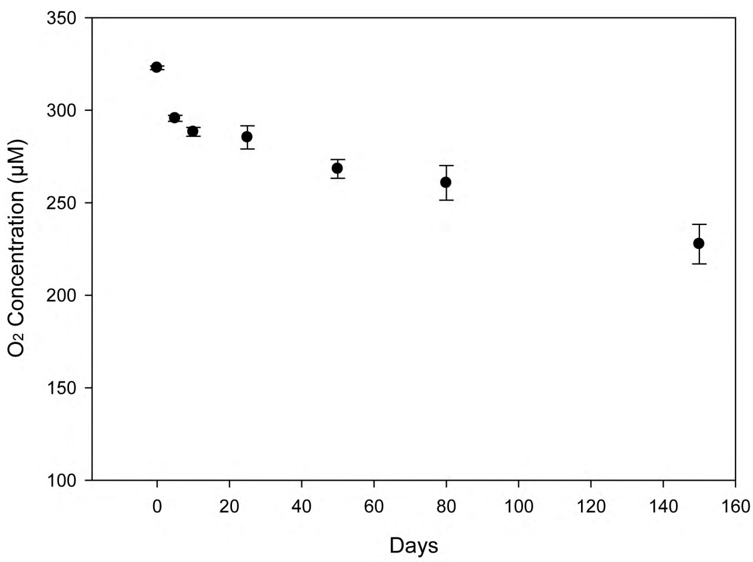
5.10 ITACA² Dayside aurora joint observations in the Greenland-Svalbard sector

Stefano Massetti

The 2005 summer season, was our fourth stay in Daneborg. Between 18-20 July, the ITACA-DNB auroral observatory was checked and set up for the incoming winter campaign (2005/2006), as usual. Several technical problems were found on the equipment. The Inmarsat-B satellite phone, which ensures the remote control of the instrument, wasn't able to properly connect to the satellite(s) and the station was left without connection. For the second consecutive year, the observatory run without any possibility to be remotely controlled. Other troubles were due to the failure of the electronic unit that keeps the narrow band filters at constant temperature. The thermostat probably broke, causing the burning of both resistors and the crack of one filter (red, 630.0nm). Since the temperature inside the observatory is roughly controlled by a heater, the instrument should still be able to operate in nearly "normal" conditions, even without the broken unit, which was removed. In addition, several tests showed that the images recorded with the cracked filter are good enough to monitor the auroral activity during the 2005/2006 winter season. The filter will be replaced in the next summer.

The quicklooks (named *keograms*, from *keoitt*, an old Eskimoan word meaning "aurora") of the data collected by the ITACA-DNB station are now available online at the ITACA2 website (http://sung3.ifsi.rm.cnr.it/~massetti/in-

Fig. 5.12 Oxygen consumption as an indication of DOC mineralisation in incubated water samples from Young Sound.



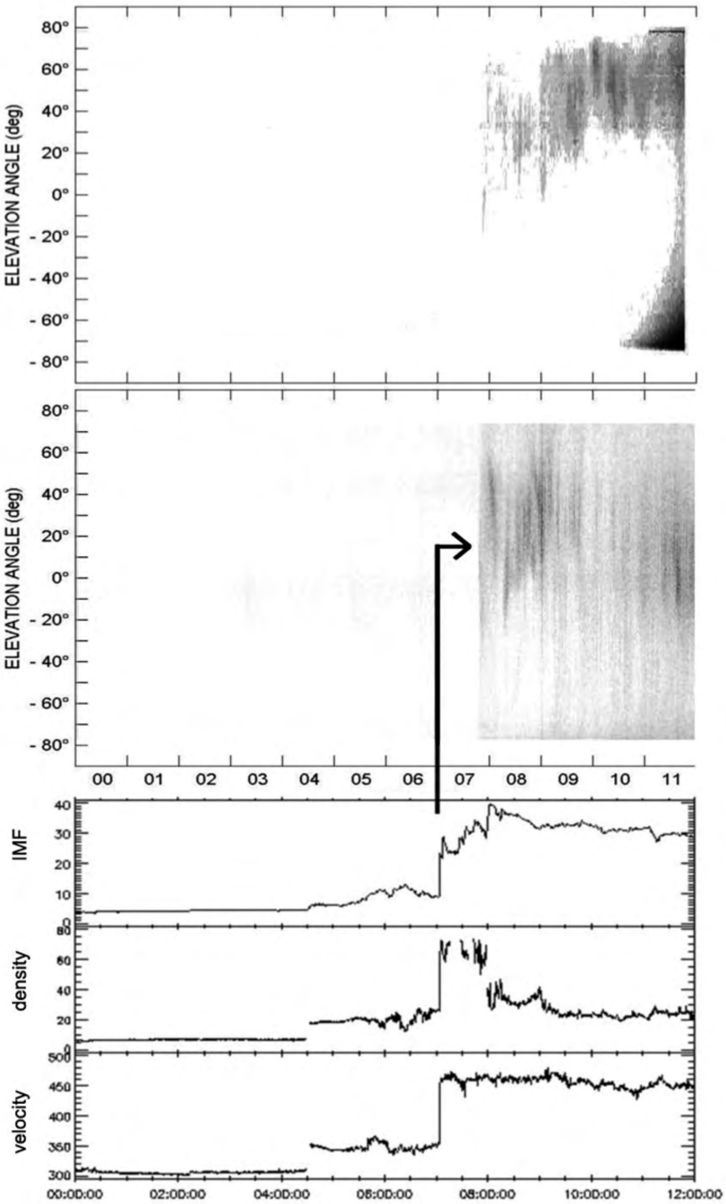


Fig. 5.13 Dayside auroral response to the impinging interplanetary perturbation produced by a coronal mass ejection (CME). Top and middle panels: auroral red emission at 630.0 nm, observed from ITACA-DNB (Greenland), and ITACA-NAL (Svalbard), respectively. Lower panel: IMF B field (nT, top), Solar Wind density (cm^{-3}, middle), and velocity (km/s, bottom) recorded by the WIND satellite. About 60 minutes are needed for the perturbation to reach the Earth.

dex.html), together with the ITACA-NAL keograms. Upon request, the all-sky images from both locations can be merged to generate a wide field-of-view projection covering a big portion of the high-latitude Greenland and Svalbard zone.

Our research of solar wind – magnetosphere – ionosphere coupling, during IMF B_Y-dominated periods is still in progress, while a paper with some interesting results has been submitted to Annales Geophysicae (*ANGEO*). Another field of research, in the context of the so-called *Space Weather*, consists in the study of the relationship between the Coronal Mass Ejections (CMEs, ejection of both plasma and magnetic field from the Sun's corona) and the dayside auroral activity. This is currently also the subject of a degree thesis in collaboration with the University of Catania (Italy). As an example, Fig. 5.13, shows the activation of the dayside red-aurora emission (top panels) during the transit of a CME, as recorded by the WIND satellite (bottom panel), which was located about 60 min. upstream the Earth's magnetosphere. The study of the magnetosphere – ionosphere system response during strong interplanetary shocks is important to understand the *geo-effectiveness* of such perturbations, and to help in developing models able to perform reliable *space forecastings*.

Data from the ITACA-DNB station (February 2003) were also used for an interesting multi-instrument study devoted on auroral sun-aligned (transpolar) arcs (*theta* aurora). Preliminary results are presented at the EGU 2006 (Vienna – Austria).

Since 1st January 2006, our institute moved to the National Institute of Astrophysics (INAF). The new contact is: stefano.massetti@ifsi-roma.inaf.it, IFSI-INAF, via Fosso del Cavaliere 100, I-00100 Roma – Italy.

5.11 Mites at Zackenberg

Olga Makarova

In 2005, selected samples of mites Acarina collected by BioBasis and Jens Böcher at Zackenberg were identified to species. The species identified are given in the list below, where an * marks species new to Greenland.

Mesostigmata

Parasitellus arcticus (Karg, 1984)
Parasitellus papei (Karg, 1984)
**Vulgarogamasus* sp. aff. *oudemansi* (Berlese, 1903)
**Arctoseius multidentatus* Evans, 1955
Arctoseius "haarlovi Lindquist, 1963" ms. = *A. laterincisus* Thor, 1930 sensu Haarløv, 1942
**Proctolaelaps parvanalis* (Thor, 1930)
Amblyseius apcutic Chant et Hansell, 1971
Amblyseius cf. *tobon* Chant et Hansell, 1971
Laelaps semitectus (L. Koch, 1878)
Pneumolaelaps groenlandicus (Trägårdh, 1904)
Pneumolaelaps cf. *patae* Husband et Hunter, 1973
Haemogamasus ambulans (Thorell, 1872)
**Thinoseius spinosus* (Willmann, 1939)
Zercon hammerae Sellnick, 1960

Prostigmata
*Nanorchestes sp.
Eupodes sp. 1
Eupodes sp. 2
Eupodes sp. 3
*Cocceupodes sp.
*Penthalodes ovalis (Dugès, 1884)
Neomolgus littoralis (Linnaeus, 1758)
*Neomolgus cf. *clypeatus* Thor, 1930
Rhagidia sp. 1
Rhagidia sp. 2
*Stigmaeus sp.
*Paralorryia sp.
Microtrombidium sucidum (L. Koch, 1879)
Abrolophus cf. *unidentatus* (Trägårdh, 1904)
Hydrachnidia fam. gen. sp. 1
Hydrachnidia fam. gen. sp. 2

Cryptostigmata
Camisia horrida (Hermann, 1804)
Trhypochthonius tectorum (Berlese, 1896)
Hermannia reticulata Thorell, 1871
Ceratoppia sphaerica (C.L. Koch, 1879)
Tectocepheus velatus (Michael, 1880)
Liebstadia similis (Michael, 1888)
Oribatula tibialis (Nicolet, 1855)
Peloribates pilosus Hammer, 1952
Ceratozetes thienemanni Willmann, 1943
Diapterobates notatus (Thorell, 1871)
Edwardzetes edwardsii (Nicolet, 1855)
Iugoribates gracilis Sellnick, 1944

Astigmata
Kuzinia laevis (Dujardin, 1849)
*Schwiebea sp.

6 Disturbance in the study area

Jannik Hansen

Surface activities in the study area

In 2005, the number of 'person-days' (one person in the field one day) spent in the main research zone 1 (Table 6.1) was near the norm. The 'low impact area' 1b was visited slightly more than usual. The 'goose protection area', zone 1c, was visited only rarely, as in most previous years. Like in 2004, zone 2 was visited marginally more than usual.

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. Only one trip went past the climate station, but stayed on the designated road.

Aircraft activities in the study area

This season, fixed-wing aircrafts landed and took-off 48 times, which is fairly close to average (Table 6.2).

Four flights by helicopters took place in 2005, all involved in flying supplies from Daneborg to the research station, following the arrival of the yearly supply ship.

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.

A water closet was in use from 24 May, and from 10 June a second water closet was established. 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. During 19-21 May and 27-30 August, the mill was out of function, and waste was poured untreated into Zackenbergelven.

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 19 May – 30 August 2005. Trips on roads to the climate station and the delta of Zackenbergelven are not included.

	May	June	July	Aug	Total
1	44	129	181	182	536
1b	2	3	29	17	51
1c (20.6-10.8)		0	2	2	4
2	0	2	12	4	18
ATV-trips				1	1

Waste stored during 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 990 'person-days'.

Manipulative research projects

The UV stress research project (see section 5.2) 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 on *Salix arctica* at site 4 (UTM zone 27: 8264400 mN, 512750 mE), and a new site, site 5 (UTM zone 27: 8264350 mN, 512650 mE), was setup for the season 2006, in order to look at long term effects on the photosynthesis on *Vaccinium uliginosum*.

For the second season, snow melt and temperature was manipulated at two sites, each with 30 plots. UTM 8264733 mN, 513460 mE and 8264984 mN, 513717 mE (see section 5.1).

Take of organisms and other samples

A total of 47,661 land arthropods were collected during the season, as part of the BioBasis programme (section 3.4).

For an arthropod hatching study, just under 1500 arthropods were collected in Malaise traps (section 5.6). These were placed at six sites: (all in UTM zone 27) trap 1: 8264553 mN, 512982 mE, trap 2: 8264528 mN, 512955 mE, trap 3: 8264518 mN, 512948 mE, trap 4: 8264103 mN, 512827 mE, trap 5: 8264091 mN, 512820 mE, trap 6: 8264078 mN, 512812 mE.

Leaves from *Dryas*, *Salix*, *Vaccinium*, *Cassiope*, *Rhodondendrun* and *Pedicularis hirsuta* were sampled for a project on herbivory across climatic zones, from two sites: East (UTM zone 27, 8265015 mN, 513847 mE), and west (UTM zone 27, 8265995 mN, 510949 mE) (see section 5.5).

The UV stress research project sampled leaves of *Salix arctica*, *Vaccinium uliginosum* and *Betula nana*, from sites 1, 2, 3 and 4 (see Manipulative research projects and section 5.2).

Four complete female individuals and three males of *Salix arctica* were collected in addition to 10 twigs for dendrochronological examination (section 5.3).

Blood samples each of approximately 10 ?l were collected from six chicks from five broods of *Calidris alpina arctica* for a DNA-study (section 5.7).

In addition, two dead ruddy turnstone *Arenaria interpres* chicks found trampled by musk oxen were collected, and tissue samples were taken from them. Likewise, a non-anadromous, dwarf arctic char *Salvelinus alpinus* found dead in an Ella trap (section 3.7), was collected and stored in alcohol for ageing and stomach content investigation. At the old trapping station, the Sirius Dogsled Patrol caught a couple of hundred arctic char, which has been the norm over the years.

	May	June	July	Aug	Total
Fixed-wing aircraft	4	6	10	28	48
Helicopter				4	4

Table 6.2. Numbers of flights with fixed-winged aircrafts and helicopters, respectively, over the study area in Zackenbergdalen 19 May – 30 August 2005. Each ground visit of an aircraft is considered two flights.

7 Logistics

Henrik Philipsen

In 2005, Research Station Zackenberg was open for 106 days from 19 May to 30 August. In this period 31 scientist and five logisticians and staff from Danish Polar Center worked from the station. The station was visited by Rear Admiral Niels Wang, Royal Danish Navy and 4 other guests in August.

Zackenberg's branch facility at the old weather station in Daneborg was used by one scientists and one logistician from 18 to 25 July, and by six scientists from 2 to 23 August. The total number of person days at Zackenberg and Daneborg was 1091.

Transportation

On 19 May two logisticians from Danish Polar Center and three scientists arrived at Zackenberg and began to prepare the opening of the station. On 31 May six scientists and a cook arrived.

In 2005 the number of fixed wing landings and take offs with aircraft was 28 of which sixteen were landings with personnel, one with visitors, two for refuelling, one for searching and eight with cargo.

The number of helicopter landings and take offs was two of which one was used for transportation of a new generator between Daneborg and Zackenberg.

Local transport was carried out by ATV on the marked roads. 17 trips went to the climate station and 29 trips carried supplies for Daneborg to the coast or went to the zodiac landing site to make improvements. The ATV is often used and demands regular maintenance. New belts were mounted in 2005

Houses

The Weatherhaven shelters for accommodation of guests demand some maintenance, but will still be usable for some years. The condition of the houses is good, and they are continuously being maintained.

Electrical power supply

The station received one new 38 KW generator to supply the station which had minor problems in getting started. There are now two 38 KW generators and one 15 kW generator for back up. Besides these, the station has five smaller generators for power supply in the field. The two 38 KW generators are placed in a generator hut and the maintenance is now easier and less dependent on weather conditions.

Water supply

The Zackenberg waterplant worked well and produced 130 cubic meters for cleaning, cooking, dishwashing, toilets, showering, laundry and work in the wet lab.

Due to high water level from late July until late August the water in Zackenberg River was very muddy and the consumption of water filters raised markedly. A tarpeulin inside one of the small water tanks had a leak and was sent to Denmark for repair.

Two water closets with an electrical shredder are working properly.

Telecommunication

Communication is still done by Iridium and Inmarsat satellite telephones, fax and e-mail. 1,152 e-mail were send and received through our server at Institute of Geography, University of Copenhagen. Telephone communication totaled 1,469 minutes.

HF-radios are used for communication with other stations in Northeast Greenland. VHF-radios are used for local communication and were lent out 938 times. The VHF-repeater station mounted on top of the mountain Dombjerg in 2004 covers the area between Revet and the outer coast of Sandøen, but not Store Sødal where it is most needed.

Boats

The Zackenberg fleet has four boats, mostly used for transportation to and from

Daneborg of passengers, supplies and equipment.

A trailer to the big RIB was purchased in 2005 and is now launched and hauled up at the landing site south of the station.

Medicals

Head aches, a sprain ankle, one nettle rash, blisters and a shoulder out of position were treated.

Daneborg

Zackenberg supplied the branch facilities in Daneborg with a generator, water pipes, fuel, technical equipment, one Iridium telephone, weapons, gas, food and one logistician to serve the scientist there.

Expeditions

Research Station Zackenberg fully equiped an expedition with two Zodiacs, fuel, tents, sleeping bags, stoves and provision, rifles, flare guns , HF and VHF radios, GPS, first aid kits.

River crossing

In late July the east bank foundation of the rope across the river, right beneath the station, was flushed away by melting water. A new foundation was established and the process of tightening the steel wire and nylon rope was improved to make it possible for one person to tighten it.

Waste

The shredder for kitchen waste had a new two stroke engine installed. Glass, metal and plastic waste is sorted as usual in empty fuel barrels and will be transported out of the area later.

8 Personnel and visitors

Compiled by Henrik Philipsen and Morten Rasch

Research

Zackenberg

Kristian Albert, Ph.D. Institute of Biology, University of Copenhagen (Climate and UV-B manipulations, 15 June – 28 June, 19 July – 2 August)

Marie Arndal, Student, Institute of Biology, University of Copenhagen (Climate and UV-B manipulations, 15 June – 16 August)

Christian Bay, Ph.D., National Environmental Research Institute, Denmark (BioBasis, 13 July – 2 August)

Torben Røjle Christensen, Ph.D., Professor, GeoBiosphere Science Centre, University of Lund, Sweden (Methane Emission Monitoring, 2 August – 16 August)

Eric Steen Hansen, M.Sc., Botanical Museum, University of Copenhagen, and National Environmental Research Institute, Denmark (BioBasis, 19 July – 2 August)

Jannik Hansen, M.Sc., National Environmental Research Institute, Denmark (BioBasis, 31 May – 2 August)

Toke Th. Høye, Ph.D. student, National Environmental Research Institute, Denmark (BioBasis, 28 June – 26 July)

Line Anker Kyhn, M.Sc. student, National Environmental Research Institute, Denmark (BioBasis, 15 June – 30 August)

Mihail Mastepanov, M.sc., GeoBiosphere Science Centre, University of Lund, Sweden (Methane Emission Monitoring, 2 August – 16 August)

Hans Meltofte, D.Sc., National Environmental Research Institute, Denmark (BioBasis, 31 May – 15 June)

Sebastian Haugaard Mernild, Ph.D. Student, Institute of Geography, University of Copenhagen (GeoBasis, 19 July – 16 August)

Marie-Luise Øllgaard Meyhoff, M.Sc. student, National Environmental Research Institute, Denmark (BioBasis, 13 July – 2 August)

Angela Moles, M.sc., Department of Biology, Macquarie University, Australia (The World Herbivory Project, 13 July – 20 July)

Maria Rask Pedersen (GeoBasis, 2 August – 30 August)

Jonathan N. K. Petersen, Technician, ASIAQ (ClimateBasic, 2 August – 16 August)

Peer Sarkov, Technician, ASIAQ (ClimateBasic, 2 August – 16 August)

Niels Martin Schmidt, Ph.D. student, National Environmental Research Institute, Denmark (BioBasis, 19 May – 15 June)

Charlotte Sigsgaard, M.sc., Institute of Geography, University of Copenhagen (GeoBasis, 19 May – 2 August)

Lena Ström, M.sc. GeoBiosphere Science Centre, University of Lund, Sweden (Methane Emission Monitoring, 2 August – 16 August)

Mikkel P. Tamstorf, Ph.D., (GeoBasis, 19 May – 31 May)

Daneborg

Peter Bondo, Ph.D., National Environmental Research Institute, Denmark (MarineBasis, 2 August – 16 August)

Tage Dalsgaard, Ph.D., National Environmental Research Institute, Denmark (MarineBasis, 2 August – 16 August)

Göran Ehlme, Diver, Waterproof, Sweden (MarineBasis, 2 August – 16 August)

Magnus Elander, National Environmental Research Institute, Denmark (Marine Basis, 2 August – 16 August)

Egon R. Frandsen, National Environmental Research Institute, Denmark (MarineBasis, 2 August – 16 August)

Robert Gilbert, Professor, Queens University, Canada (GeoArk, 29 August)

Bjarne Grønnow, Archaeologist, The Danish National Museum (GeoArk, 29 August)

Bjarne Holm Jakobsen, Institute-principal, Institute of Geography (GeoArk, 29 August)

Stefano Massetti, Istituto di Fisica dello Spazio Interplanetario, Rome, Italy (All Sky Camera for Auroral Activity, 19 July – 26 July)

Henrik Sulsbrück Möller, Ph.D. student, Institute of Geography (GeoArk, 29 August)

Mikael Sejr, National Environmental Research Institute, Denmark (MarineBasis, 2 August – 16 August)

Sabine Island

Robert Gilbert, Professor, Queens University, Canada (GeoArk, 17 August – 28 August)
Bjarne Grønnow, Archaeologist, The Danish National Museum (GeoArk, 17 August – 28 August)
Bjarne Holm Jakobsen, Institute-principal, Institute of Geography (GeoArk, 17 August – 28 August)
Henrik Sulsbrück Möller, Ph.D. student, Institute of Geography (GeoArk, 17 August – 28 August)

Logistics

Zackenberg

Malene Friis, Cook, 31 May – 30 August
Marc Overgaard Hansen, Logistician, 28 June – 20 July, 28 July – 16 August
Ulrik Nielsen, Logistician, 31 May – 29 July, 3 August – 30 August
Henrik Philipsen, Logistics Manager, 19 May – 30 August
Morten Rasch, Ph.D., Station Manager, 19 May – 31 May

Daneborg

Marc Overgaard Hansen, Logistician, 21 July – 27 July
Ulrik Nielsen, Logistician, 30 July – 2 August

Others

Zackenberg

Lasse Degn, The Dog Sledge Patrol Sirius, 20 August
Aage Buur Jensen, Captain, Royal Danish Navy, 20 August
Erik Lund, Journalist, 20 August
Henning Mortensen, Journalist, 20 August
Niels Wang, Rear-admiral, Royal Danish Navy, 20 August

Daneborg

Christian Holm Andersen, NANOK (19 July – 30 August)
Hans Henrik Carlsen, NANOK (19 July – 30 August)
Rasmus Gregersen, NANOK (19 July – 30 August)
Anders Ibsen, NANOK (19 July – 30 August)
Erik Jochumsen, NANOK (19 July – 30 August)
Kunuk Olsen, NANOK (19 July – 30 August)

Further contributers to the annual report

Kirsten Christoffersen, Ph.D., Freshwater Biological Laboratory, University of Copenhagen (BioBasis)
Steen K. Frank, M.Sc. student, National Environmental Research Institute, Denmark (BioBasis)
Thomas Friborg, Institute of Geography, University of Copenhagen
Louise Grøndahl, National Environmental Research Institute
Erik Jeppesen, D.Sc., National Environmental Research Institute, Denmark (BioBasis)
Gunnhild Marthinsen, Natural History Museum, University of Oslo, Norway
Dorthe Petersen, ASIAQ, Greenland Survey
Kisser Thorsøe, ASIAQ, Greenland Survey
Liv Wennerberg, Natural History Museum, University of Oslo, Norway

9 Publications

Compiled by Vibeke Sloth Jakobsen

Scientific papers

Albert, K.R., Mikkelsen, T.N. & Ro-Poulsen, H. 2005: Effects of ambient versus reduced UV-B radiation on high arctic *Salix arctica* assessed by measurements and calculations of chlorophyll *a* fluorescence parameters from fluorescence transients. – Physiologia plantarum 124 : 208-226

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Forchhammer, M.C., Post, E., Berg, T.B.G., Høye, T.T. & Schmidt, N.M. 2005: Local-scale and short-term herbivore-plant spatial dynamics reflect influences of large-scale climate. – Ecology 86 : 2644-2651

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Reneerkens, J., Piersma, T., Jukema, J., De Goeij, P., Bol, A., & Meltofte, H. 2005: Sex-ratio and body size of sandpiper chicks at Zackenberg, northeast Greenland in 2003. – Wader Study Group bulletin 106 : 12-16

Rennermalm, A.K., Soegaard, H. & Nordstroem, C. 2005: Interannual variability in carbon dioxide exchange from a High Arctic fen estimated by measurements and modeling. – Arctic, Antarctic and alpine research 37(4) : 545-556

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Forskning uten spor : integrering av miljøhensyn i forsknings- og utdanningssektoren – Grønland, Island og Svalbard. – Kbh. : Nordisk Ministerråd, 2005. – 163 pp. – (TemaNord 2005:547)

Heal, O.W., Bayfield, N., Callaghan, T.V., Høye, T.T., Järvinen, A., Johansson, M., Kohler, J., Magnusson, B., Mortensen, L., Neuvonen, S., Rasch, M. & Saelthun, N.R. 2005: SCANNET: a Scandinavian-North European network of terrestrial field bases. pp 359-364. In: Mountains of northern Europe / ed. by D.B.A. Thompson, M.F. Price and C.A. Galbraith.

Hjort, C. & Håkansson, L. 2005: A cosmogenic approach to the glacial history of Greenland. pp 103-108. In: Polarforskningssekretariatets årsbok 2004

Jensen, C.W. 2005: Undersøgelse over grønlandske svampemygs (Diptera: Mycetophilidae) flyveaktivitet i relation til klimatiske faktorer. Baseret på indsamlinger fra Zackenbergdalen, Nordøstgrønland. – MSc thesis, Institute for Biology and Chemistry, University of Roskilde.

Meltofte, H., Piersma, T., Boyd, H., McCaffery, B., Ganter, B., Golovnyuk, V.V., Graham, K., Gratto-Trevor, C.L., Morrison, R.I.G., Nol, E., Rösner, H.U., Schamel, D., Schekkerman, H., Soloviev, M.Y., Tomkovich, P.S., Tracy, D.M., Tulp, I. & Wennerberg, L. 2005: A circumpolar review of the effects of climate variation on the breeding ecology of arctic shorebirds. pp 26. In: Abstract catalogue, 11th Scientific Wadden Sea Symposium, Esbjerg 4-8 April 2005.

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