Zackenberg Ecological Research Operations

7th Annual Report, 2001

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Front of cover: Digital elevation model (DEM) of Young Sund and Tyrolerfjord. The DEM has been produced by Danish National Environmental Research Institute.

Back of cover: The two Zackenberg logisticians, Aka Lynge and Henrik Philipsen, enjoying a quiet moment in the mess room. Photo Charlotte Sigsgaard.

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Executive summary

Morten Rasch and Hans Meltofte

In 2001, Zackenberg Station was open 93 days, from 31 May to 31 August. During this period, 20 researchers and five logisticians worked on the station, and 14 guests paid the station a visit. The affiliation in Daneborg was used from 21 July to 31 August by 13 researchers and 10 visitors. The total number of overnights in Zackenberg and Daneborg was 1,276.

Climate data and data on water discharge in Zackenbergelven from 1999, 2000 and 2001 (January-August) are reported in this report. This is due to the 1999 climate data and data on water discharge not being ready for the 6th Annual Report dead line.

The summer of 2001 was in sense of climate very close to average. The mean annual air temperature for June, July and August were respectively 2.1°C, 4.9°C and 5.8°C.

The flow of water in Zackenbergelven started on 8 June, and during the 2001 season 137 mill. m^3 of water drained from the catchment area.

The snow cover of 2001 was close to average. Hence, snow melt in Zackenbergdalen, ice melt on the ponds and lakes around the research station and start of running water in the rivulets from Aucellabjerg together with break up of the fjord ice of Tyrolerfjord and Young Sund was also close to average. However, a snowstorm during 15-16 June covered the lowland with about 10 cm of new snow, which lasted 1-2 days. Considerably more snow fell on the higher slopes of Aucellabjerg, where it remained for up to a week and caused several land slides.

2001 was a year of many flowers and e.g. white arctic bell-heather flowered extensively after three years of poor flowering. In accordance with the progress of snowmelt, timing of flowering was close to average for the previous six years. However, plant production as measured by greening of the vegetation (NDVI) was considerably below 'normal' both when measured in the flowering plots and from satellite images. The total CO_2 flux budget for June-August showed a net accumulation in the order of 8.7 g C per m^2 against 3.1 g C per m^2 in 1997 and 19.1 g C per m^2 in 2000.

Arthropod numbers were close to average, but very few bumblebees, woollybear caterpillars and butterflies were recorded, and no depredation on *Dryas* flowers and female *Salix arctica* pods was found in the study plots.

Bird populations in Zackenbergdalen continued to be relatively stable, except dunlins, which continued their steady increase. The number of rock ptarmigans was low for the second year in succession. The breeding season started normally with egg laying in mid June in waders and long-tailed skuas, but was severely disturbed by the snowstorm in mid June, and most waders had to re-nest or gave up entirely. Several waders died, and a number of eggs were laid scattered on the ground. The predation by foxes was in the upper end of the range from previous years. In spite of all this, the waders seemed to have had a good breeding season in the region in general. Also, the number of juvenile long-tailed skuas were similar to those of other years with many lemmings (see below). An all time low number of barnacle geese brought their young to the study area in Zackenbergdalen, and very few were found in Store Sødal as well. This is in accordance with data from the wintering grounds in Scotland. On the contrary, more immature barnacle geese than ever moulted in the study area, i.e. about 500.

Numbers of lemmings increased from last years low, and the number of occupied summer burrows was higher than found before. Musk oxen utilised Zackenbergdalen in much higher numbers during June and the first half of July than previously recorded. Also the number of calves was in the high end of the range compared to previous years. Foxes had a good season with a total of 17 pups in five out of 12 known dens in and around Zackenbergdalen.

Conductivity and pH in the two monitoring lakes, Langemandssø and Sommerfuglesø in Morænebakkerne, were similar to measurements from previous years. Total phosphourus concentrations were, however, higher than previously found. The total nitrogen concentration in Sommerfuglesø was similar to the two previous years, but higher in Langemandsø than recorded before. The most likely explanation for the high nutrient levels is an increased run-off from the catchment area due to early melting of snow and ice. The chlorophyll *a* concentration varied within the range found previously. Thus, no obvious effects of the increased amount of total phosphorous were recorded. Even though phytoplankton diversity varies from year to year, it seems that chrysophytes totally dominate in years with early ice-melt, while dinophyceans become equally important in a more cold year like 1999. The zooplankton diversity and density were similar to those of previous years and owe to the direct and indirect effects of the predation from fish in Langemandssø. The early ice-out and the subsequent early rise in water temperature favour the reproduction potential of especially *Daphnia* and *Cyclops*.

In 2001, six research projects worked at Zackenberg, one research project worked on the south coast of Clavering Ø, and one research project worked at Daneborg. The projects at Zackenberg investigated changes of snow and vegetation coverage in Zackenbergdalen (Section 5.1), CO_2 dynamics in the soils (Section 5.2), the effects of increased air temperature on unicellulars and plants (Section 5.3), UV-B radiation effects on arctic perennial plants (Section 5.4), the influence of the North Atlantic Oscillation in muskox – *Salix* feedback dynamics (Section 5.6) and the lemming population (Section 5.7). The project on Clavering Island was on the altitude distribution of vascular plants (Section 5.5) The project in Daneborg consisted of many smaller sub-projects all studying different aspects of the marine ecology in the Young Sund / Tyrolerfjord system (Section 5.7).

1 Introduction

Morten Rasch

In 2001 Zackenberg Station hosted twenty scientists and two artists (a painter and a photographer) at Zackenberg, and 13 scientists in Daneborg during the three months the station was open. Five logisticians maintained the station and served the scientists. The total number of bed-nights, 1276, at the station was a bit larger than in 2000 but still far below the capacity of the station.

Extension of the facility

At the secretariat it is considered important to extend the station at Zackenberg with a building for permanent accommodation and a power station including a workshop and a garage. Further, the secretariat finds it important to restore the marine facility at Daneborg. The existing accommodation facilities in both Zackenberg and Daneborg are rather primitive and will have a limited durability. The secretariat has been in contact with the foundation *Aage V. Jensens Fonde* concerning a possible financing of the project. Representatives of the foundation visited Zackenberg in 2000, and in 2001 the foundation funded a project plan for an extension of Zackenberg Station and a restoration of the Daneborg facility. The plan was produced by Jørgen Raae Andersen from Greenland Contractors in cooperation with Danish Polar Center staff.

Cooperation with Greenland sites

Zackenberg Station continues to be involved in formalised cooperation with other research facilities in Greenland. The facilities are *Arctic Station* (central West Greenland), *Greenland Institute of Natural Resources* (southern West Greenland), *Kangerlussuaq International Science Support* (mid West Greenland), *Sermilik Station* (Southeast Greenland) and *Zackenberg Station* (Northeast Greenland). A Letter of Intent formalising the cooperation was signed, and a common folder has been published presenting the opportunities at the different facilities for guest scientists.

International cooperation

Zackenberg Station continued its participation in the two EU-funded international networks ENVINET and SCANNET. ENVINET consists of seventeen arctic and alpine research facilities in Europe, while SCANNET consists of nine research facilities around the North Atlantic Ocean. The participation in SCANNET has allowed Zackenberg Station to employ a biologist, Toke Thomas Høye, to collect recent and historical data on species performance and phenology from the nine facilities. In ENVINET, Zackenberg Station is leading the Station Manager Forum promoting increased cooperation and information exchange among the station managers at the participating facilities. Further information about the networks can be obtained on the internet (SCANNET: http://www.envicat.com/scannet/scannet, ENVINET: http://envinet.npolar.no).

Danish Polar Center and Zackenberg Station is planning to join forces with the Swedish Polar Research Secretariat in future logistical cooperation. The first joint project was a Danish-Swedish Biodiversity Project at Zackenberg in 2002. However, due to the funding system in Denmark the Danish scientists in the project had to apply for funding of their logistic expenses from the Danish Research Councils, and it was not possible for Danish Polar Center to match the Swedish contribution to the project.

Plans for the 2002 field season

In 2002, we continue to plan for an extension of the facility at Zackenberg and a restoration of the facilities in Daneborg, and we will finish improving the water supply.

Further information about Zackenberg Station and its study area

Details about Zackenberg Station and its study area are given in earlier annual reports (Meltofte and Thing 1996, 1997; Meltofte and Rasch 1998; Rasch 1999; Caning and Rasch 2000, 2001). Further information is available on the Zackenberg Station homepage (www.zackenberg.dk).

The ZERO Site Manual contains all relevant information for travellers to Zackenberg. The manual can be obtained either by contacting the Zackenberg Secretariat (The Zackenberg Secretariat, Danish Polar Center, Strandgade 100H, DK-1401 Copenhagen K, Denmark. Phone: +45 32880100, Fax: +45 32880101, E-mail: mr@dpc.dk) or by down load from our home page (www.zackenberg.dk).

2 Logistics

Aka Lynge

In 2001 Zackenberg Station was open for 93 days, from 31 May to 31 August. During this period 20 researchers and 5 logisticians worked on the station, and 14 guests paid a visit. The affiliation in Daneborg was used from 21 July to 31 August by 13 researchers and 10 visitors.

The total number of overnights in Zackenberg and Daneborg was 1276. In previous years the numbers were *105* (1991), *250* (1992), *0* (1993), *210* (1994), *321* (1995), *1422* (1996), *1462* (1997), *1474* (1998), *2077* (1999) and *1221* (2000).

Transportation

Due to snow on the airstrip on 31 May, the opening team was put down by a Twin Otter at Daneborg and made the last 25 km by snow scooter. Clearing of the airstrip started next day by means of a wheel barrow and gravel. The airstrip was ready for landing in less than a week.

Also this year, transport of heavy material took place with the All Terrain Vehicle (ATV) and a trailer, and was restricted to a clearly defined traffic corridor. This year we took off the crawler belts after snow melt in order to protect the ground as much as possible.

The airstrip was graded using a homemade grader constructed from two ordinary pallets tied together and pulled by the ATV. The result was excellent.

This year we brought a new and stronger out board engine for the rubber boat in order to improve security. The rubber boat used for crossing the Zackenbergelven was replaced with a smaller one which is easier to pull across by hand.

The number of take offs / landings by plane counted 40, 32 in connection with arrivals and departures of researchers and freight, and eight in connection with transport of ship freight from Daneborg.

No helicopters visited Zackenberg this year.

Accomodation

As in previous years all guests were accomodated in shelters. Building of new houses for accomodation and technical purposes were planned for this year but were postponed.

Electrical power production

The Zordan generator from 1999 has been working without problems. In August we took over a similar generator from the University of Antwerpen, thus securing sufficient backup of electrical power for a number of years.

Water supply

The soft water tanks had their last season. Two tanks of stainless steel, each of them carrying c. 2 m^3, and one tank carrying c. 13 m^3 were made ready for use next year.

Waste

Containers of stainless steel for waste storage during winter were purchased last year. They kept the waste untouched and dry throughout the winter. As in previous years, all solid waste was transported to Constable Pynt.

Tele communication

As in previous years, all communication between Zackenberg and the world outside Northeast Greenland went by satellite phone, fax and e-mail. Tele communication is still expensive but works well.

A new antenna mast, 15 m high and made of steel, was erected. The mast has wires going down from 5, 10 and 15 metres and is strong enough to stand all winter. The mast is equipped with antennas for HF and VHF and has improved the quality of communication significantly. For the first time we were able to communicate with the weather station at Daneborg without a help from the Sirius sledge patrol.

3 Zackenberg Basic: The GeoBasis and ClimateBasis programmes

Morten Rasch (editor)

The GeoBasis and ClimateBasis programmes collect data describing the physical and geomorphological environment at Zackenberg. This includes the climate in the Zackenberg area, the water balance of Zackenberg river drainage basin, the sediment, solute and organic matter yield of Zackenberg river drainage basin, the dynamics of selected physical landscape elements, and the seasonal development of the active layer, its temperature conditions and its soil water chemistry.

GeoBasis is operated by Institute of Geography at University of Copenhagen and Danish Polar Center in cooperation.

Climate Basis is operated by Asiaq, Greenland Field Investigations. They take care of the run and the maintenance of the climate station and the hydrometric station. It was not possible for Asiaq to report data from the years 1999 and 2000 in the annual report for 2000, and as a result this report contains ClimateBasis reporting of data from 1999, 2000 and 2001 (1 January – 31 August).

The GeoBasis and ClimateBasis installations have been described in previous annual reports (Meltofte and Thing 1996; Meltofte and Rasch 1998; Rasch 1999; Caning and Rasch 2000). Data from the two programmes are available free of charge, and may be ordered from Institute of Geography, University of Copenhagen (mr@geogr.ku.dk).

3.1 The meteorological station

Dorthe Petersen

The meteorological station at Zackenberg was constructed in the summer of 1995. The technical specifications of the station are described in Meltofte and Thing (1996). Two major changes have been made since the station was established. In

Parameter	Mean	Max.	Min.
Air temperature, 2 m above terrain (°C)	–9.5	15.2	–36.3
Air temperature, 7.5 m above terrain (°C)	–8.9	14.6	–34.4
Relative air humidity 2 m above terrain (%)	70.1	99.3	30.3
Air Pressure (hPa)	1006.3	1035.3	960.6
Incoming shortwave radiation (W/m^2)	100.3	889.0	0.0
Outgoing shortwave radiation (W/m^2)	55.7	602.7	0.0
Net Radiation (W/m^2)	4.4	470.8	–99.9
Wind Velocity, 2 m above terrain (m/s)	3.0	19.3	0.0
Wind Velocity, 7.5 m above terrain (m/s)	3.7	22.0	0.0
Precipitation (mm w.eq.), total	161		
Ground temperature, 0 cm below surface (°C)	–8.2	18.36	–26.85
Ground temperature, 2.5 cm below surface (°C)	–8.0	21.19	–25.16
Ground temperature, 5 cm below surface (°C)	–7.3	18.43	–24.08
Ground temperature, 10 cm below surface (°C)	–6.6	15.20	–23.09
Ground temperature, 20 cm below surface (°C)	–8.0	8.76	–22.91
Ground temperature, 40 cm below surface (°C)	–8.4	6.16	–20.66
Ground temperature, 60 cm below surface (°C)	–6.6	8.19	–16.08
Ground temperature, 80 cm below surface (°C)	–6.3	0.97	–14.59
Ground temperature, 100 cm below surface (°C)	–7.6	0.00	–15.31
Ground temperature, 130 cm below surface (°C)	–7.8	–2.30	–13.24

Table 3.1. Summary of selected climate parameters 1999.

Year	Month	Air Temperature °C 2.0 m	Air Temperature °C 7.5 m	Rel. humidity %	Air Press. hPa	Net Rad. W/m²	Shortwave Rad. W/m² In	Shortwave Rad. W/m² Out	Wind Velocity m/s 2.0 m	Wind Velocity m/s 7.5 m	Dominant Wind Dir. 7.5 m
1999	Jan	–22.1	–20.9	67.4	1003.0	–26.3	0.2	0.1	3.6	4.6	NNW
1999	Feb	–19.7	–18.8	70.7	1001.8	–17.7	5.9	4.8	4.1	5.9	NNW
1999	Mar	–18.0	–16.8	66.0	1014.7	–26.3	62.1	53.0	–	3.8	–
1999	Apr	–15.2	–13.9	61.6	1015.8	–27.2	171.0	145.7	2.4	2.9	–
1999	May	–4.1	–3.8	76.8	1010.3	–9.6	229.8	193.0	4.0	4.8	–
1999	Jun	1.5	1.6	78.1	1002.8	33.2	294.2	206.4	1.9	2.3	–
1999	Jul	6.2	6.1	76.8	1005.5	123.1	212.3	31.8	2.2	2.6	–
1999	Aug	2.9	2.7	80.8	1008.0	73.4	142.9	16.2	2.1	2.5	SE
1999	Sept	–0.9	–0.6	70.0	1003.2	6.0	62.9	10.0	3.0	3.6	NNW
1999	Oct	–10.9	–10.2	66.5	1009.4	–24.3	16.8	6.5	3.2	3.8	NNW
1999	Nov	–12.9	–12.2	65.7	997.6	–23.3	0.9	0.3	3.5	4.0	NNW
1999	Dec	–21.8	–20.4	60.7	1003.0	–33.8	0.3	0.1	3.4	3.9	NNW
2000	Jan	–17.9	–16.7	61.1	999.3	–23.2	0.4	0.2	3.3	4.2	NNW
2000	Feb	–19.5	–18.3	63.7	999.7	–29.2	6.6	5.4	4.2	4.8	NNW
2000	Mar	–21.1	–19.8	59.6	1011.5	–29.4	63.0	55.6	1.6	3.2	NNW
2000	Apr	–16.1	–14.8	65.4	1015.5	–26.8	179.6	147.1	2.0	2.2	NNW
2000	May	–5.5	–5.3	71.7	1008.8	–5.7	272.3	220.4	3.1	3.6	NNW
2000	Jun	1.9	1.7	79.2	1010.3	126.2	293.6	103.4	1.8	2.1	SE
2000	Jul	5.3	4.9	76.1	1006.7	140.9	227.5	26.7	2.6	2.9	SE
2000	Aug	4.0	3.9	76.5	1006.1	82.0	152.8	19.0	2.1	2.3	SE
2000	Sept	–2.0	–1.7	79.4	1003.4	5.3	71.7	29.3	2.4	2.8	NNW
2000	Oct	–9.6	–9.0	74.4	1002.5	–20.1	15.4	13.0	2.8	3.6	NNW
2000	Nov	–17.5	–16.2	68.6	1012.4	–22.7	1.3	0.5	1.9	2.5	NNW
2000	Dec	–23.0	–21.5	59.9	1014.6	–28.3	0.2	0.1	0.9	2.8	NNW
2001	Jan	–20.5	–19.2	69.0	1003.6	–16.6	0.3	0.2	2.8	3.1	–
2001	Feb	–21.1	–20.1	68.6	1010.0	–19.1	6.8	6.1	3.1	3.6	–
2001	Mar	–23.7	–22.3	64.4	1017.5	–26.9	61.7	54.4	1.9	2.2	–
2001	Apr	–19.5	–18.2	61.6	1013.2	–26.1	179.5	151.6	2.2	2.4	–
2001	May	–6.3	–6.1	77.3	1011.7	–8.3	274.2	223.6	2.1	2.4	–
2001	Jun	2.1	2.0	79.2	1010.6	67.5	293.1	167.5	1.9	2.1	–
2001	Jul	4.9	4.5	75.7	1007.5	146.5	230.9	26.6	2.6	2.9	–
2001	Aug	5.8	5.6	79.7	1006.6	83.6	179.8	19.9	2.4	2.8	SE

Table 3.2. Monthly mean values of selected climate parameters, January 1999-August 2001.

1997, the radiation sensors were moved to a separate mast, and a mast for snow depth measurements was erected (see Meltofte and Rasch 1998).

In 2000 and 2001 no major changes to the station were conducted. The sensors are calibrated and checked by ASIAQ – Greenland Field Investigations. Maintenance of the climate station during the field season is carried out by GeoBasis employees supervised by ASIAQ technicians.

Meteorological data from 1999

Table 3.1 shows a summary of measured climatic parameters in 1999. Tables 3.2 and 3.3 show monthly mean values (January 1999-August 2001) of climate parameters and ground temperatures, respectively. The variation of selected climate parameters and wind parameters are shown in Figs. 3.1 and 3.2, respectively.

In 1999, the mean annual air temperature measured 2 m above terrain was –9.5°C, the maximum temperature was 15.2°C (mid August) and the minimum temperature was –36.3°C (end of March). The temperature varies much more during the winter than during summer. The period with frequent temperatures above 0°C started in late May and ended in mid September (Fig. 3.1).

The total amount of measured precipitation in 1999 was 161 mm.

The mean air pressure was 1006.3 hPa.

Table 3.3. Monthly mean values of ground temperatures, January 1999-August 2001

Year	Month	0 cm	–2.5 cm	–5 cm	–10 cm	–20 cm	–40 cm	–60 cm	–80 cm	–100 cm	–130 cm
1999	Jan	–14.6	–15.0	–13.9	–13.1	–14.2	–14.2	–11.8	–10.6	–11.6	–10.6
1999	Feb	–13.4	–13.7	–12.7	–12.0	–13.1	–13.3	–11.2	–10.4	–11.5	–10.9
1999	Mar	–11.6	–11.7	–10.9	–10.2	–11.5	–12.0	–10.1	–9.7	–10.9	–10.7
1999	Apr	–12.0	–12.2	–11.3	–10.6	–11.8	–12.2	–10.3	–9.7	–10.9	–10.7
1999	May	–10.4	–10.5	–9.7	–9.1	–10.5	–11.1	–9.4	–9.2	–10.5	–10.6
1999	Jun	–2.3	–2.3	–1.8	–1.4	–3.2	–4.7	–4.1	–5.0	–6.6	–8.0
1999	Jul	7.6	7.9	8.0	7.4	3.7	0.2	0.5	–0.3	–2.2	–4.3
1999	Aug	5.0	4.2	4.8	5.3	3.4	1.4	2.0	0.8	–0.9	–2.9
1999	Sept	–1.0	–0.7	0.2	1.1	–0.1	–0.7	0.9	0.8	–0.8	–2.4
1999	Oct	–11.4	–9.9	–8.9	–7.8	–8.1	–6.5	–3.4	–2.5	–3.6	–3.5
1999	Nov	–12.8	–12.1	–11.2	–10.4	–11.2	–10.6	–7.9	–7.0	–8.1	–7.1
1999	Dec	–21.7	–20.7	–19.8	–18.9	–19.2	–17.8	–14.0	–12.6	–13.3	–11.4
2000	Jan	–16.3	–15.9	–15.1	–14.3	–15.2	–15.0	–12.6	–11.9	–12.9	–12.1
2000	Feb	–19.9	–19.5	–18.7	–17.9	–18.7	–18.3	–15.4	–14.5	–15.4	–14.1
2000	Mar	–17.5	–17.2	–16.5	–15.7	–16.7	–16.6	–14.2	–13.6	–14.7	–14.0
2000	Apr	–17.1	–17.0	–16.3	–15.6	–16.7	–16.7	–14.5	–14.0	–15.1	–14.5
2000	May	–10.8	–11.3	–10.6	–10.0	–11.6	–12.6	–11.3	–11.3	–12.7	–13.0
2000	Jun	3.2	1.2	1.3	1.4	–1.2	–3.9	–3.4	–4.4	–6.3	–8.4
2000	Jul	8.5	6.9	7.1	7.5	4.8	1.3	1.3	0.2	–1.6	–4.0
2000	Aug	–	–	–	–	–	–	–	–	–	–
2000	Sept	–0.8	–0.7	0.2	1.1	–0.1	–0.7	0.9	0.8	–0.8	–2.5
2000	Oct	–5.2	–4.7	–3.7	–2.8	–3.5	–3.3	–1.2	–0.7	–2.1	–2.8
2000	Nov	–12.7	–12.2	–11.3	–10.5	–11.2	–10.3	–7.2	–6.0	–7.0	–6.1
2000	Dec	–15.8	–15.2	–14.3	–13.5	–14.2	–13.3	–10.2	–8.9	–9.9	–8.9
2001	Jan	–16.45	–16.20	–15.36	–14.60	–15.45	–14.86	–12.07	–10.95	–11.96	–10.93
2001	Feb	–15.27	–15.10	–14.31	–13.56	–14.55	–14.25	–11.80	–10.95	–12.04	–11.37
2001	Mar	–15.94	–15.80	–15.03	–14.28	–15.28	–14.99	–12.55	–11.73	–12.81	–12.15
2001	Apr	–15.32	–15.27	–14.52	–13.78	–14.88	–14.84	–12.60	–11.95	–13.07	–12.60
2001	May	–10.92	–11.22	–10.52	–9.86	–11.29	–12.13	–10.63	–10.47	–11.78	–11.90
2001	Jun	1.67	0.50	0.65	0.97	–1.50	–3.81	–3.32	–4.43	–6.24	–8.17
2001	Jul	8.30	6.77	6.90	7.35	4.72	1.19	1.23	0.17	–1.68	–3.99
2001	Aug	6.89	5.66	5.98	6.71	4.51	2.07	2.32	0.93	–0.83	–2.86

The air pressure was generally more stable during summer than during winter.

The relative humidity was highest during the summer period. Mean annual relative humidity was 70.1%.

The monthly mean net radiation was positive in June, July, August and September and negative in the remaining part of the year. The same distribution was seen in 1998. The mean annual net radiation was 4.4 W / m^2, considerably less than in both 1998 and 2000. The net radiation depends on the occurrence of snow, as the net radiation increases considerable as the last snow melts away in the beginning of July (Fig. 3.1). The disappearance of snow at the climate station in 1999 was approximately 8 days later than in 1998 and 19 days later than in 2000.

Mean wind speed 2.0 m and 7.5 m above ground was respectively 3.0 m / s and 3.7m / s. The highest annual mean value (averaged over ten minutes) was 19.3 m / s at 2 m above ground and 22.0 m / s at 7.5 m above ground. In earlier reports, e.g. Caning and Rasch 2000, maximum wind gust rather than maximum 10 minutes mean values have been reported. The wind speeds are generally higher in winter than in summer.

The wind direction sensor was unfortunately out of order in 1999 between late February and late August, when it was replaced. The distribution of wind from different directions is therefore not calculated for 1999. In the winter period, the dominant wind direction was NNW (Table 3.2 and Fig. 3.2).

Meteorological data from 2000

Table 3.4 shows a summary of measured climatic parameters in 2000. Monthly mean values of climate parameters are given in Table 3.2. In Table 3.5 statistics of the measured wind speed and wind directions are given. The variation of selected climate parameters and wind parameters are shown in Figs. 3.3 and 3.4, respectively.

In 2000, the mean air temperature measured 2 m above terrain was –10.0°C, the maximum temperature was 19.1°C (beginning of July) and the minimum temperature was –36.7°C (end of January). The maximum temperature is 4-5°C higher than in the previous two years, whereas the mean and minimum temperatures are equal or very close to the mean and minimum temperatures measured in the previous two years. The period with frequent temperatures above 0°C started in beginning of June and ended in mid September.

The total amount of measured precipitation in 1999 was 176 mm.

The mean air pressure was 1007.6 hPa.

The relative humidity was highest during the summer period. Mean relative humidity was 69.6%.

The mean net radiation was 14.2W / m^2. The monthly mean net radiation was positive in June, July, August and September and negative in the remaining months. The same distribution was seen in 1998 and 1999. The last snow melted away in mid June resulting in a large increase in the level of the net radiation. The disappearance of snow was earlier than the previous two years (see above). The low snow depth at the measuring station can explain this (maximum snow depth was 0.5 m in 2000 compared to 1.3 m in 1999 and 0.9 m in 1998). In the autumn snow reappeared early giving large outgoing radiation from mid September until the sun disappeared for the winter (Fig. 3.3).

Mean wind speed 2.0 and 7.5 m above ground was 2.4 m / s and 3.1 m / s, respectively. The highest annual mean wind speed (measured as 10 minutes average) was 20.7 m / s at 2 m above ground and 23.5 m / s at 7.5 m above ground. The wind speeds are generally higher during winter than during summer.

In the winter period, the dominant wind direction was NNW. In summer it was SE (Table 3.2). Calm weather with wind speeds lower than or equal to 0.5m / s occurred with a frequency of 9.4%. Wind directions with a frequency above 5% fall into two groups; winds from the NW-N with a total frequency of 42.1% and winds from ESE-SE with a total frequency of 16.5% (Table 3.4). This is close to the situation in 1998, where the corresponding figures were 42.4% and 16.1%, respectively (Caning and Rasch 2000).

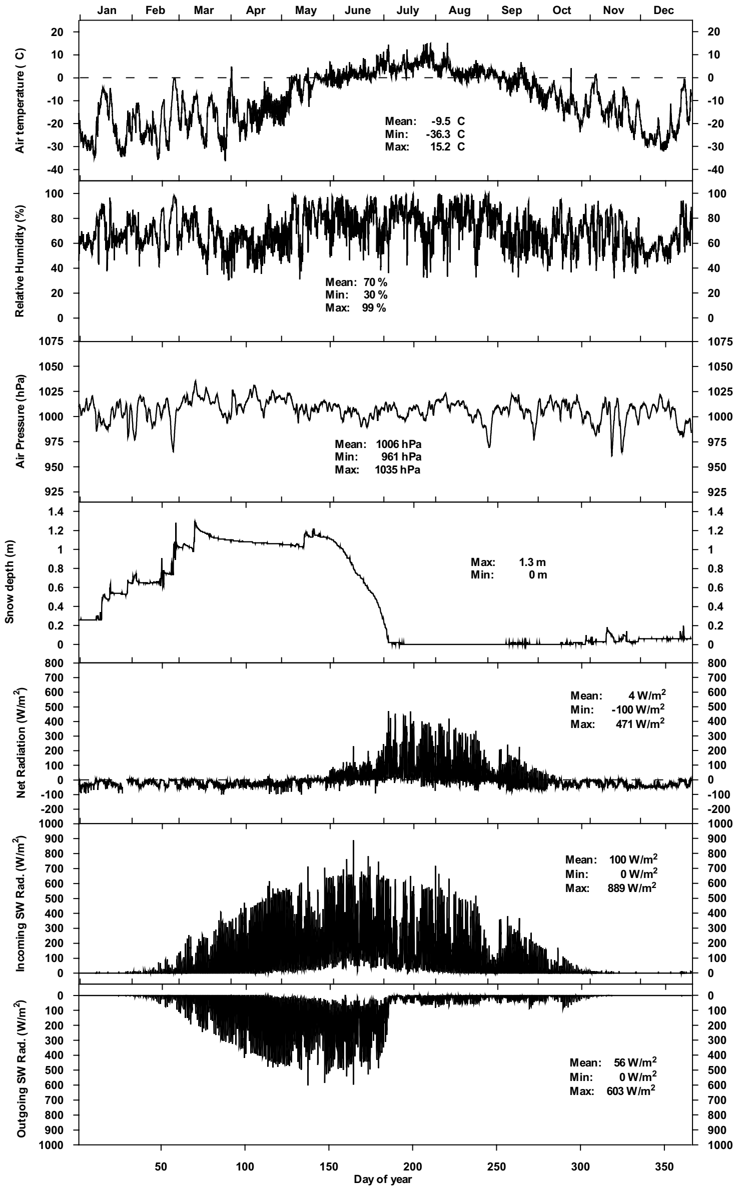


Fig. 3.1. Variation in 1999 of selected climate parameters. From above: Air temperature, relative humidity, air pressure, snow depth, net radiation, incoming short wave radiation and outgoing short wave radiation. All parameters are measured 2 meters above terrain.

Meteorological data from 2001

Monthly mean values of climate parameters are given in Table 3.2. The variation of selected climate parameters is shown for the period January-August in Fig. 3.5.

The monthly mean values of the climatic parameters show the same trend as in previous years. The monthly mean temperatures and net radiation became posi-

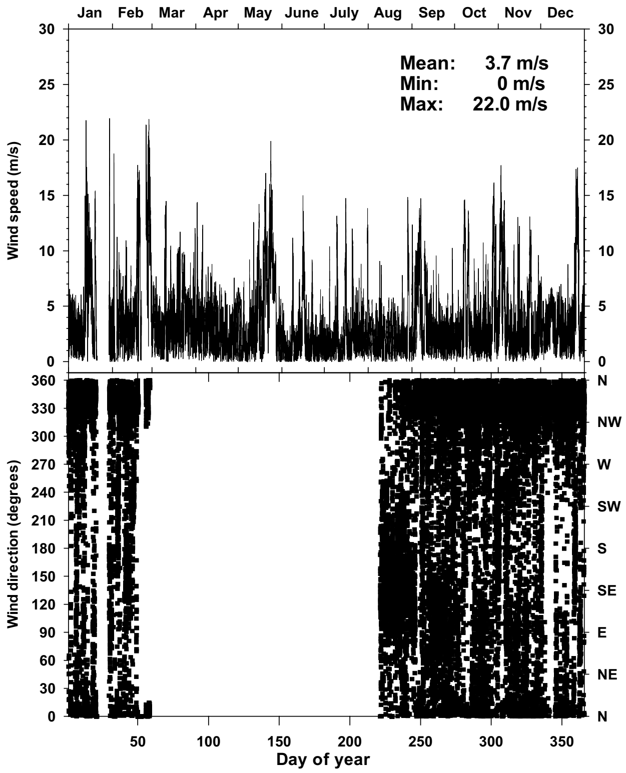


Fig. 3.2. Variation in wind speed (m/s) and wind direction in 1999. Parameters are measured 7.5 meters above terrain.

tive in June. The monthly mean relative humidity exceeded 70% from the beginning of May.

The snow depth reached a maximum of 0.7m in the winter 2000/2001. This was 0.2m above the level in 2000 but still only approximately 50% of the depth reached in 1999, which was an extremely snow rich year (Caning and Rasch 2000). The last snow disappeared from the measuring station in late June giving a large positive net radiation in the following period.

The wind direction sensor was unfortunately out of order from mid January until the climate station was checked by Asiaq technicians in late July.

3.2 TinyTalk/TinyTag dataloggers

Morten Rasch and Charlotte Sigsgaard

GeoBasis operated a total of thirty dataloggers in 2000 for measurements of air temperature at soil surface at three sites, soil temperature profiles (incl. air temperature at soil surface) at six sites, water temperature at one site and air temperature in- and outside a snow patch at four sites. The purpose of the measurements has been described together with the position of the dataloggers, the interval between measurements and period of operation in Table 3.2.1 in Meltofte and Rasch (1998). Statistics from the period 1996-2000 are given in Table 3.6. Unfortunately there were serious problems with the TinyTag dataloggers in 2000. Seventeen out of thirty dataloggers did not work well throughout 2000. This is definitely not satisfying and as a result we have started to improve the set up by making the casings for the dataloggers more resistant towards water and moisture.

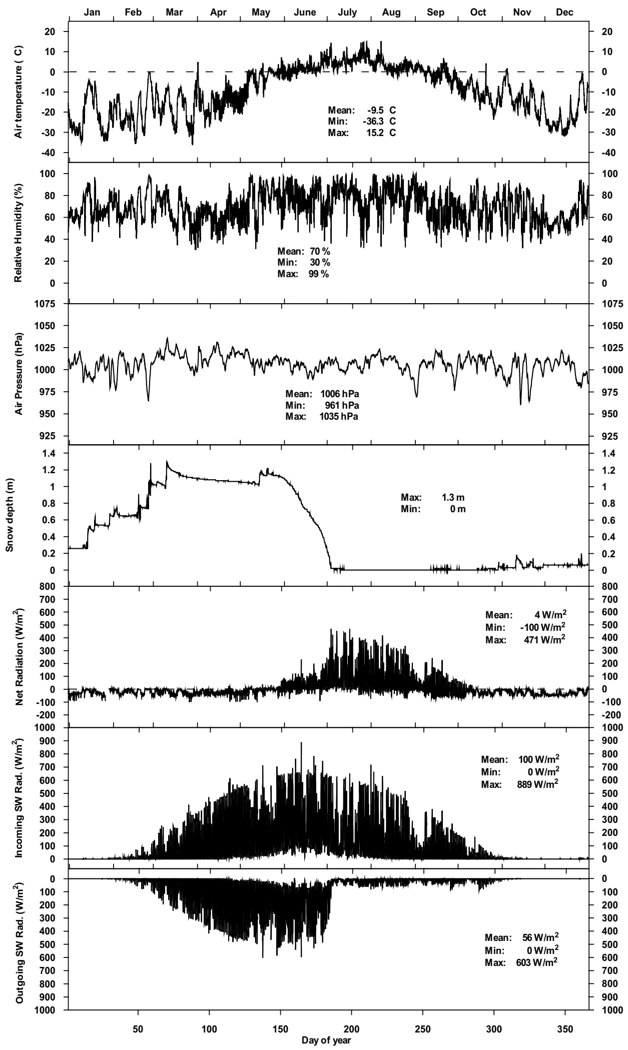


Fig. 3.3. Variation in 2000 of selected climate parameters. From above: Air temperature, relative humidity, air pressure, snow depth, net radiation, incoming short wave radiation and outgoing short wave radiation. All parameters are measured 2 meters above terrain.

Table 3.4. Summary of selected climate parameters 2000.

Parameter	Mean	Max.	Min.
Air temperature, 2 m above terrain (°C)	–10.0	19.1	–36.7
Air temperature, 7.5 m above terrain (°C)	–9.4	18.8	–34.1
Relative air humidity 2 m above terrain (%)	69.6	100.0	18.6
Air Pressure (hPa)	1007.6	1035.9	968.5
Incoming shortwave radiation (W/m^2)	107.2	810.0	0.0
Outgoing shortwave radiation (W/m^2)	51.8	581.4	0.0
Net Radiation (W/m^2)	14.2	627.2	–128.5
Wind Velocity, 2 m above terrain (m/s)	2.4	20.7	0.0
Wind Velocity, 7.5 m above terrain (m/s)	3.1	23.5	0.0
Precipitation (mm w.eq.), total	176		
Ground temperature, 0 cm below surface (°C)	–8.68	23.08	–23.04
Ground temperature, 2.5 cm below surface (°C)	–8.41	13.85	–21.88
Ground temperature, 5 cm below surface (°C)	–8.15	12.51	–20.93
Ground temperature, 10 cm below surface (°C)	–7.03	11.74	–20.15
Ground temperature, 20 cm below surface (°C)	–8.79	7.56	–20.56
Ground temperature, 40 cm below surface (°C)	–8.97	2.91	–19.54
Ground temperature, 60 cm below surface (°C)	–7.49	2.41	–16.20
Ground temperature, 80 cm below surface (°C)	–6.93	1.06	–15.23
Ground temperature, 100 cm below surface (°C)	–8.56	–0.69	–16.14
Ground temperature, 130 cm below surface (°C)	–8.60	–2.35	–14.84

3.3 The hydrometric station

Dorthe Petersen, Håkon Gjessing Karlsen and Morten Rasch

The hydrological measurements started at Zackenbergelven in 1995. The hydrometric station is described in details in Meltofte and Thing (1996). The station records the water discharge from the drainage basin of Zackenbergdalen, Store Sødal, Lindemansdalen and Slettedalen. The basin covers an area of 514 km^2. Glaciers cover 106 km^2.

At the station the water level is logged automatically with a sonic range sensor. This sensor determines (by the use of sound) the distance from a fixed point (the sensor) to the water surface. This signal is transformed to a water level, which can be transformed to a discharge, using an established relation between water level and discharge (a Q/h-relation)

The Q/h-relation

Discharges and corresponding water levels have been measured in the field seasons from 1995 to 2001. The function that describes the relation between water level and discharge is shown in Fig. 3.6. The Q/h-relation is based on discharge measurements performed in the years 1995 to 1998, ranging from 5,98 to 70 m^3/s. The good correlation of the data and the Q/h-relation indicates that the cross profile at the hydrometric station was stable in the period 1995 to 1998. Manual discharge measurements in 1999, 2000 and 2001 sup-

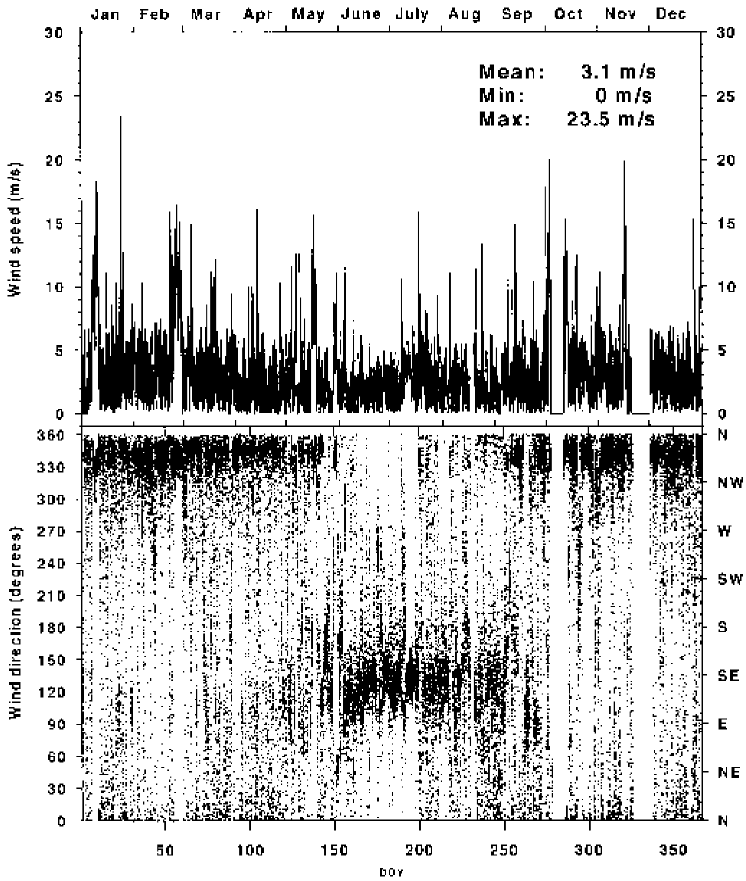


Fig. 3.4. Variation in wind speed (m/s) and wind direction in 2000. Parameters are measured 7.5 meters above terrain.

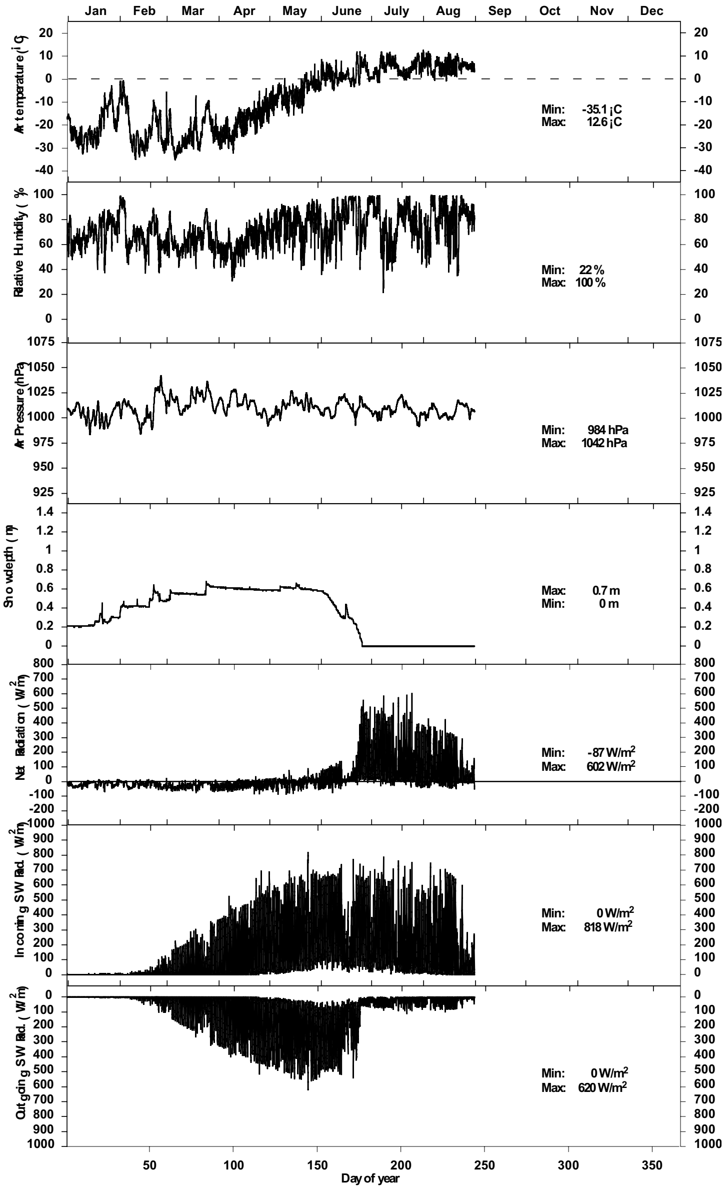


Fig. 3.5. Variation in 2001 of selected climate parameters. From above: Air temperature, relative humidity, air pressure, snow depth, net radiation, incoming short wave radiation and outgoing short wave radiation. All parameters are measured two meters above terrain.

port that the cross profile also has been stable in the last years.

The Q / h-relation is only valid when the river bed and banks are ice and snow free because snow covering the banks will change the cross profile of the river, and because ice layers at the bottom of the river give a false water level.

Late in the season 1999 the discharge was measured to 3.65 m^3 / s, this was lower than expected from the Q / h relation. This might suggest that the lower part of the Q / h-relation should be described with another function than the one given in Fig. 3.6. Further discharge measurement should be carried out during low flow (0 og 5 m^3 / s) to confirm or reject whether a new Q / h-relation for discharges lower than 5 m^3 / s should be established.

River water discharge

The water discharge curves for Zackenbergelven 2000 and 2001 are shown in Figs. 3.7 and 3.8, respectively.

In 2000 water was first observed in the river on 8 June. Until 26 June the riverbanks were covered with snow and ice. For this period the Q / h-relation is therefore not considered accurate (see above) and only manually measured discharges are shown as points in Fig. 3.7. These manually measurements are used for the calculation of the accumulated discharge for this period. After 26 June the sonic range sensor measurements are used to calculate the discharge.

The total amount of water drained from the catchment in 2000 was 149 mill. m^3. With a drainage basin area of 514 km^2 this corresponds to a total water loss of 289 mm from the area. The precipitation in the hydrological year 2000 (1 October 1999 – 30 September 2000) was 170 mm. To understand the large difference it is relevant to note that measurements of precipitation at Zackenberg are always connected with great uncertainty.

In 2001 water was first observed in the river on 8 June. For the year 2001 there are no observations on the snow / ice cover of the riverbanks. Therefore the sonic range sensor measurements are used for the entire period. This will expectedly give a slight overestimate of the water discharge in the beginning of the period.

The total amount of water drained from the catchment area in 2001 was 137 mill. m^3. With a drainage area of 514 km^2 this corresponds to a total water loss of 266 mm from the area. The precipitation in the hydrological year 2001 (1 October 2000 – 30 September 2001) was 240 mm.

Sediment, solute and organic matter yield

Sediment concentrations, solute concentrations (Na, K, Ca, Mg, Fe, Al, Mn, Cl, NO_3, SO_4, HCO_3) and organic matter concentrations are measured in samples of river water taken from Zackenbergelven near its mouth once every day at 8:00 in the morning. Water samples are analysed for alkalinity, pH, sediment concentrations and conductivity at Zackenberg. All other chemical analyses on water samples from Zackenbergelven are carried out at Institute of Geography at University of Copenhagen.

As an example of data from 2001, the variation of sediment and organic matter concentrations are shown in Fig. 3.9.

All water concentration data from 2001 and earlier years (1997-2000) are available and can be ordered from Institute of Geography, University of Copenhagen (mr@geogr.ku.dk).

Due to financial reasons (lack of man power) it has still not been possible to calculate the annual fluxes of sediment, solute and organic matter in Zackenbergelven.

3.4 Landscape monitoring

Morten Rasch, Jens Ernst Søndergaard, Jørgen Hinkler, Hans Meltofte and Charlotte Sigsgaard

GeoBasis performs the following monitoring of landscape elements and dynamics at Zackenberg:

1. photomonitoring of 24 different dynamic landforms (e.g. rock glaciers, coastal spits, gullies, frost boils),
2. monitoring of the snow cover in Zackenbergdalen with automatic digital cameras,
3. active layer depth measurements on a horizontal site (ZEROCALM-1) and on a sloping site (ZEROCALM-2),
4. soil water chemistry measurements at both active layer depth sites,
5. ice wedge growth measurements at two sites,
6. measurements of cross shore landscape changes (accretion or erosion) at six sites, and
7. measurements of vertical salt marsh accretion at two sites.

Monitoring photos

GeoBasis includes repeated photos of different dynamic landforms at 24 sites. These photos were originally planned to be taken manually once every year. Very limited changes of the landforms has however occurred since GeoBasis started the monitoring in 1995. For that reason the photos where not taken in 2000. In 2001 all photos were taken, still confirming that the changes of the selected landforms occur very slowly.

Direction	Observations	Frequency	Mean Speed	Max. Speed
N	5349	10.2	3.8	20.5
NNE	1449	2.8	1.8	14.2
NE	1252	2.4	2.7	15.3
ENE	1396	2.7	2.2	10.4
E	2306	4.4	2.2	8.1
ESE	3944	7.5	2.3	9.8
SE	4727	9.0	2.7	7.5
SSE	2316	4.4	2.5	8.4
S	1636	3.1	2.4	6.5
SSW	1093	2.1	2.1	7.8
SW	1079	2.1	2.1	7.8
WSW	1181	2.3	2.5	10.5
W	1175	2.2	2.5	23.5
WNW	1762	3.4	2.7	19.0
NW	3518	6.7	3.7	18.3
NNW	13199	25.2	5.0	20.1
Calm	4934	9.4		

Table 3.5.Wind statistics 2000, 7.5 m above terrain. Calm is defined as wind speed lower than 0.5 m/s.

The automatic photo monitoring of the snow cover in the lower part of Zackenbergdalen were continued in 2001. The photo monitoring is carried out with automatic cameras situated at c. 450 m a.s.l. on the mountain Zackenberg west of Zackenbergdalen. The techniques used for transformation of the oblique photos into ortho-photos, identification of snow in the photos, and measurement of snow cover

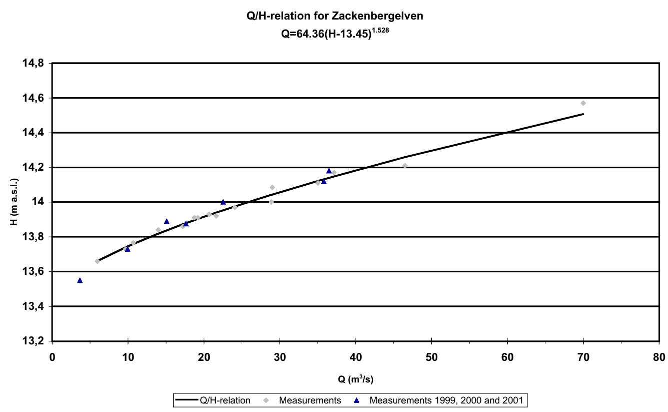


Fig. 3.6. Water level – discharge relation curve (Q/h-relation) for Zackenbergelven at the hydrometric station, 1995-1998. The coefficient of correlation for the curve is 0.99.

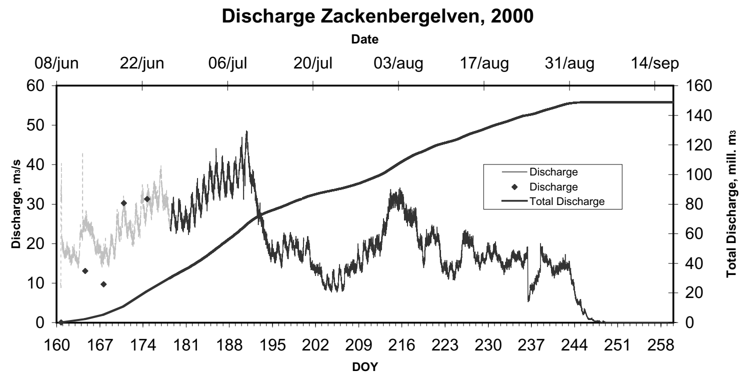


Fig. 3.7. Variation of river water discharge in Zackenbergelven, 2000.

Table 3.6. Statistics on time series from the TinyTag/TinyTalk dataloggers operated by GeoBasis. NV means 'no value'.

	1996			1997			1998		
	Mean °C	Min. °C	Max. °C	Mean °C	Min. °C	Max. °C	Mean °C	Min. °C	Max. °C
P1									
0 cm	–7.7	–37.6	29.9	–9.8	–40.7	30.7	–9.1	–40.7	28.1
10 cm	NV	NV	NV	–9.6	–39.1	19.1	–8.8	–37.6	17
50 cm	–6.7	–25.2	7.3	–9.0	–29.4	8.8	–8.3	–28.4	7.3
118 cm	–5.9	–15.6	–0.1	–8.1	–18.3	–0.1	–7.8	–17.6	–0.1
P2									
0 cm	–5.6	–30.5	34.1	–7.8	–29.4	25.9	–7.5	–24.1	22
10 cm	–6.1	–24.6	12.4	–8.4	–25.7	12.8	–7.9	–21	18.8
70 cm	–6.0	–19.1	2.3	–8.1	–19.6	2.3	–7.2	–17	3.1
155 cm	–6.5	–14.6	–1.4	–8.6	–16.4	–1.8	–8.0	–14.6	–1.8
P3									
0 cm	–6.2	–31.5	25.2	–9.6	–36.3	23.4	–7.6	–34.8	23.4
10 cm	–5.9	–27.5	18.1	–8.6	–32.6	18.8	NV	NV	NV
66 cm	–5.5	–20.3	6.9	–8.7	–23.3	6.5	NV	NV	NV
P4									
0 cm	–8.5	–33.7	27.0	–10.7	–39.1	27.4	–8.2	–27.5	30.7
10 cm	–8.0	–28.4	16.3	–10.5	–33.7	14.9	–8.0	–24.9	19.1
85 cm	–7.6	–18.9	1.9	–10.4	–22.5	1.1	–8.6	–20.3	2.7
P5									
0 cm			–9.2	–36.0	20.4	NV	NV	NV	–9.9
75 cm			–8.9	–22.4	11.0	NV	NV	NV	–9.2
140 cm			–8.6	–21.7	11.3	NV	NV	NV	–14.8
P6									
0 cm			–10.1	–37.6	19.1	–9.5	–32.6	18.4	–8.2
10 cm			–9.9	–25.7	10.6	NV	NV	NV	NV
30 cm			NV	NV	NV	NV	NV	NV	NV
60 cm			NV	NV	NV	NV	NV	NV	NV
S1									
Plateau	–8.1	–35.6	25.3	NV	NV	NV	–12.5	–39.1	18.1
Slope/slope high	NV	NV	NV	NV	NV	NV	–5.8	–21.7	22.3
Snow/slope low	–5.9	–35.2	24.5	NV	NV	NV	NV	NV	NV
Below/front	NV	NV	NV	NV	NV	NV	–8.0	–32.6	22.3
T1									
air	–7.3	–33.6	21.6	–9.8	–37.2	23.6	–9.2	–39.1	19.1
T2									
air	–7.9	–35.0	20.6	–10.3	–39.1	21.6	–9.8	–40.7	24.5
T3									
air	–9.2	–36.0	19.8	NV	NV	NV	–10.2	–40.7	20.2
V1									
water	–2.5	–11.9	8.4	–5.1	–11.8	20.2	NV	NV	NV
V2									
water	–10.8	–23.8	15.9	–8.0	–27.4	19.4	NV	NV	NV

were described in details in Sections 3.4 and 5.1 in Caning and Rasch (2000).

In 2001 the photo monitoring was supplemented with an extra camera taking pictures of the northernmost part of southern Zackenbergdalen. Examples of the different pictures from the cameras are given in Fig. 3.10.

Fig. 3.11 shows snow melt in Zackenbergdalen in the years 1998 – 2001. The year 2001 was on average compared to the years 1998-2000.

Active layer depth

The development of the active layer is being monitored at a horizontal, well drained *Cassiope* heath at the climate station (ZEROCALM-1) and at a southerly exposed slope with a snow patch (ZERO-

1999 Mean	1999 Min.	1999 Max.	2000 Mean	2000 Min.	2000 Max.
°C	°C	°C	°C	°C	°C
–9.3	–40.7	30.3	NV	NV	V
–8.7	–36.3	19.5	–9.4	–36.3	19.5
–8.3	–27.5	8.8	–9.0	–27.5	8.0
–8.0	–17.0	0.4	–8.1	–18.2	0.4
–7.1	–26.6	22.7	NV	NV	NV
NV	NV	NV	NV	NV	NV
NV	NV	NV	NV	NV	NV
NV	NV	NV	NV	NV	NV
–10.5	–36.8	19.8	–8.3	–39.2	32.1
–9.0	–26.5	15.6	–7.5	–28.3	21.5
NV	NV	NV	–7.4	–21.5	8.4
–10.9	–32.0	26.3	NV	NV	NV
–10.4	–28.3	14.2	–9.2	–29.4	19.1
–9.7	–19.7	1.0	–9.4	–20.5	1.7
–33.7	19.1	NV	NV	NV	
–19.6	9.5	NV	NV	NV	
–27.5	0.6	NV	NV	NV	
–32.6	24.1	NV	NV	NV	
NV	NV	NV	NV	NV	
NV	NV	NV	NV	NV	
NV	NV	NV	NV	NV	
–10.0	–39.1	33.3	–10.0	–40.7	31.1
–6.5	–17.6	24.1	–5.3	–11.2	21.6
NV	NV	NV	NV	NV	NV
–13.0	–35.0	14.5	–11.7	–36.3	16.7
–9.8	–37.6	18.4	–10.2	–39.1	24.5
–11.1	–40.7	18.8	–10.0	–36.3	20.9
NV	NV	NV	NV	NV	NV
NV	NV	NV	NV	NV	NV
NV	NV	NV	NV	NV	NV

CALM-2). ZEROCALM-1 consists of 121 measuring points in a 100 m x 100 m grid while ZEROCALM-2 consists of 208 measuring points in a 120 m x 150 m grid. A detailed description of the plots were given in section 5.1.12 in Meltofte and Thing (1997). The actual measurements of the active layer is carried out by hand using a metal spear with a centimetre division. Data from the active layer measure-

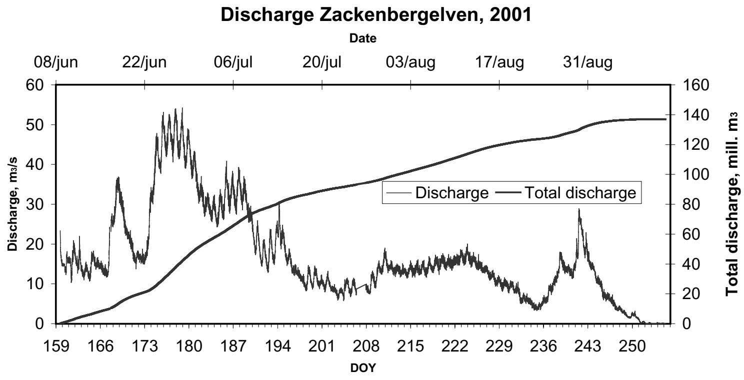
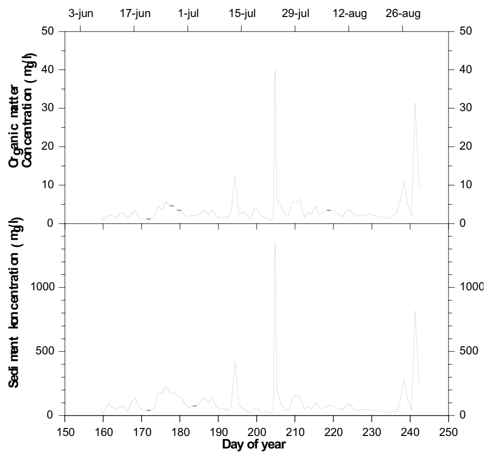


Fig. 3.8. Variation of river water discharge in Zackenbergelven, 2001.



◄ Fig. 3.9. Sediment and organic matter concentration in Zackenbergelven in 2001. There were no obvious events leading to the high sediment and organic matter concentrations on 23 July. The high concentrations might however be due to extended snow melt at the high lying plateaus due to relatively high temperatures.

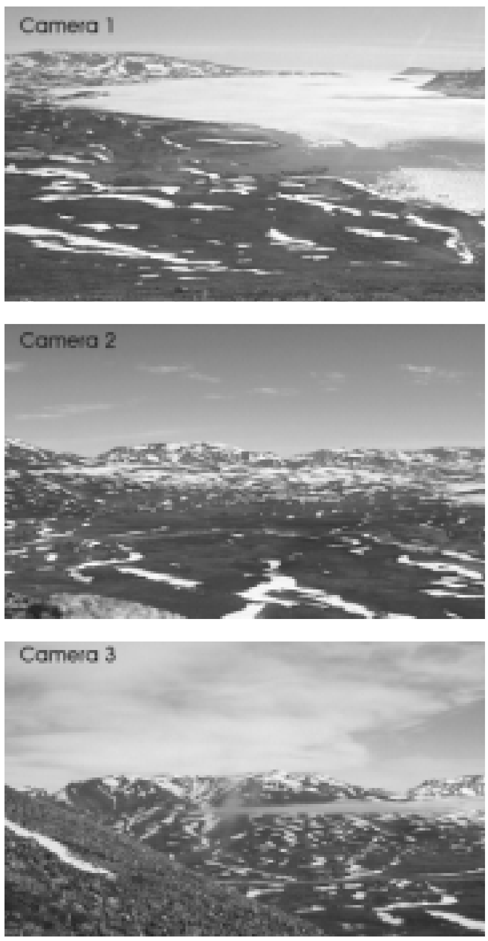


Fig. 3.10. Pictures from the three different snow monitoring cameras at Zackenberg. Together the pictures cover the lower reach of Zackenbergdalen and the eastern part of Young Sund. The pictures were taken on 6 July.

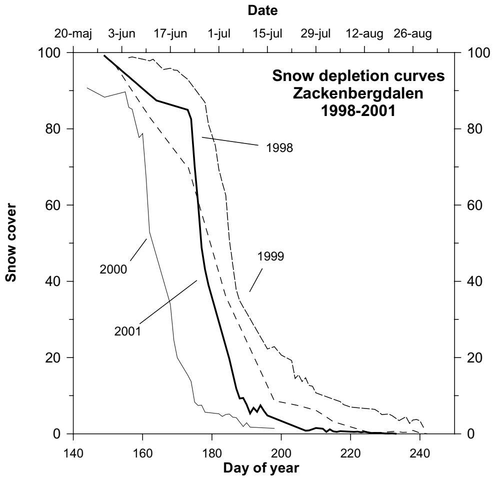


Fig. 3.11. Snow depletion curves for the southern part of Zackenbergdalen, 1998-2001.

ments are reported to the circumpolar monitoring programme CALM (Circumpolar Active Layer Monitoring) which is being run by International Permafrost Association.

Figs. 3.12 and 3.13 shows the active layer development in respectively ZEROCALM-1 and ZEROCALM-2 in the summers 1997-2001.

Figs. 3.14 and 3.15 show the 2001 situation with maximum active layer depths at the two sites, measured on 30 August 2001.

Soil water chemistry

Soil water samples are collected at different depths in the active layer at two sites. One site is situated on an *Eriophorum* fen immediately south of the ZEROCALM-2 site. At this site water is sampled from the depths 5, 10, 15, 20, 30, 40, 50 and 60 cm below the surface. The other site is situated on *Cassiope* heath close to the climate station. At this site water is sampled from the depths 5, 10, 15, 20, 30, 40, 50, 60 and 70 cm below the surface. Water samples from the two sites are analysed for pH, conductivity and alkalinity (HCO_3-concentration) in the laboratory at Zackenberg and for concentrations of Na, K, Ca, Mg, Fe, Mn, Cl, NO_3 and SO_4) in the laboratory at Institute of Geography at University of Copenhagen. A thorough description of the seasonal changes in soil water chemistry at the two sites was given in the annual report for 1999 (Caning and Rasch 2000). All water chemistry data from 2001 and earlier years (1996-2000) are available and can be ordered from Institute of Geography, University of Copenhagen (mr@geogr.ku.dk).

Coastal geomorphology

The coastal monitoring at Zackenberg comprises measurements of coastal cliff recession at four sites, measurements of the morphological changes in two cross shore profiles at a coastal spit (Fig. 3.16) and photo monitoring of dynamic coastal landscape features at different sites along the southern coast of Zackenbergdalen (Fig. 3.4.4.1 in Meltofte and Rasch (1998)). All the planned observations were performed in 2001. The landscape changes in the two cross shore profiles at the coastal spit are surprisingly small. In fact no changes of more than 15 cm (in both vertical and horizontal dimensions) has occurred since the monitoring was initiated in 1991. The results of the coastal cliff ero-

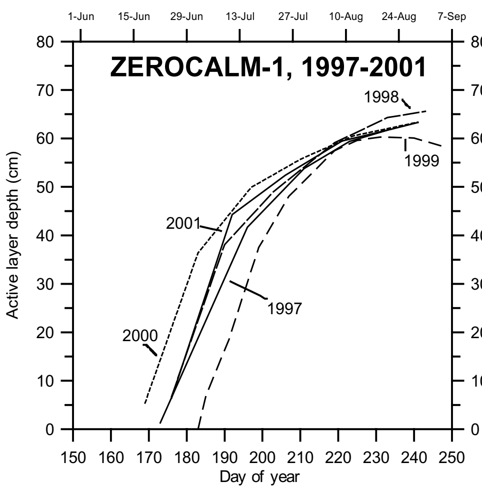


Fig. 3.12. Active layer development in ZEROCALM-1, 1997-2001.

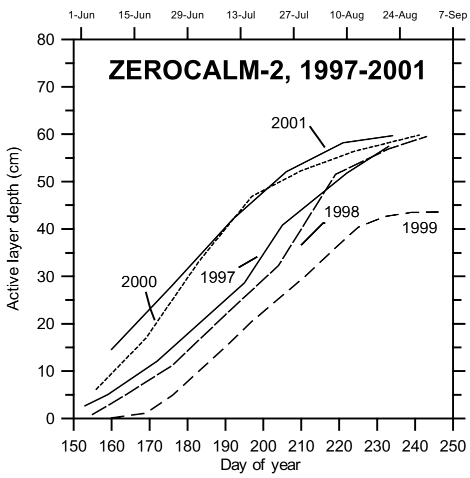


Fig. 3.13. Active layer development in ZEROCALM-2, 1997-2001.

	Recession (m)			
	Site 1	Site 2	Site 3	Site 4
1996-1997	0	0	0.3	1.0
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

Table 3.7. Total coastal cliff recession at the southern coast of Zackenbergdalen in the period 1996-2001.

sion measurements are given in Table 3.7. No coastal cliff recession was experienced in the period 2000-2001.

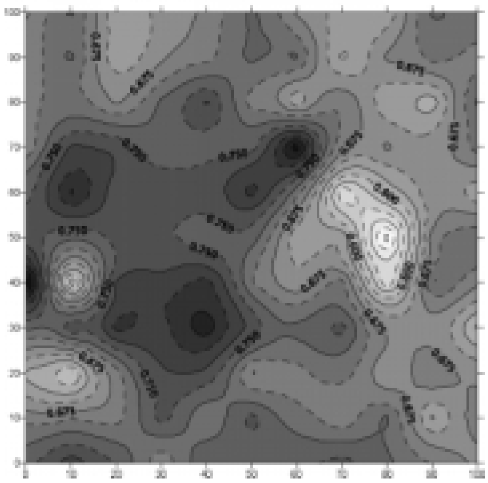


Fig. 3.14. Maximum active layer thickness in ZERO-CALM-1, 30 August 2001.

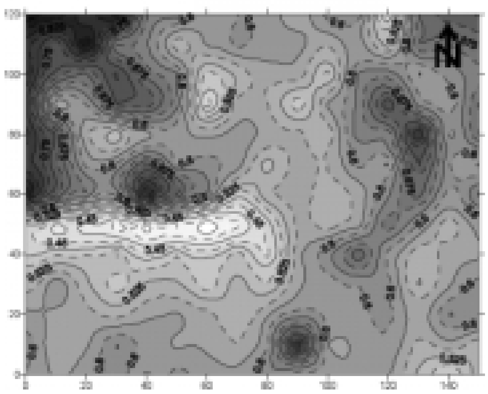


Fig. 3.15. Maximum active layer thickness in ZERO-CALM-2, 30 August 2001. In ZEROCALM-2 mean active layer depth reached its maximum (0.6 m) already on 22 August.

Block slumping in the river delta

The block slumping in the river delta that was described in the 6th ZERO Annual Report (Caning and Rasch 2001) seemed to have stabilised in 2001. New fractures occurred on the plateaus above the cliff, but no new blocks of sediment fell down. The blocks that fell down in 2000 had more or less disintegrated due to the melting of the permafrost. However, the remains of the blocks were still lying at the foot of the cliff, probably stabilising the cliff and protecting it from fluvial erosion.

Landslides

After a heavy snowfall on 15-16 June a number of major landslides took place on the high slopes of Aucellabjerg. About five slides occurred on slopes between 400 and 500 m a.s.l. and one east of Pyramiden at an altitude of 500-600 m. Each slide was estimated to be 100-200 m long, 10-30 m wide and 20-30 cm deep, forming a front in the bottom end of at least 1 m. The slides between 400 and 500 m a.s.l. took place on highly uniform slopes (c. 12-13$^1/_2$ declination) with no traces of similar slides before. The vegetation mainly consists of scattered, very old individuals of *Dryas spp*. also indicating the rare nature of the event. The slide between 500 and 600 m took place in an area with a few old slides of a similar type, but now overgrown with old individuals of *Salix arctica*, grasses etc. The soils on the slopes are clay, gravel and stones, which are almost saturated with water in June and early July and very difficult to walk on. The slides clearly took place on the surface of thawing permafrost, probably provoked by excess melt water from the newly fallen snow.

3.5 General observations on ice conditions

For practical reasons the section '*General observations on ice conditions*' has been moved to section 4.2 (in the BioBasis chapter) and renamed '*Ice conditions and streams*'.

4 Zackenberg Basic: The BioBasis programme

Hans Meltofte (editor)

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 programme Dancea – Danish Cooperation for Environment in the Arctic. The authors are solely responsible for all results and conclusions presented in the report, and 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 2001), 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.

During 2001, a preliminary analysis of the main parts of the data gathered at Zackenberg during the seven years of operation was carried out. The resulting report, in Danish, was published in early 2002 (Meltofte 2002).

4.1 Spring snow cover

Hans Meltofte and Jørgen Hinkler

The spring snow cover in BioBasis bird and mammal study areas has now been analysed for all study years based on photos from a height of 500 m on the east facing slope of Zackenbergfjeldet supplemented by satellite photos from 1995 and 1996 (Table 4.1). The data confirm prior estimates that 1995, 1996, 1997 and 1998 had relatively similar snow cover in early spring (10 June) and thereby average snow melt, while 1999 was very late, and 2000 extraordinary early (see also sections 3.1 and 3.4). In fact, 1999 was among the latest seasons during 1988-2000, as documented by satellite images, while 2000 was among the earliest (Pedersen and Hinkler 2000).

2001 was again a year of average snow cover. However, on the night of 15-16 June a snow storm raged, which covered the lowland in about 10 cm of new snow, and the higher slopes and mountains in much more. The snow in the lowland took 1-2 days to disappear from the ground, but on

Table 4.1. Snow cover on 10 June in 13 bird and mammal study sections in Zackenbergdalen and on the slopes of Aucellabjerg 1995-2001 (see Fig. 4.1 for map of sections). Photos were taken from a fixed point 500 m a.s.l. on the east facing slope of Zackenbergfjeldet within +/- 3 days of 10 June. Photos were analysed and data extrapolated according to the methods described by Pedersen and Hinkler (2000). Proportions of 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.

Region	1995	1996	1997	1998	1999	2000	2001	Area hidden (%)
1 (0-50 m)	78	74	65	77	91	60	73	3.4
2 (0-50 m)	89	88	90	85	91	57	87	1.2
3 (50-150 m)	88	81	83	83	94	51	89	0.0
4 (150-300 m)	73	74	68	66	86	33	79	0.0
5 (300-600 m)	16	54	73	43	85	31	56	0.0
6 (50-150 m)	86	86	84	87	98	55	84	75.3
7 (150-300 m)	90	81	76	90	97	54	84	69.3
8 (300-600 m)	49	55	66	64	84	37	45	27.5
9 (0-50 m)	92	87	96	91	97	54	96	6.2
10 (50-150 m)	94	85	95	97	98	60	97	2.9
11 (150-300 m)	91	72	86	92	96	77*	97	0.2
12 (300-600 m)	40	66	89	68	89	65	73	0.0
13 (Lemmings)	89	80	76	80	87	58	83	1.0
Total	**76**	**77**	**81**	**80**	**92**	**54**	**82**	12.9

* Partly cloud covered, giving too high snow cover

	1995	1996	1997	1998	1999	2000	2001
West pond		4.6	Dry	5.6	10.6	30.5	8.6
East pond		3.6	Dry	6.6	16.6	1.6	6.6
South pond		<3.6	30.5	7.6	12.6	1.6	8.6
Lomsø		4.7	2.7	8.7	10.7	1.7	4.7
Rivulets		6.6	11.6	11.6	15.6	4.6	10.6
Zackenbergelven	<26.5	<3.6	4.6	10.6	20.6	8.6	8.6
Young Sund (Zac.)		13.7	19.7	14.7	14.7	8.7	13.7
Young Sund (all)	12.7	13.7	22.7	22.7	24.7	17.7	23.7

Table 4.2. Visually estimated dates of 50% ice cover on selected ponds and lakes around the research station, together with dates for start of running water in rivers and break up of the fjord ice in Young Sund. "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 major flow in the river, and Young Sund is divided between break up of the fjord ice off Zackenbergdalen and in all of the fjord. The 50% ice cover date for Lomsø is tentative, as it is estimated from the research station.

the higher slopes – i.e. above 300 m on Aucellabjerg – it took about a week.

4.2 Ice conditions and streams

Hans Meltofte

The melt of the ice on the ponds north and south of the research station and on Lomsø was close to average, and so was the start of running water in the rivulets from Aucellabjerg (Table 4.2). Only a few square meters of open water were present in the eastern pond in Gadekæret, when we arrived on 31 May, but heavy thaw occurred during early June, and around 10 June most ponds were more or less ice-free. In connection with the snow storm on 16 June, most ponds were partly covered in slush, which soon melted away. Due to the very dry weather during the rest of June and all of July, the most shallow ponds south of the station started to dry up during late July, but rain in late August 'filled' them up again.

On 27 June the shallow parts of Lomsø were ice-free. The remaining ice broke up on 8 July and on 12 July it had all gone. The ice melt on Sommerfuglesø and Langemandssø in Morænebakkerne was relatively early (see Table 4.46). On 10 July, more than 95% of Store Sø was still ice-covered, but on 20 July only 40% remained, and it had all gone by 30 July.

On 7 June, Aucellaelv and some of the streams north-west of the river had started to run, and on 10 June, both Ræveelv, Tørveelv, Kærelv and Grænseelv were running, so that Rylekærene were inundated. The usual 'flood wave' in Zackenbergelven passed the research station on 8 June, which is neither early, nor particularly late (Table 4.2).

When we flew up to Zackenberg on 31 May it was estimated that the edge of fast ice was 3-5 km east of Sandøen. From late June, an open water area formed in Young Sund off Zackenbergelven, and during early July it developed into an area of more than 1 km^2. On 11 July the fjord ice off Zackenbergdalen started to break up, but though it had broken up fully on 13 July, not much open water was seen until 16 July. On the next day it had broken up almost out to Basaltø, but the ice in the outer part of the fjord did not break up until six days later (Table 4.2). On 11 August, much polar drift ice entered Young Sund as far as Lille Sødal and Basaltø, where it remained for almost a week.

4.3 Vegetation

Hans Meltofte, Mikkel Tamstorf, Henrik Søgaard, Morten Rasch and Jens Søndergaard

The weekly records on amounts and phenology of flowering etc. were made by Claus Bang-Berthelsen during the entire season.

Reproductive phenology

Snowmelt in the flowering plots was much like 1996 and 1997 (Table 4.3 and Table 4.1 in Caning and Rasch 2001), i.e. close to 'average' and in good accordance with the general snow patterns (see section 4.1). The timing of flowering differed somewhat between the species and populations. The early snow free populations of purple saxifrage, arctic willow, mountain avens and moss campion tended to be a bit later than 1996 and 1997, and the more snow covered populations of these and the remaining species were generally between these two years (Table 4.4).

A preliminary analysis of our data shows that mountain avens and purple

	50% snow	50% flowers	50% senes.	50% open
Cassiope 1	7.6	4.7	23.7	
Cassiope 2	21.6	12.7	26.7	
Cassiope 3	20.6	11.7	25.7	
Cassiope 4	21.6	19.7	29.7	
Dryas 1	<31.5	22.6	1.7	
Dryas 2	3.7	1.8	7.8	
Dryas 3	6.6	6.7	14.7	
Dryas 4	7.6	6.7	15.7	
Dryas 5	5.6	5.7	14.7	
Dryas 6	28.6	29.7	8.8	
Papaver 1	20.6	12.7	1.8	16.8
Papaver 2	21.6	14.7	29.7	16.8
Papaver 3	21.6	17.7	1.8	18.8
Papaver 4	27.6	(27.7)	9.8	24.8
Salix 1	<31.5	8.6		2.8
Salix 2	21.6	29.6		18.8
Salix 3	7.6	24.6		14.8
Salix 4	11.6	28.6		13.8
Saxifraga 1	<31.5	8.6	20.6	8.8
Saxifraga 2	<31.5	8.6	21.6	14.8
Saxifraga 3	(27.5)	9.6	22.6	13.8
Silene 1	<31.5	28.6	11.7	
Silene 2	<31.5	30.6	14.7	
Silene 3	(27.5)	4.7	19.7	
Silene 4	28.6	29.7	11.8	

Table 4.3. Inter- and extrapolated dates of 50% snow cover, 50% open flowers (50/50 ratio of buds/open flowers), 50% senescent flowers and 50% open seed capsules 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 *2001. Interpolations based on samples of less than 50 buds/flowers are given in brackets.*

saxifrage apparently compensate for a late snowmelt by using fewer days from snowmelt to flowering in late years, while arctic poppy is unable to compensate. However, the latter species can shorten the time period from flowering until opening of the seed capsules in late years (Mølgaard *et al.* 2002).

Quantitative flowering

2001 was a year of many flowers (Table 4.5). This may be the result of the very early snowmelt in 2000, when these species develop flower buds (Mølgaard *et al.* 2002). Particularly white arctic bell-heather recovered after three years of poor flowering.

Only one female arctic willow pod in our *Salix* plots was infested by fungus this year (Table 4.6).

Berry production

For the first time since the plots were established in 1998, there was a considerable production of crowberries (Table 4.7). Also alpine bearberry saw a good season, whereas arctic blueberry production was absent.

NDVI in flower plots

As is probably normal, peak NDVI-values for the 26 flower plots were reached in late July or early August in most of the plots (Table 4.8). In accordance with the measurements from satellite images, the peak indices were much lower than in the very early snow free season of 2000, but also lower than in the very late season of 1999. We have no apparent explanation for this latter discrepancy.

NDVI in bird and mammal study plots

A SPOT 4 satellite image from 31 July 2001 was analysed for Normalised Difference Vegetation Indices (NDVI) by the National Environmental Research Institute, Department for Arctic Environment, after an agreement with Asiaq (Greenland Field Investigations). The analyses were funded by Dancea, the Environmental Protection Agency, Ministry of Environment, Denmark.

Data for 2001 are presented in Table 4.9, and in Table 4.10 they are compared with previous years (see Fig. 4.1 for location of sections). All mean values from 2001 were lower than values for 2000 but higher than values for 1999, a year with very late snowmelt. Sections 10 and 11 experienced maximum values of NDVI at 1.0, which has only occured rarely since 1995.

According to the plot measurements, 31 July 2001 was close to peak greening in most plant communities (see chapter above). The NDVI data for all the regions based on the 31 July values from 1995 to 2001 show that the 1999 values were exceptionally low (Table 4.10). 2000 had earlier snowmelt than the seasons of 1995-1998, but this did not result in significantly higher NDVI values for the monitored areas (Tamstorf and Bay 2002). Hence, it seems that a late snowmelt can influence the NDVI in a negative direction (e.g. 1999), while an earlier than normal snowmelt will not result in higher NDVI values (e.g. 2000). The reason for the low values in 2001 as compared to most values of 1995-98 and 2000 may be related to the snowfall in mid June.

Table 4.4. Inter- and extrapolated dates of 50% 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 *for flower plots 1996-2001. Interpolations based on samples of less than 50 buds/flowers are given in brackets.*

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

Summertime carbon budget for the Zackenberg heath

During June-August 2001, the measurements of carbon dioxide exchange were continued at the Zackenberg heath site about 100 m north of the climate station. This monitoring is run in co-operation between the National Environmental Research Institute and the Institute of Geography, University of Copenhagen. During the field season, the equipment is serviced by GeoBasis personnel. In 2001, the eddy correlation measurements were initiated on 8 June and continued until 27 August without interruptions.

The instrumentation for measuring the vertical fluxes of water vapour and carbon dioxide consists of a three-dimensional (3-D) sonic anemometer (Solent 1012R2, Gill Instruments, Lymington, UK) for measuring wind speed and direction together with an Infrared Gas Analyzer (IRGA) (Li-6262, LI-COR, Nebraska, USA) measuring water vapour and carbon dioxide concentrations.

The sonic anemometer and the sampling tube inlet of the IRGA are situated 3 m above ground level. Data collecting and processing is based on the Edisol software package (Moncrieff *et al.* 1997). As a supplement to the atmospheric fluxes, a number of micro-meteorological parameters are measured simultaneously. These data include air temperature and air humidity (MP100A, Rotronic, Campbell scientific. LTD, UK), soil temperature (thermocouple), IR surface/canopy temperature (KT-17, Heimann, Germany), soil moisture (Delta-T Cambridge, UK).

Fig. 4.2 shows the temporal variation in daily air temperature and the daily net exchange of CO_2 also denoted the Net Ecosystem Exchange (NEE). Here, the

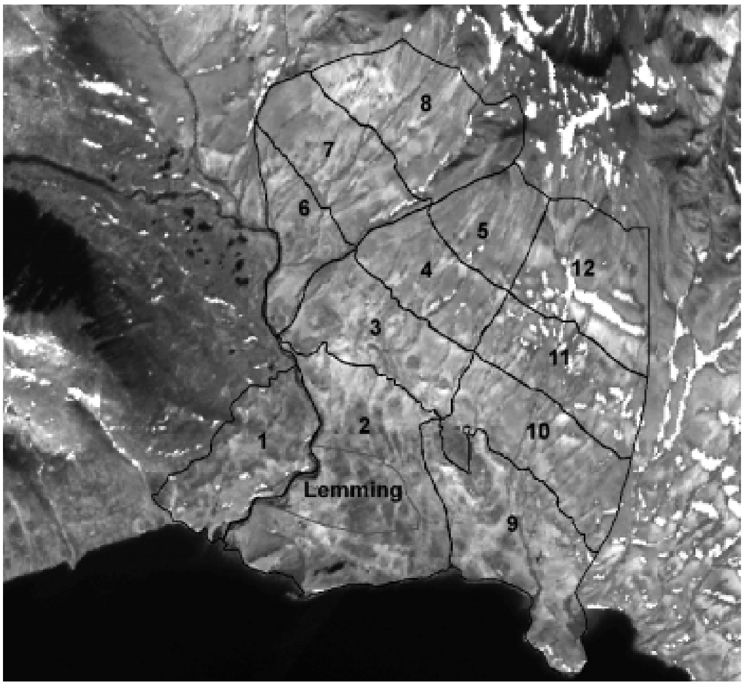


Fig. 4.1. Sections 1-13 of the bird and musk ox monitoring area. The lemming monitoring area (no. 13) is included in section 2. The areas are shown on a b/w view of the near-infrared channel from a SPOT HRV image from 31 July 2001.

Table 4.5. 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 *(corrected data for 1996) and 'dark cotton-grass'* Eriophorum triste *in flower plots in 1995-2001. Numbers in brackets have been extrapolated from 1995 and 1996 data to make up for enlarged plots (see Meltofte and Rasch 1998).*

Plot no.	Area	1995	1996	1997	1998	1999	2000	2001
Cassiope 1	2	1321	1386	1855	322	312	28	1711
Cassiope 2	3		1759	550	19	16	8	1353
Cassiope 3	2	256	844	789	35	18	0	771
Cassiope 4	3	456	1789	391	24	6	3	578
Cassiope 5	2.5			1224	455	474	50	3214
Cassiope 6	2			>350	16	3	1	544
Dryas 1	4	(936)	(797)	138	223	852	607	1016
Dryas 2	60	534	1073	230	42	49	46	172
Dryas 3	2	603	522	123	255	437	266	577
Dryas 4	6	(325)	(164)	155	69	356	55	301
Dryas 5	6	(654)	(504)	123	191	655	312	506
Dryas 6	91	809	1406	691	10	25	140	550
Dryas 7	12			787	581	1355	574	1340
Dryas 8	12			391	240	798	170	403
Papaver 1	105	302	337	265	190	220	197	237
Papaver 2	150	814	545	848	316	315	236	466
Papaver 3	90	334	238	289	266	183	240	259
Papaver 4	91	196	169	192	80	30	35	65
Salix 1 mm.	60		807	959	63	954	681	536
Salix 1 ff.		520	1096	1349	149	1207	900	1047
Salix 2 mm.	300		790	1082	132	416	55	803
Salix 2 ff.		617	1376	1909	455	418	95	1304
Salix 3 mm.	36	239	479	412	32	52	330	1196
Salix 3 ff.		253	268	237	38	68	137	1009
Salix 4 mm.	150		1314	831	509	718	965	680
Salix 4 ff.		1073	1145	642	709	880	796	858
Saxifraga 1	7		(1010)	141	163	584	1552	558
Saxifraga 2	6		513	387	432	158	387	515
Saxifraga 3	10		529	322	288	707	403	558
Silene 1	7		(251)	403	437	993	1327	674
Silene 2	6		493	524	440	400	692	568
Silene 3	10		348	211	127	313	274	348
Silene 4	1	466	270	493	312	275	358	462
E. scheuz. 1	10		395	423	257	309	229	111
E. scheuz. 2	6		537	344	172	184	201	358
E. scheuz. 3	10		392	545	482	587	38	367
E. scheuz. 4	8		260	755	179	515	117	121
E. triste 1	10		0	3	1	1	1	0
E. triste 2	6		98	59	21	16	43	56
E. triste 3	10		0	0	0	0	0	0
E. triste 4	8		0	0	0	0	0	0

daily values are expressed as g C per m^2 / d. Fluxes directed towards the surface are given with negative sign whereas upward directed fluxes are given as positive figures. Basically, the net carbon budget consists of two main components, i.e. the CO_2 uptake caused by photosynthesis and the CO_2 emission from the soil mostly due to microbial activity in the upper 5 cm of the soil, i.e. soil respiration in combination with plant root respiration. Besides weather conditions, the carbon assimilation depends on the amount and type of vegetation. Around the mast, the dominant species is white arctic bell-heather *Cassiope tetragona*. The leaf area index is relatively low (0.2-0.3). Soil respiration is controlled by the amount of organic matter in the topsoil and increases exponentially with the soil temperature.

The data collection started at the end of the winter, where the ground was snow covered and the air temperature around zero. A slight CO_2 emission is found, because photosynthesis is small compared to the soil respiration. The main snowmelt on the heath took place during the last week of June (day numbers 174-181). Due to release of CO_2 from below the snow and the subsequent heating of the surface the CO_2 emission from the soil increased rapidly. By comparison with the temperature plot it is found that there is a strong correlation between air temperature and CO_2 emission rates. This period lasted until 6 July.

During the summertime period, daily net accumulation rates were around 0.9 g C per m^2/d, only interrupted on a couple of occasions with bad weather, where the net exchange could even reverse and the ecosystem function as a carbon source. For dwarf shrub vegetation it has previously been reported that there is a very rapid transition from winter to summer conditions. Comparing the course of the air temperature and the course of the CO_2 exchange, it seems that the onset of the CO_2 accumulation was triggered by a warm period during the early part of July (day numbers 185-198) having air temperatures around 6-7°C for several days.

The end of August was characterised by carbon loss. The transition from summer to autumn in terms of carbon sink/source took place around 18 August. Due to exceptionally high temperatures at the end of August, the soil respiration rate was high and reached, in fact, the absolute maximum (0.9 g C per m^2/d) by day 238.

The more general trend in the seasonal variation is summarised in Table 4.11, where results from 2001 are compared with results from the same site during previous years. Compared to year 1997 and year 2000, the summer season of 2001 was intermediate. The total budget for June-August shows a net accumulation in the order of (–) 8.7 g C per m^2 against (–) 3.1 C per m^2 in 1997 and (–) 19.1 C per m^2 in 2000.

From a technical viewpoint the collection of flux data within the BioBasis programme was a success in 2001. More than 1900 hours of consistent flux measurements were collected, and less than 2% were lost due to malfunction, maintenance and calibration procedures.

A more comprehensive analysis and discussion of the results from the three years has been presented by Søgaard (2002).

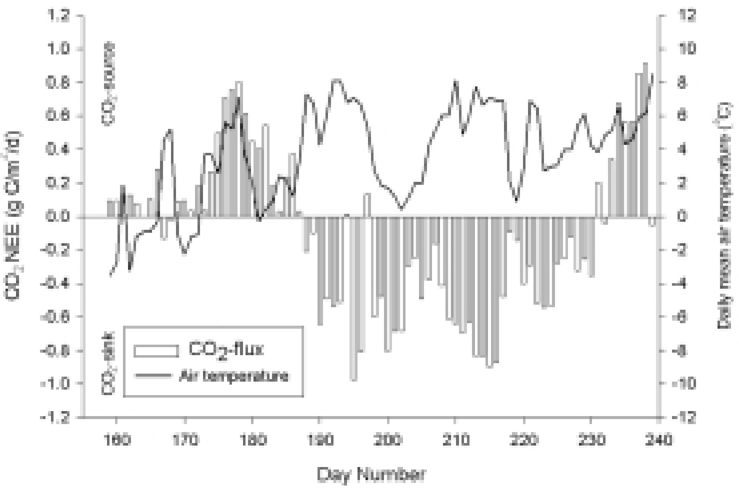


Fig. 4.2. Temporal variation in daily carbon dioxide exchange and mean air temperature on the Cassiope *heath north of the climate station in 2001.*

4.4 Arthropods

Helle Hansen and Hans Meltofte

During the 2001 season, the five yellow pitfall trap stations and the two window traps were operated in the same way as in 1999 and 2000. Sampling was performed

Table 4.6. Peak ratio of female Salix *pods infested by fungi in* Salix *plots in 1996-2001.*

Plot	1996	1997	1998	1999	2000	2001
Salix 1	5	4	0	22	4	1
Salix 2	0	1	2	2	0	0
Salix 3	0	0	0	6	0	0
Salix 4	16	3	0	6	0	0

Table 4.7. Area size (m^2) and numbers of berries recorded in alpine bearberry Arctostaphylos alpina*, Arctic blueberry* Vaccinium uliginosum *and crowberry* Empetrum nigrum *plots in 1998-2001.*

Species	Area	1998	1999	2000	2001
Arctostaphylos alpina	6	365	455	36	249
Vaccinium uliginosum	4	240	532	9	0
Empetrum nigrum	4	27	1	17	3081

Plot no.	1999		2000		2001	
	NDVI	Date	NDVI	Date	NDVI	Date
Cassiope 1	0.40	29.7	0.41	29.7	0.37	5.8
Cassiope 2	0.41	29.7	0.46	22.7	0.38	22.7
Cassiope 3	0.41	19.8	0.37	12.8	0.33	5.8
Cassiope 4	0.38	26.8	0.41	22.7	0.35	29.7
Dryas 1	0.43	22.7	0.41	22.7	0.37	22.7
Dryas 2	0.39	19.8	0.42	22.7	0.39	29.7
Dryas 3	0.45	29.7	0.45	22.7	0.42	26.7
Dryas 4	0.34	19.8	0.32	22.7	0.33	22.7
Dryas 5	0.34	29.7	0.33	22.7	0.31	22.7
Dryas 6	0.35	26.8	0.41	22.7	0.34	26.7
Papaver 1	0.41	19.8	0.41	22.7	0.38	29.7
Papaver 2	0.44	19.8	0.45	22.7	0.41	29.7
Papaver 3	0.37	26.8	0.41	22.7	0.35	29.7
Papaver 4	0.35	26.8	0.41	22.7	0.34	26.7
Salix 1	0.57	29.7	0.59	22.7	0.54	8.7
Salix 2	0.52	29.7	0.52	22.7	0.49	29.7
Salix 3	0.41	29.7	0.44	22.7	0.39	29.7
Salix 4	0.46	29.7	0.47	22.7	0.43	2.8
Saxifraga/Silene 1	0.28	29.7	0.34	7.8	0.27	8.7
Saxifraga/Silene 2	0.36	29.7	0.38	22.7	0.34	19.7
Saxifraga/Silene 3	0.23	29.7	0.26	22.7	0.27	15.7
Silene 4	0.32	26.8	0.36	22.7	0.27	29.7
Eriophorum 1	0.57	5.8	0.60	14.7	0.60	29.7
Eriophorum 2	0.58	29.7	0.58	22.7	0.53	26.7
Eriophorum 3	0.54	19.8	0.56	22.7	0.47	29.7
Eriophorum 4	0.73	5.8	0.72	22.7	0.68	29.7

Table 4.8. Peak Normalised Difference Vegetation Indexes (NDVI) recorded in the flower plots in 1999-2001 together with date of maximum record. NDVI values presented are transformed averages of eight (four in very small plots) 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.

by Claus Bang-Berthelsen. Helle Hansen sorted the main part of the material. All sorted material is kept in 70% alcohol at the Zoological Museum, University of Copenhagen.

Snow and ice melt in most arthropod plots was close to the 'normal' years of 1997 and 1998 (Table 4.12). The number of arthropods collected this year (51,973) was lover than last year (75,932). For a possible explanation of this, see Larsen (2002). As in 1999 (in contrast to the first years) Ceratopogonidae was seperated from Chironomidae, Sciaridae from Mycetophiliidae and Anthomyiidae from Muscidae.

Window traps

The two window traps were opened on 3 June and remained open continuously until 26 August. Catches from the two traps were pooled and the catches from each week in the 2001 field season are presented in Table 4.13 together with total catches from 1996-2000.

In 2001, a single addition was made to the fauna list of the window traps, when two Aphidoidea were found, a taxon normally only found in the pitfall traps.

In 1996-1998, Sciaridae was not separated from Mycetophiliidae, and in 2000 there seems to have been difficulties differentiating these taxa. In 1999 and 2001 Mycetophiliidae made up less than 10% and less than 40%, respectively, of the Mycetophiliidae / Sciaridae complex, while in 2000 the Mycetophiliidae / Sciaridae complex consisted of 90% Mycetophiliidae. This may indicate that the number of Sciaridae was underestimated in 2000.

The total number of individuals caught this year (8162) seems to be in line with the average catches from the previous years. 1418 Nematocera were unidentifiable this year due to bad condition (missing wings and other body parts) of the samples. We expect the main part of these to be Chironomids. Chironomidae normally make up the bulk of specimens. This year, they constituted about 65% of the sample compared to 80% last year.

Pitfall traps

All pitfall traps were put in place at the end of the 2000 season and were activated as soon as the ground was snow free. The first traps were opened on 3 June and all traps were active on 24 June. They all remained open until 26 August, and no traps were disturbed by foxes or musk oxen. However, a lemming had defecated in a trap on 17 June. The total numbers of arthropods caught each week during the field season are presented in Table 4.14, where total catches from 1996-2000 are also given for comparison.

The number of individuals caught this year (43,811) is in line with average catches from the previous years, but far below the record year 2000 (65,344). Again, it is the taxa with many individuals that make the big difference, especially Muscidae, Acarina and Collembola.

In 2001, the taxon diversity was higher than the first three years but almost the same as in the previous three years. In 1996-1998, Ceratopogonidae was not separated from Chironomidae and Sciaridae not from Mycetophiliidae, and in 2000 there seems to have been difficulties differentiating these taxa. We expect that the number of Sciaridae normally make up the main part for the Mycetophiliidae / Sciaridae complex, since they made up 80% in 1999 and 76% in 2001. In the pitfall traps, compared to the window traps, the number of Ceratopogonidae is insignificant compared to the number of Chironomidae, but they are probably present in most years.

One addition to the fauna list was made in 2001, when a single adult specimen of the family Tortricidae was found on 15 July. The larvae of Tortricidae often live in the cavity of rolled up leaves (spun together with silk), and the family includes many pests. The species is probably not uncommon in the area, but not prone to fall into the traps.

Tardigradae was found for the second time (also found in 1999), and was represented with two specimens both found on 8 July in Plot 2 situated in a fen. *Nysius groenlandicus*, a species that is not found every year, was represented with two specimens this year. An all time high of 40 specimens was found in 1996.

The number of *Clossiana* sp. in the plots seems to have declined rapidly since the initial season of 1996 (1052 specimens) and a minor peak in 2000 (329 specimens). This year, only 49 specimens were found. *Colias hecla* seems to fluctuate less, but also with peaks in 1996 (88) and 2000 (77). No specimens of this species were caught this year, but several were observed (see below).

A total of 41 taxa (including larvae) was found this year, and the accumulation during the season is presented in Fig. 4.4. Most taxa appear before mid July. The total number of taxa caught in pitfall traps is now 48 with 33 in the first year, and the rest added consecutively during the years.

Section	Min.	Max.	Mean	Std. Dev.
1 (0-50 m)	0.00	0.81	0.34	0.18
2 (0-50 m)	0.00	0.80	0.43	0.18
3 (50-150 m)	0.00	0.78	0.47	0.15
4 (150-300 m)	0.00	0.76	0.36	0.16
5 (300-600 m)	0.00	0.74	0.26	0.16
6 (50-150 m)	0.00	0.68	0.39	0.17
7 (150-300 m)	0.00	0.70	0.38	0.17
8 (300-600 m)	0.00	0.97	0.28	0.21
9 (0-50 m)	0.00	0.76	0.44	0.17
10 (50-150 m)	0.00	1.00	0.48	0.14
11 (150-300 m)	0.00	1.00	0.35	0.19
12 (300-600 m)	0.00	0.90	0.34	0.22
13 (Lemmings)	0.00	0.78	0.41	0.15
Total	**0.00**	**0.82**	**0.38**	**0.17**

Table 4.9. 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 SPOT 4 HRV satellite image from 31 July 2001 (see Fig. 4.1 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, giving water and snow covered areas similar values from year to year.

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

As in 2000, no larvae of *Sympistis zetterstedtii* were encountered in the *Dryas* study plots in 2001, and no depredation was recorded during the season (Table 4.15).

Woolly-bear caterpillars *Gynaephora groenlandica* were not recorded inside the *Salix arctica* plots this year, and the bird census worker encountered only four larvae during June and July (Table 4.16).

Sawfly Tenthredinidae larvae were not found this year in ripe female *Salix* pods (Table 4.17).

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

Table 4.10. 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 and SPOT 4 HRV satellite images 1998-2001 (see Fig. 4.1 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.

Table 4.11. General characteristics of the CO_2 exchange on the Cassiope heath north of the climate station in 1997, 2000 and 2001.

Year	1997	2000	2001
Beginning of growing season	7.7	25.6	6.7
End of growing season	21.8	11.8	18.8
Length of growing season	46 days	47 days	43 days
Beginning of measuring season	7.6	6.6	8.6
End of measuring season	25.8	25.8	27.8
Length of measuring season	80 days	81 days	81 days
NEE for growing season (g C/m^2)	(–) 12.5	(–) 22.7	(–) 19.1
NEE for whole measuring season (g C/m^2)	(–) 3.1	(–) 19.1	(–) 8.73
Avg peak daily accumulation (g C/m^2/d)	(–) 0.65	(–) 0.92	(–) 0.94

Bumblebees and butterflies

The first bumblebee *Bombus polaris/hyperboreus* was recorded on 7 June. During bird census work in June, a total of only 12 individuals were recorded by Hans Meltofte and a further 15 in July (for effort, see Table 4.19). These are much lower figures than in the previous two years (Table 4.18).

During the line transects in mid July, six bumblebees were seen in Store Sødal (three queens and three workers), but none between Daneborg and Zackenberg.

For the first time, fritillary *Clossiana* sp. and arctic clouded yellow butterflies *Colias hecla* were recorded systematically during bird census work in June and July. The first fritillary was seen on 9 June and the first arctic clouded yellow on 29 June. The date for fritillary is the earliest so far, compared to the years 1996-2000, when first observation dates ranged between 10 and 19 June for fritillary and between 26 June and 9 July for arctic clouded yellow. Total numbers seen were 14 fritillary in June and 64 in July together with one arctic clouded yellow in June and 29 in July (see also catches presented above).

Table 4.12. Date of 50% snow-cover (ice cover on pond at Station 1) in the arthropod plots 1996-2001.

Station no.	1996	1997	1998	1999	2000	2001
1	3.6	Dry	6.6	16.6	1.6	6.6
2	<3.6*	28.5	29.5	8.6	<4.6*	<31.5*
3	14.6	19.6	18.6	27.6	9.6	19.6
4	14.6	22.6	26.6	2.7	7.6	21.6
5	4.6	<29.5*	1.6	12.6	<4.6*	8.6
7	-	-	-	<3.6	<4.6*	<30.5**

* 0% snow
** 25% on 3 June

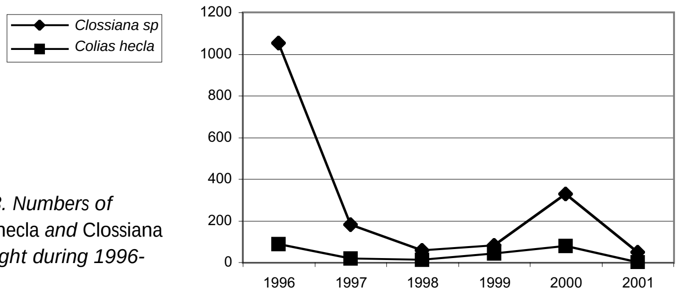


Fig. 4.3. Numbers of *Colias hecla* and *Clossiana* sp. caught during 1996-2001.

4.5 Birds

Hans Meltofte

Bird observations were recorded by the author during 31 May – 2 August and by Thomas B.G. Berg during 2 August – 30 August. Valuable observations were provided by several other researchers and staff during the entire season.

During June, the main effort was to census the breeding birds in the 19 km^2 census area in Zackenbergdalen, while in July emphasis was on breeding phenology, *i.e.* finding nests and young and rechecking these. During late July and all of August, waders and other waterbirds were counted every third day in the recent and the old delta of Zackenbergelven.

For scientific names in this chapter, see section on Other observations.

Breeding populations

The 18.8 km^2 census area in Zackenbergdalen was covered on almost daily trips between mid June and late July (Table 4.19). The effort in both June and July was similar to recent years. The initial complete census of waders took place beteeen 12 and 26 June. During the period 13-21 June inclement weather prevailed, which hampered the census considerably. The upper slopes of Aucellabjerg were covered in new snow for about one week after the snow storm on 16 June (see section 4.1 and sections below), hence the area above 300 m a.s.l. was not censused until 4 July, when the situation had settled. In total, the initial census took 48 hours to complete; of which 6,5 hours were spent censusing the higher slopes on 4 July including the walk up and down. The timing for the censuses was analysed and discussed by Meltofte (2001).

Based on records made during the initial census supplemented by records during the rest of the season (see Meltofte and Berg 2001), population estimates for five sections of the census area are presented in Table 4.20. Since most of the census was performed during the days after the snow storm, many birds were not settled, and several individuals especially from the upper slopes rambled in the lowland. Therefore, a number of 'stray' birds recorded in the lowland were omitted from the totals, relative to the numbers found later on the upper slopes. This applies especially to 12 single common ringed plovers recorded below 100 m a.s.l., but also to a few sanderlings and dunlins.

Most populations were within the range estimated for previous years, except for dunlin that seems to have increased during 1996-2001 (Table 4.21). Like in 2000, the ptarmigan population was low, but a number of broods were recorded west of the census area (see Other observations below). The European golden plover territory was based on an alarm calling bird on 26 June, and no birds were found on the site later (see Other observations).

Reproductive phenology in waders

The snow cover in early June 2001 was close to average in Zackenbergdalen (see Table 4.1), so start of egg laying could be expected to peak in mid-June. Due to the snow storm on 16 June almost all waders lost their initial clutches (see next section). Since this was when most waders probably either had started or was just about to start egg laying, the original timing of egg laying can not be documented. Instead, the data presented in Table 4.22 are highly dominated by replacement clutches initiated 6-12 days after the snow storm (relaying after predation may also be involved for course). Only the four clutches of common ringed plover, one red knot clutch from 17 June, five sanderling clutches from 10, 13, 14, 17 and 18 June, one dunlin clutch from 16 June and three ruddy turnstone clutches from 16, 20 and 20 June, respectively, represent original clutches and are indicative of the 'true' timing of egg laying.

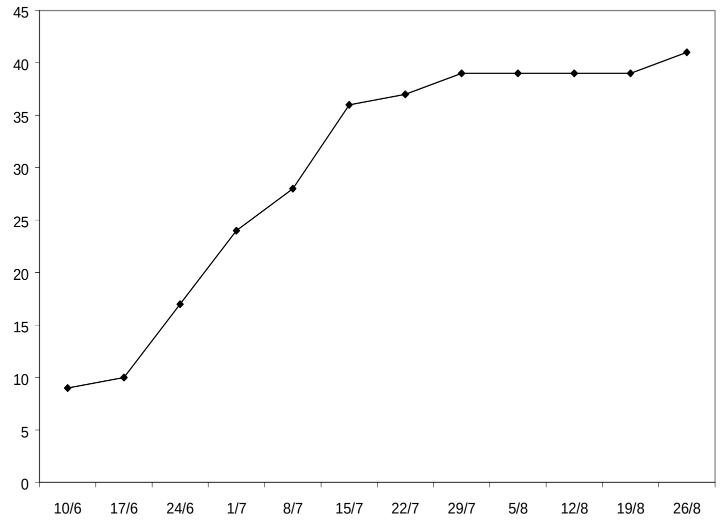


Fig. 4.4. Cumulated numbers of new taxa during the 2001 season. Taxa include larval stages of Chironomidae etc.

Breeding success in waders

Most waders probably had initiated or were just about to initiate egg laying, when poor weather prevailed during 13 to 21 June, culminating with a snow storm during the night of 15-16 June. The ground was covered with about 10 cm of new snow that took 1-2 days to melt in the lowland, but about a week on the higher slopes, where the cover may have been considerable thicker. Up to 33 red knots gathered in the communal feeding area in Gadekæret on 16 June, and several remained in flocks until at least 21 June. Many other waders rambled in the valley or gathered in smaller flocks (see section on Other observations). Several may have died, such as one dunlin found dead already on 16 June (see Other observations). During the following period, one fresh ruddy turnstone egg and one fresh dunlin egg were found at random on the ground, and many more may have gone unnoticed or were taken by foxes etc.

Out of a total of 43 clutches and broods found during the season only one common ringed plover, three sanderling, one dunlin and one ruddy turnstone clutch had been initiated before or during the snow storm (see section above). The others were either initiated shortly after the storm or – more frequently – were replacement clutches initiated 6-12 days after the loss of the original clutch. The

Table 4.13. Weekly totals of arthropods etc. caught at the window trap station in 2001. The station holds two window traps situated perpendicular to each other. Each window measures 20 x 20 cm. Values from each date represents catches from the previous week. Totals from 1996-2000 are given for comparison. An asterisk marks that the group was not separated from a related group in that year.

DATE	**10.6**	**17.6**	**24.6**	**1.7**	**8.7**	**14.7**	**22.7**	**29.7**	**5.8**	**12.8**	**19.8**
No. of trap days	14	14	14	14	14	14	14	14	14	14	14
COLLEMBOLA	1	14	0	12	21	18	11	10	9	4	9
COLEOPTERA											
Latridius minutus	0	0	0	0	0	0	0	0	0	0	0
HEMIPTERA											
Nysius groenlandicus	0	0	0	0	0	0	0	0	0	0	0
Aphidoidea	0	0	0	0	0	0	0	0	1	0	0
Coccoidea	0	0	0	0	0	0	0	0	0	0	0
THYSANOPTERA	0	0	0	1	0	0	0	0	0	0	0
LEPIDOPTERA											
Colias hecla	0	0	0	0	0	0	0	0	0	0	0
Clossiana sp.	0	0	0	0	0	0	0	1	0	0	0
Noctuidae	0	0	0	0	0	0	0	0	0	0	0
Geometridae	0	0	0	0	0	0	0	0	3	0	0
DIPTERA											
Nematocera larvae	0	0	0	0	0	0	0	0	0	0	0
Nematocera undet.	0	0	0	1300	20	0	0	0	98	0	0
Tipulidae	0	0	0	0	0	0	0	0	0	0	0
Trichoceridae	0	0	0	0	0	0	0	0	0	0	0
Culicidae	0	0	0	12	15	77	20	38	41	6	0
Ceratopogonidae	0	0	0	118	21	7	3	3	11	2	3
Chironomidae	14	12	626	1617	517	403	96	258	224	58	41
Cecidomyiidae	0	0	0	4	0	0	0	0	0	0	0
Mycetophiliidae	0	0	0	0	0	4	3	5	10	1	0
Sciaridae	0	0	0	19	2	4	3	3	1	0	1
Empididae	0	0	0	0	0	0	0	1	3	2	2
Phoridae	1	0	0	0	0	0	0	0	0	0	0
Syrphidae	0	0	0	0	0	2	0	0	0	2	0
Agromyzidae	0	0	0	0	0	0	0	0	0	0	0
Anthomyiidae	0	0	0	0	1	1	0	0	0	0	0
Calliphoridae	1	0	0	0	0	0	0	0	0	0	0
Heleomyzidae	0	0	0	0	0	0	0	0	1	0	0
Muscidae	6	7	18	73	269	300	185	230	126	38	39
Scatophagidae	0	0	0	0	0	0	0	0	0	0	0
Tachinidae	0	0	0	0	0	0	0	2	0	0	0
HYMENOPTERA											
Braconidae	0	0	0	0	0	0	0	0	0	0	0
Ichneumonidae	0	0	0	0	1	5	14	8	5	1	0
Chalcidoidea	0	0	0	2	1	8	3	0	0	0	0
Bombus sp.	0	0	0	0	0	0	0	0	0	0	0
ACARINA	0	0	1	33	45	130	64	29	19	12	19
ARANEA											
Linyphiidae	0	0	0	0	4	2	0	2	4	2	0
Lycosidae	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**23**	**33**	**645**	**3191**	**917**	**961**	**402**	**590**	**556**	**128**	**114**

ruddy turnstone clutch initiated around the storm was incubated for about 32 days and held no embryos.

To what extent the individual wader species produced replacement clutches is hard to evaluate, but based on numbers of birds giving alarm calls in the area in July, I got the impression that most sanderlings and dunlins re-nested. On the other hand, numbers of dunlin nests and broods found (11) were much below numbers in earlier years. This may be the result of several biases, however. The period in which it was possible to find them was two weeks shorter than in an early year like 2000, when we found 24. I concentrated much on finding sanderling and ruddy turnstone nests and young to ensure a reason-

26.8	**2001**	**2000**	**1999**	**1998**	**1997**	**1996**
14	**168**	166	153	174	184	182
10	**119**	102	61	5	15	65
0	**0**	0	2	0	0	0
0	**0**	0	0	0	0	4
1	**2**	0	0	0	0	0
0	**0**	3	0	0	0	14
0	**1**	0	0	0	0	8
0	**0**	2	0	0	0	1
0	**1**	2	1	1	1	6
0	**0**	0	0	0	2	2
0	**3**	0	0	0	1	3
0	**0**	0	1	0	0	0
0	**1418**	0	0	0	0	0
0	**0**	0	1	0	0	0
0	**0**	0	0	1	1	0
0	**209**	111	322	138	142	98
0	**168**	*	1799	*	*	*
10	**3876**	8522	5787	3743	7725	6477
0	**4**	32	6	0	0	1
0	**23**	22	16	624	240	64
0	**33**	2	171	*	*	*
0	**8**	10	9	9	1	77
0	**1**	2	3	0	0	0
0	**4**	5	1	8	16	4
0	**0**	0	0	0	4	0
0	**2**	*	3	26	11	*
0	**1**	4	5	7	6	2
1	**2**	0	1	0	0	0
21	**1312**	1455	754	745	809	1355
0	**0**	2	10	0	30	11
0	**2**	6	1	0	0	0
0	**0**	0	0	1	1	0
0	**34**	48	24	18	44	43
0	**14**	0	0	0	2	0
0	**0**	0	1	2	6	5
6	**358**	246	191	826	189	299
1	**15**	10	6	1	1	8
0	**0**	2	0	0	1	0
60	**7610**	**10588**	**9177**	**6155**	**9248**	**8547**

able sample of these too. Hence, sanderlings were found in 'normal' numbers, while turnstones were also low. Since the latter species is normally easy to deal with, I feel confident that only a smaller part of the turnstones re-nested – perhaps only about one third. This supports the general impression that ruddy turnstones – probably together with red knots – are more sensitive to poor conditions than the smaller species (Meltofte 2002).

A number of nests held aberrant numbers of eggs. One common ringed plover nest, initiated around the snow storm, held two eggs and one sanderling only one. A ruddy turnstone nest, initiated around 27 June, held six eggs. Four eggs had the same colour, while the remaining two were paler, so they were either laid by two different females, or the two pale eggs were from around the snow storm, and the rest re-laid in the same nest-cup. Only one young hatched from this clutch, even though four more eggs held highly developed embryos, while the remaining (pale) egg held a less developed embryo. Evidently, the adults were unable to incubate six eggs efficiently. Mean clutch sizes of original and replacement clutches together are presented in Table 4.24, and it appears that the averages generally are in the low end of the range from previous years.

With a predation rate of at least 30%, 2001 was in the upper end of the range of predation experienced during previous years (Table 4.25). By far, most predation was by foxes, of which an estimated total of at least four individuals were hunting inside the bird census area during June and July. Two dens held pups inside the area, and one more just outside. This is not much different from other years with similar predation rate, which again point to the conclusion that it is the number of foxes and their hunting effort that determine the predation rate on wader nests in our area, and not the number of lemmings of which there were quite many this summer (see section 4.6 and the section on long-tailed skuas below).

Numbers of juvenile waders recorded on the tidal delta flats at the coast of Zackenbergdalen were higher for common ringed plover and ruddy turnstone than recorded previously (Table 4.26). Sanderling numbers were also high, while dunlins appeared in more ordinary numbers. This may indicate that the breeding success of waders in the region in general was not reduced by the snow storm in mid June.

Reproductive phenology and success in long-tailed skuas

The egg laying phenology of long-tailed skuas was a bit late for a season with many lemmings (Table 4.27). The first egg

Table 4.14. Weekly totals of arthropods etc. caught at the five pitfall trap stations in 2001. Each station holds eight yellow pitfall traps measuring 10 cm in diameter. Values from each date represent catches from the previous week. Totals from 1996-2000 are given for comparison. Data from 1996-1998 have been extrapolated to fit the sampling design from 1999 onwards (see Caning and Rasch 2000). *Asterisks mark groups that were not separated from closely related groups in that year. The butterfly species* Plebeius franklinii *has been mentioned in some of the previous rapports as* Plebeius glandon. *It is the same species, but there has been some confusion regarding the correct scientific name.*

DATE	**10.6**	**17.6**	**24.6**	**1.7**	**8.7**	**14.7**	**22.7**	**29.7**	**5.8**	**12.8**	**19.8**
No. of active stations	3	3	3	5	5	5	5	5	5	5	5
No. of trap days	126	140	168	280	280	280	280	280	280	280	280
COLLEMBOLA	48	216	1849	2152	1343	4449	1337	3070	676	574	193
HETEROPTERA											
Nysius groenlandicus	0	0	0	0	0	1	0	0	1	0	0
Aphidoidea	0	0	0	5	18	32	18	35	112	57	71
Coccoidea	1	0	0	1	0	4	0	0	3	0	0
THYSANOPTERA	0	0	0	0	0	0	0	0	0	0	0
LEPIDOPTERA											
Lepidoptera larvae	0	0	0	0	1	4	4	1	0	2	1
Colias hecla	0	0	0	0	0	0	0	0	0	0	0
Clossiana sp.	0	0	0	0	0	2	1	11	15	11	9
Lycaenidae	0	0	0	0	0	0	0	0	0	0	0
Plebeius franklinii	0	0	0	0	0	2	1	6	9	0	1
Noctuidae	0	0	0	0	0	3	4	1	4	1	2
Tortricidae	0	0	0	0	0	1	0	0	0	0	0
DIPTERA											
Nematocera larvae	0	0	7	3	1	1	0	1	0	0	0
Tipulidae larvae	0	0	0	0	1	0	0	1	1	0	0
Tipulidae	0	0	0	0	0	3	6	2	1	0	1
Trichoceridae	0	0	0	1	0	0	2	1	2	1	0
Culicidae	0	0	2	1	5	10	7	2	5	1	0
Chironomidae	5	28	111	269	322	578	190	183	138	88	30
Ceratopogonidae	0	0	0	0	0	2	3	0	0	1	0
Cecidomyiidae	0	0	0	1	4	3	0	0	0	0	0
Mycetophiliidae	0	0	0	2	2	18	82	49	13	7	3
Sciaridae	0	0	11	24	49	121	77	142	60	38	36
Brachycera larvae	0	0	0	0	0	0	0	0	0	0	0
Empididae	0	0	0	0	2	0	0	0	0	12	13
Phoridae	0	0	0	1	0	2	18	245	57	54	52
Syrphidae	1	1	4	1	0	1	0	0	3	2	3
Cyclorrhapha larvae	0	0	0	0	0	0	0	0	0	0	0
Agromyzidae	0	0	1	1	0	0	0	0	0	1	0
Anthomyiidae	0	0	51	1	3	0	1	0	1	0	0
Calliphoridae	0	1	0	1	0	0	0	1	1	0	0
Fannidae	0	0	0	0	0	0	0	0	0	0	0
Heleomyzidae	0	0	0	0	0	0	0	2	1	0	1
Muscidae	150	154	153	497	1207	1757	529	933	659	313	316
Scatophagidae	0	0	0	0	0	0	0	0	0	0	0
Tachinidae	0	0	0	0	0	0	1	6	12	1	9
HYMENOPTERA											
Hymenoptera larvae	0	0	0	0	0	0	0	0	0	0	0
Ichneumonidae	0	0	4	22	74	101	34	65	45	36	32
Braconidae	0	0	0	2	0	0	1	0	3	1	2
Ceraphronoidea	0	0	0	0	0	0	0	1	1	1	0
Chalcidoidea	0	0	0	1	5	15	7	21	17	9	27
Cynipoidae	0	0	0	0	0	0	0	0	0	0	0
Scelionidae	0	0	0	0	0	0	0	0	0	0	0
Bombus sp.	0	0	0	0	0	1	0	0	0	2	0
ACARINA	95	109	882	1476	1149	902	1261	952	1154	887	806
ARANEA											
Dictynidae	0	0	0	0	0	0	0	0	0	0	0
Linyphiidae	165	87	198	224	164	150	133	155	164	142	130
Lycosidae	36	15	137	389	434	283	95	166	253	285	398
Lycosidae egg sac	0	0	1	4	3	21	8	17	21	9	1
Thomisidae	13	3	14	21	14	40	14	16	25	2	10
OSTRACODA	0	0	0	0	0	0	0	0	0	0	0
SIPHONAPTERA	0	0	0	0	0	0	0	0	0	0	0
NEMATODE	0	0	0	0	0	0	0	0	0	0	0
UNIDENTIFIED	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**514**	**1016**	**3425**	**5100**	**4803**	**8507**	**3834**	**6085**	**3457**	**2538**	**2147**

26.8	2001	2000	1999	1998	1997	1996
5	5	5	5	5	5	5
280	2954	3155	2706	2702	2797	(1512)
1805	17970	21726	23443	8957	10830	4636
0	2	0	1	0	5	40
11	359	3	11	185	10	6
0	9	781	431	3	548	254
0	0	0	2	0	0	2
3	16	18	21	106	168	354
0	0	77	42	12	19	88
0	49	329	82	56	180	1052
0	0	4	1	0	0	0
0	19	0	0	1	1	2
0	15	4	6	2	45	68
0	1	0	0	0	0	0
2	15	279	105	58	39	52
0	3	4	1	0	0	0
1	14	2	4	1	4	14
0	7	0	3	0	1	0
1	34	61	83	22	16	2
10	1958	3666	8542	2402	3337	3292
1	7	0	68	*	*	*
0	8	24	0	1	0	0
5	181	820	205	1764	1194	526
15	573	4	796	*	*	*
0	0	4	3	0	0	0
1	28	14	21	10	6	8
16	445	1316	435	344	214	118
2	18	43	50	28	81	72
0	0	7	7	19	75	16
1	4	2	0	0	1	0
0	57	*	88	416	573	*
1	5	218	26	49	48	48
0	0	0	0	0	1	0
2	6	1	7	0	0	0
74	6766	12805	10005	5463	6217	8114
0	0	1	41	0	385	26
0	**29**	37	37	0	19	0
0	**0**	4	0	2	0	0
29	**442**	710	386	297	567	954
2	**11**	15	10	105	59	44
0	**3**	15	5	0	0	0
4	**106**	21	9	2	123	48
1	**1**	0	0	0	1	0
3	**3**	0	101	0	0	0
0	**3**	10	2	6	12	2
198	**9929**	15256	8263	6304	19781	8182
0	**0**	0	79	0	53	0
101	**1833**	3523	2243	1108	1644	1436
92	**2618**	3254	2118	2123	3806	4548
0	**85**	101	160	160	138	82
4	**177**	134	144	89	245	198
0	**0**	46	84	0	0	0
0	**0**	0	3	0	0	0
0	**0**	3	0	0	0	0
0	**0**	2	0	0	0	120
2385	**43811**	**65344**	**58174**	**30095**	**50446**	**34404**

was probably laid around 12 June with the bulk of egg laying within the next five days. This means that most eggs were laid just before and during the snow storm on 16 June (see section 4.1), and – opposite to the waders – most survived! (See Other observations.) A few more clutches were initiated 19-20 June, whereas two clutches of 24 June may have been replacements, and two of 29-30 June definitely were so.

Most likely, all pairs produced at least one clutch, and at least 10 pairs hatched young. The eggs in two clutches – one from 12 June and one from 19 June were rotten. They were both incubated until late July! The remaining un-hatched clutches were predated by foxes.

The number of young fledged is more uncertain, but at least five young fledged, of which two were from the same brood, so that four pairs produced juveniles. This is about the same number as in the previous good lemming years 1997 and 1998 (Table 4.27).

Breeding barnacle geese

On 28 June, the first barnacle goose pair with one small gosling appeared in the delta of Zackenbergelven. This means that egg laying must have started around 27 May, or close to the date in other 'normal' years. Very few other family groups showed up in the study area, so that a maximum of four pairs with 1, 1, 2 and 3 goslings were present in Kystkærene and the old delta of Zackenbergelven on 5 July together with three pairs without young. Three families with 1, 2 and 2 goslings remained in the area during July, and in August families with 1, 2 or 3 large gosling were seen in different places along the coast and at Lomsø until last recorded on 17 August.

On the line transect survey through Store Sødal, two pairs with one gosling were encountered in the innermost part of the valley on 19 July. This is much less than in the previous three years, when 14-23 goslings were found here (see Table 4.30).

Hence, very few barnacle geese brought their young to the study area this year. The brood size and juvenile percentage on the wintering grounds in Scotland also document a poor breeding season for Greenland barnacle geese (Table 4.28).

Table 4.15. Peak ratio of Dryas *flowers depredated by larvae of* Sympistis zetterstedtii *in* Dryas *plots in 1996-2001.*

Plot	1996		1997		1998		1999		2000		2001	
	Date	Pred.	Date	Pred.	Date	Pred.	Date	Pred.	Date	Pred.	Date	Pred.
Dryas 1	17.7	2	24.6	6	15.7	3		0		0		0
Dryas 2		0	5.8	5		0		0		0		0
Dryas 3	1.7	11	24.6	18	8.7	3		0		0		0
Dryas 4	24.6	17	15.7	1	15.7	7		0		0		0
Dryas 5	8.7	2	8.7	8	15.7	2		0		0		0
Dryas 6		0		0		0		0		0		0
Dryas 7		–		–		0	21.8	26		0		0
Dryas 8		–		–		0	21.8	27		0		0

Month	1996	1997	1998	1999	2000	2001
June	1	2	7	7	10	2
July	0	1	4	17	2	2
Total	**1**	**3**	**11**	**24**	**12**	**4**

Table 4.16. Numbers of woolly-bear caterpillars Gynaephora groenlandica *recorded by one observer (Hans Meltofte) in study area 1A (the bird monitoring area) in June and July 1996-2001.*

Plot	1996	1997	1998	1999	2000	2001
Salix 1	+	0	0	43	2	0
Salix 2	3	0	0	6	0	0
Salix 3	9	0	0	3	5	0
Salix 4	0	0	0	1	7	0

Table 4.17. Peak ratio of female Salix arctica pods infested by sawfly larvae in 1996-2001.

Table 4.18. Numbers of bumblebees Bombus polaris/hyperboreus *recorded by one observer (Hans Meltofte) in study area 1A (the bird monitoring area) in June and July 1999-2001.*

Month	1999	2000	2001
June	–	59	12
July	35	34	15
Total	**–**	**93**	**27**

Table 4.19. Number of trips and hours (trips; hours) allocated to bird censusing and breeding phenology sampling west and east of Zackenbergelven during June and July, respectively.

Month	West of river	East of river	Total
June	6; 17	15; 60	21; 77
July	11; 37	20; 72	31; 109
Total	17; 54	35; 132	52; 186

Line transects

The results of the line transect counts in mid / late July through Store Sødal and between Daneborg and Zackenberg are generally in good accordance with the records from previous years (Tables 4.29 and 4.30). Numbers of moulting immature pink-footed geese in Store Sødal were still relatively low (see section on Other observations). Common ringed plovers were back to 'normal', and snow buntings in Store Sødal 'recovered'. The relatively high number of long-tailed skuas was due to a group of eight seen in the upper part of Zackenbergdalen on 18 July.

Sandøen

Sandøen was not visited by BioBasis personnel this year, but arctic tern pulli were recorded on the islet on 17 August.

Other observations

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

Red-throated diver *Gavia stellata*

The first red-throated diver circled calling over Zackenbergdalen on 3 June, whereupon birds were heard or seen almost daily until a pair landed on Gadekæret on 9 June. Hereafter, a pair was present on Sydkærene and on 13 June even a pair east of Lomsø.

On 17 June, the birds displayed intensively in the large pond in Sydkærene, and a bird visited the nesting turf, where it was incubating from 19 June. A young was seen for the first time on the water on 22 July, and from 25 July, two pulli were present on the water. On 19 August, they tried to lift, but they remained on the pond until one of them left on 28 or 29 August, while the other one was still present on the last day of observations on 30 August. On that date, the other young was seen together with six adults on the fjord off the deltas.

The pair at Lomsø was less successful. On 24 June one was sitting on a nest on

Species	West of river <50 m (3.39 km²)	East of river <50 m (7.52 km²)	East of river 50-150 m (3.34 km²)	East of river 150-300 m (2.49 km²)	East of river 300-600 m (2.06 km²)
Red-throated diver	0	2	0	0	0
Pink-footed goose	0	1	0	0	0
Common eider	0	1	0	0	0
King eider	0	2-4	0	0	0
Long-tailed duck	0	5-7	0	0	0
Rock ptarmigan	0	0-1	2-3	0	0
Common ringed plover	6-7	18-20	4	12	11
European golden plover	0	0	1	0	0
Red knot	2	11-13	5-6	9	0
Sanderling	10-13	31-35	5	11-13	1-4
Dunlin	29-30	57-61	13-14	3	2
Ruddy turnstone	6-7	27-30	11-13	1	0
Red-necked phalarope	0	1-3	0	0	0
Red phalarope	0	1	0	0	0
Long-tailed skua	3-4	10-11	8-9	1	0
Snow bunting	20	11-15	15-18	2-5	0

Table 4.20. Estimated numbers of pairs/territories in five sectors of the 18.8 km² census area in Zackenbergdalen, 2001.

Species	1996	1997	1998	1999	2000	2001
Red-throated diver	1-2	2	3	2-3	2-3	2
Pink-footed goose	0	1	0-1	2	1	1
Common eider	0	0	0	0	1	1
King eider	2-3	2	1	2-3	2-4	3-4
Long-tailed duck	5-8	4-6	6-8	7-8	5-8	5-7
Rock ptarmigan	3	11-15	4-6	7-8	1-3	2-4
Common ringed plover	54-56	40-48	38-45	51-65	41-43	51-54
European golden plover	0	0	0	0	0	1
Red knot	33-43	35-44	27-32	25-33	24-27	27-30
Sanderling	50-63	55-70	62-70	60-67	59-67	58-70
Dunlin	69-82	75-91	75-94	81-95	98-103	104-110
Ruddy turnstone	42-52	49-58	56-63	43-49	48-50	45-51
Red-necked phalarope	0-1	0-2	1-2	1-2	1-2	1-2
Red phalarope	0	0	0-1	0	0	1
Long-tailed skua	25-29	22-25	21-24	19-24	21-28	22-25
Northern wheatear	0	0	1	0	0	0
Snow bunting	45-55	45-56	41-46	52-64	42-47	48-58

Table 4.21. Census results from the 18.8 km² census area in Zackenbergdalen, 1996-2001.

the shore of the lake, but already on 27 June the nest had been predated. Already on 30 June, they were active at a new mud-nest some 10 m from the shore, where one was incubating on 7 July. On 14 July, the nest had been predated, whereupon the birds left the lake. On 6 July a fox was swimming around the nest.

During the summer, pairs were seen both on Vesterport Sø, on Ryledammene and on Lindemanssø, but no breeding was observed, so these pairs probably failed.

From 20 June, pairs and single individ-

Species	Median date	Range	N
Common ringed plover	18.5 June	14-19 June	4
Red knot	26 June	17-28 June	3
Sanderling	22.5 June	10-30 June	12
Dunlin	25 June	16-28 June	11
Ruddy turnstone	23 June	16-27 June	13
Red-necked phalarope	20 June	–	1

Table 4.22. Median first egg dates for waders at Zackenberg, 2001, as estimated from incomplete clutches, egg floating, hatching dates and weights of pulli. Note that most clutches recorded were re-laid.

Table 4.23. Snow cover on 10 June together with median first egg dates for waders at Zackenberg 1995-2001. Data based on less than 10 nests/broods are in brackets, less than five are omitted. The snow cover is pooled (weighted means) from sections 1, 2, 3 and 4 (see section 4.1), from where the vast majority of the egg laying phenology data originate.

Species	1995	1996	1997	1998	1999	2000	2001
Snow cover on 10 June	84	82	76	80	91	53	84
Sanderling		(16 June)	18 June	18 June	23.5 June	16 June	22.5 June
Dunlin	(18 June)	11.5 June	13 June	16.5 June	22 June	11.5 June	25 June
Ruddy turnstone	(12 June)	18.5 June	13 June	12.5 June	24 June	11 June	23 June

uals appeared in the open water off Zackenbergelven, and during the second half of July, up to six were seen on the fjord off the deltas and up to five on Lomsø. In August, up to 11 were counted on the fjord and up to six on Lomsø.

Great northern diver *Gavia immer*

On 25 August, a great northern diver was seen on the fjord off Zackenbergdalen. None were seen on the former breeding lake in uppermost Store Sødal in mid July.

Pink-footed goose *Anser brachyrhynchus*

Until the moult migration began on 18 June, up to five pink-footed geese were recorded in the bird census area. On 6 June a nesting pair was found at Kamelen, but

Table 4.24. Mean clutch sizes in waders at Zackenberg, 1995-2001. Samples of less than five clutches are given in brackets.

Species	1995	1996	1997	1998	1999	2000	2001
Common ringed plover	(4.00)	(4.00)	(3.50)	(4.00)	(3.50)	(4.00)	(3.50)
Red knot				(4.00)	(4.00)		(4.00)
Sanderling	(4.00)	4.00	3.86	4.00	3.67	4.00	3.43
Dunlin		(4.00)	(3.75)	3.90	3.70	3.93	3.63
Ruddy turnstone		3.71	3.79	3.81	3.58	3.75	3.75[1]

1) One turnstone nest held 6 eggs in 2001, which was treated as two broods of 4 and 2, respectively (see text).

Species	1996	1997	1998	1999	2000	2001
Common ringed plover	(100)	(0-25)	(0)	(25)	(0-25)	(25-50)
Red knot			(0-100)	(50)		(100)
Sanderling	17	0-40	0-11	21-29	17-33	57
Dunlin	(0)	(0)	11-33	0-33	13	13
Ruddy turnstone	0-29	0-8	27-47	18-55	33-38	20
Red-necked phalarope				(100)		
All species pooled	**13-27**	**0-17**	**14-34**	**20-39**	**22-28**	**30-33**
N	15	24	35	41	46	30
Foxes encountered	14	5	7	13	11	14
Fox dens with pups	2	0	1	0	2	2

Table 4.25. Predation rate in wader nests at Zackenberg, 1996-2001 expressed as minimum and maximum per cent nests predated of those found with eggs throughout the nesting period. Partially predated nests are given as successful, if at least one young hatched, and so are nests eventually controlled with starred or pipped eggs found empty and without indications of predation later on. Nest failures for other reasons are omitted. Samples of less than five nests are given in brackets. Also given are total numbers of foxes encountered in the bird census area during June-July and the number of fox dens holding pups.

Table 4.26. Cumulative numbers of juvenile waders recorded at low tide in the old and the present deltas of Zackenbergelven during counts every third day in the period 1-31 August, 1995-2001. In case of missing counts etc., data have been interpolated.

Species	1995	1996	1997	1998	1999	2000	2001
Common ringed plover	96	126	249	42	44	142	320
Sanderling	304	726	149	333	445	366	540
Dunlin	325	360	323	232	509	273	326
Ruddy turnstone	80	108	82	109	23	73	162
Waders total	**810**	**1342**	**803**	**722**	**1021**	**854**	**1351**

	1996	1997	1998	1999	2000	2001
Median 1st egg date	–	7	12	17	18	15
No. of clutches found	8	17	23	7	5	21
No. of young hatched	1	25	16	1	2	18
No. of young fledged	0	5	6	1	0	5
Lemming winter nests	161	366	721	330	184	318
Lemming summer burrows	–	789	335	455	407	869

Table 4.27. Egg laying phenology together with breeding effort and success in long-tailed skuas at Zackenberg 1996-2001. Median egg laying date is date in June, when half the original clutches were laid, thus excluding clutches estimated to have been replacements. Number of clutches found includes replacement clutches, while number of young fledged is the estimated maximum breeding output of the season. Also given are numbers of lemming winter nests and occupied summer burrows within our 2.16 km^2 lemming monitoring area (see section 4.6).

	1995	1996	1997	1998	1999	2000	2001
Primo July		(3.0)	3.07	(2.9)	1.92	(3.22)	(1.75)
Medio July		(2.3)	2.71	2.31	1.82	(3.13)	(1.67)
Ultimo July	(2.0)	(3.0)	2.63	2.22	1.72	3.09	
Primo August	(2.3)	(2.3)	2.35		1.75		(2.0)
No. of broods	>7	6-7	19-21	>18	29	11	4
Britain	2.00	2.30	1.95	2.28	1.92	2.20	1.94
Per cent juv.	7.2	10.3	6.1	10.5	8.1	10.8	7.1

Table 4.28. Average brood sizes of barnacle geese in Zackenbergdalen during July and early August, 1995-2001, 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 per cent juveniles in the population (M. Ogilvie in litt.).

the nest had been predated when checked 17 days later.

Between 18 June and 4 July a total of 641 pink-footed geese migrated north in flocks of up to 115. Some of them made short stops on the upper slopes of Aucellabjerg, and several flocks of up to 58 individuals were feeding in the area or were flying around during the same period. The last flying birds were seen on 12 July.

No moulting pink-footed geese were found along the coast when checked on 19 July, but a total of 85 was recorded during the line transect survey through Store Sødal 18-20 July (see Table 4.30). Most were found on lakes in the upper part of the valley. The lack of moulting birds at the peninsula off Zackenbergdalen may have been caused by a visit by two persons with two dogs at the site on 8 July, i.e. in the most sensitive period (see section 6).

In late August, up to 140 were feeding in Zackenbergdalen.

Snow goose *Anser caerulescens*

Two 'large' and one smaller white snow geese arrived from the north on 13 June. They were seen again on 15 and 16 June, and on the latter date a further six appeared. Of these, two were 'blue' and 2-3 mottled. Furthermore, two migrated north on 25 June.

Barnacle goose *Branta leucopsis*

During the first half of June, up to 34 barnacle geese were feeding in the bird census area, but during the snow storm on 16 June, at least 60 gathered in the fens around the research station.

Species	Store Sødal	Daneborg
	18-20 July	24 July
Red-throated diver	3	
Pink-footed goose	85	
Barnacle goose	260/1	
Common eider		11/6
Common ringed plover	55/1	8
Red knot		
Sanderling	8	4
Dunlin	59	3
Ruddy turnstone	2	
Long-tailed skua	16	5
Glaucous gull	8	2
Arctic tern	8	
Snowy owl		1/3
Common raven	3	1
Snow bunting	110/1	

Table 4.29. Birds recorded (adults/young) during line transect surveys through Store Sødal and from Daneborg to Zackenberg (see map in Meltofte and Thing 1997) in July 2000.

Table 4.30. Total numbers of birds recorded (adults/young) during line transect surveys through Store Sødal and from Daneborg to Zackenberg, July 1997-2000. Brackets denote interpolated figures.

Species	1997	1998	1999	2000	2001
Red-throated diver	3	2		2	3
Great northern diver				2/1	
Pink-footed goose	263	123	27	56	85
Barnacle goose	182	250/23	227/23	261/14-16	260/1
Goose sp.	25				
Common eider	390	119/5	55/6	10	11/6
Long-tailed duck	13		2		
Rock ptarmigan	2	1			
Common ringed plover	71	70	(78)	(105/4)	63/1
Red knot	1			3	
Sanderling	14/1	10	33	11/6	12
Dunlin	64/1	62/1	(56)	48	62
Ruddy turnstone	6	8	8	6	2
Long-tailed skua	13	9	14	4	21
Glaucous gull	11	11/2	8	(7)	10
Arctic tern	3	9	1	3	8
Snowy owl					1/3
Common raven	10	9	2	(5)	4
Snow bunting	104	64/2	(54)	(30/6)	110/1

During the last days of June and the first days of July, 126 gathered at Lomsø, where they were all flightless by 5 July. During a total survey on 18-19 July, 137 moulting immatures were found at Lomsø and 108 west of the peninsula plus one flying bird inland and a further three families at Lomsø (see section on Breeding barnacle geese). By 26 July, most had regained flight capacity, but the last birds did not fly until the first days of August.

A further 60 birds moulted at Lindemanssø in the upper part of Zackenbergdalen together with 196 in Store Sødal (see section on Line transects). Most (132) were found along Zackenbergelven downstream Store Sø together with 42 at lakes in upper Store Sødal.

Hence, a grand total of about 500 immature barnacle geese were moulting in the study area. This is again an increase from previous years (see chapter on Other observations, Caning and Rasch 2001:36).

During August, flocks of up to 145 barnacle geese were feeding in different parts of Zackenbergdalen with a total of 218 as the highest number recorded.

Common eider *Somateria mollissima*

Two common eider pairs were seen a number of times in the bird census area from 10 June. On 20 July, a female was incubating near Tørvedammen, but already five days later, the nest had been predated.

From 15 July, more females appeared along the coast, and on 19 July, 50 females with at least one duckling were present east of the peninsula. During the rest of July and all of August, numbers of females and ducklings off Zackenbergdalen increased to a maximum of about 180.

In the breeding colony among the 60-70 tethered sledge dogs at Daneborg, 23 km southeast of Zackenberg, from where most of the eiders at Zackenberg originate, 3640 eiders were counted on 2 July by Niels Fæster and Søren Kristensen from the Sirius Sledge Patrol. This included birds sitting on the fjord ice off the colony. They estimated that the true number was more likely to have been around 4000, and that about 1/8 of the total were males. A further 160 dead females were found killed by the dogs. This means that the colony probably holds at least 3000 breeding pairs, or more than twice as many as when last counted in 1975 (Meltofte 1978). Until then, the colony had grown exponentially to 1300 nests after the first pair was recorded in 1955.

Many females (and males) are killed each year, when flying so low over the dogs that the dogs can take them by jumping into the air. Also hundreds of eggs and newly hatched ducklings are taken by large pups running loose during the summer. Still, it apparently ‘pays’ for the eiders to breed among the dogs, since they create a fox free ‘island’, where the eiders can start egg-laying several weeks earlier than on Sandøen, which is accessible to foxes until the fjord ice breaks up (Meltofte 1978).

King eider *Somateria spectabilis*

One pair of king eiders arrived on the ponds at the research station on 9 June, and not until 22 June, one or two more pairs appeared. Maximum was two pairs together with one male with two females on 28 June and two pairs together with four of unknown sex on 28 June. The last males were seen off the delta of Zackenbergelven on 17 July.

On 2 July, a female entered the same nesting turf in Gadekæret as was used the previous year, and by 4 July, she was incubating. Four pulli appeared on the pond on 29 July, and already on the night of 30 July, they had left the pond. In mid August, up to five adult eiders and seven ducklings were counted on Lomsø, but it could not be established with certainty that they were all kings. Hence, most likely, at least two king eiders hatched young in the bird census area this year.

Long-tailed duck *Clangula hyemalis*

The first pair of long-tailed ducks arrived on the ponds at the research station on 7 June, and already two days later, a total of 10 individuals were present. A total count on 13 June revealed 5-6 pairs, while two pairs and five males were counted on 24 June.

The only sign of breeding this year was a depredated nest south of the research station on 14 July and an alert female north of Lomsø on 18 July. Furthermore, one egg, probably from this species was found on the ground on 2 July.

More and more birds gathered on Lomsø, in the delta of Zackenbergelven and along the coast from late June, so that 17 birds were present off the old trapping station on 12 July, 16 off the eastern part of the valley on 19 July and nine on Lomsø in late July. The last display was observed on 13 July.

Gyr falcon *Falco rusticolus*

Single gyr falcons were recorded in Zackenbergdalen three times in June, five times in July and three times in August. Furthermore, on 26 and 28 August, two (juvenile?) birds were seen.

Several times in late July, a bird was sitting on top of the radio mast of the research station, watching for the young hares on the station (see section 4.6), and on 26 July it killed a half-grown leveret and ate half of it. At each visit, up to 15 long-tailed skuas were mobbing the falcon.

Rock ptarmigan *Lagopus mutus*

Very few ptarmigans were present in the bird census area this year (see Table 4.21). A male sang at Grænseelv on 5 June and a pair was seen on the slopes of Aucellabjerg on 23 June. In July, a pair and a male was seen near Rævehøjene on 3 July, a male close by on 7 July, and an adult south of the research station on 27 July. Furthermore, a few singles and pairs were seen outside the census area during the summer.

In Favoritdal, a nest with six hatched eggs was found on 8 July, and a female was seen with 5-6 pulli on Zackenbergfjeldet on 14 July. A family group of five was encountered west of Zackenbergelven on 30 July, and on the same date a female with 10 pulli was found in Morænebakkerne. In August, only one male was seen in the census area.

Waders *Charadrii*

All the common waders, common ringed plover *Charadrius hiaticula*, red knot *Calidris canutus*, sanderling *Calidris alba*, dunlin *Calidris alpina* and ruddy turnstone *Arenaria interpres* were heard singing or seen in display at our arrival on 31 May or during the first few days thereafter. Few waders used the communal feeding area in Gadekæret this year, with 14 dunlins feeding on exposed mud in the eastern pond on 4 June as maximum. A group of eight common ringed plovers and three dunlins migrated north on 3 June.

As usual, most pairs had occupied territories by 10-12 June, and the first eggs were laid at the same time (see section on Reproductive phenology in waders). However, the snow storm on 15-16 June made many waders leave their territories and gather into flocks at snow free feeding sites. In Gadekæret, up to 33 red knots had gathered on 16 June, 20 remained on the next day and at Teltdammen again 20 on 19 June. Still on 21 June eight were present here. Similarly, about 15 dunlins were feeding in the fens around the research station on 16 June, and 10 still on the 19th. During the same period, several waders were seen flying around. A dunlin with a weight of only 26.7 g was found dead already on 16 June (normal weight is about 40-45 g), and the remains of a sanderling were found on 21 June and of a ruddy turnstone on 26 June.

The first post-breeding flock of four sanderlings was seen on 27 June, and groups of up to 10 dunlins were seen in early July. At the waterbird counts in the deltas of Zackenbergelven in late July and August, a maximum of 18 adult common ringed plovers were counted on 4 August, 40 adult sanderlings on 16 August, 35 adult dunlins on 26 July and 11 adult ruddy turnstones on 23 July.

Peak numbers of juveniles in the deltas were 103 common ringed plovers on 20 August, one red knot a few times in mid and late August, 158 sanderlings on 25 August, 105 dunlins on 22 August and 37 turnstones on 22 August. First observation dates of independent juveniles were: ringed plover 7 August, sanderling 4 August, dunlin 4 August and ruddy turnstone 7 August (2 August in Daneborg). Numbers of juveniles were high, while first dates of observation were average or late.

European golden plover *Pluvialis apricaria*

On 25 June, a golden plover flew over the research station. On the next day, a brightly coloured bird gave alarm calls, stood in an alert position and flew anxiously around me between Ræveelv and Aucellaelv at 200 m a.s.l. No birds were found here at later visits. Finally, on 16 July an adult gave alarm calls north of the research station, whereupon it disappeared far away to the south.

Sanderling *Calidris alba*

The colour of the incubating sanderlings on three nests were checked a few times. On one nest, two different birds were found at four visits, while apparently the same bird (a red ‘male’) was found three times on another nest. On the last nest, two different birds were found at two visits (for further explanation, see Caning and Rasch 2001:37-38).

White-rumped sandpiper *Calidris fuscicollis*

On 28 June, a white-rumped sandpiper was feeding in the fens west of Zackenbergelven, where it could be watched at few meters distance. This is the first record in East Greenland (Boertmann 1994).

Whimbrel *Numenius phaeopus*

A whimbrel was seen and heard on 26, 29 and 30 June.

Red-necked phalarope *Phalaropus lobatus*

On 4 June, a red-necked phalarope had arrived in Gadekæret, and from the next day a pair was present here or in Sydkærene. From 10 June, one further female was present, and on 13 June she displayed with a sanderling. On 26 June, possibly the same female attempted to take over the eggs of a sanderling, which tried to chase it away.

The red-necked phalarope pair copulated on 21 June (egg-laying began c. 20 June; Table 4.22), and on 13 July the male was found with at least two newly hatched pulli in Sydkærene. He was seen alarm-calling for the last time on 18 July.

Red phalarope *Phalaropus fulicarius*

During 16-21 June, a single red phalarope or a pair was seen almost daily in Gadekæret and Rylekærene. One was seen again on 29 June, and on 19 July one was giving alarm calls in Kystkærene apparently without having eggs or young. Finally, one was flying around and calling near Tørvedammen on 22 July.

Pomarine skua *Stercorarius pomarinus*

On 18 June, two immature pomarine skuas were mobbed intensively by long-tailed skuas near Grænseelv. Both were light, one having short tail elongations, the other with longer and twisted elongations. On 22 June, a light individual in ‘adult’ plumage was seen south of the research station. This could have been the same individual as the one most developed on 18 June.

Arctic skua *Stercorarius parasiticus*

During 19-24 June, a pair of arctic skuas was seen three times and one individual one time in the bird census area. All birds were light, although one of the mates were darker than the other one. Each time the pair was seen, they co-operated in hunting small waders, and at least one time they succeeded after having chased a wader out over the fjord ice. Single light individuals were seen on 30 June and 4 July, and on 26 and 27 July, five and two light individuals, respectively, were seen close to the coast.

Long-tailed skua *Stercorarius longicaudus*

A group of 10 long-tailed skuas was encountered by a Sirius team on the fjord ice near Basaltø on 26 May. In the bird census area in Zackenbergdalen, at least one pair was displaying on 1 June, and more pairs and single birds appeared during the following days.

Most skua nests in the census area survived the snow storm on 16 June (see section on Reproductive phenology and success in long-tailed skuas), but a group of 14 landed in the area on 18 June. This is the first observation of flocks of long-tailed skuas at this time of the year.

From mid July, pairs and groups of up to nine long-tailed skuas rambled and displayed over the area (see also section on Line transects), while up to 15 mobbed a gyr falcon visiting the research station in late July. Flying juveniles were recorded from 1 August.

Lesser black-backed gull *Larus fuscus*

Two adults were present in the deltas of Zackenbergelven on 26 July and again on 25 August.

Glaucous gull *Larus hyperboreus*

Up to five adult glaucous gulls were recorded in early and mid June, and on 19 June, four adults and two immatures were present. In late June and in July, up to nine adults and a few immatures were found along the river and in the delta, and a few birds were seen hunting lemmings. In late July, up to 52 'adults' and 21 immatures were counted in the deltas, and in late August up to 51 'adults', five immatures and one juvenile were recorded here. These are by far the highest numbers found so far.

Great black-backed gull *Larus marinus*

Two adults were seen on 22 June and one on 28 June.

Arctic tern *Sterna paradisaea*

Besides five birds at Store Sø and one pair plus one single at lakes in upper Store Sødal (see section on Line transects), none were seen in the study area this year. Breeding on Sandøen seems to have been 'normal' (see section on Sandøen).

Snowy owl *Nyctea scandiaca*

On 5 June, a snowy owl nest with six eggs was found on a snow free 'shoulder' at Ugleelv just below Oksebakkerne. A depredated egg (by a raven?) was lying a few metres from the nest. Both adults were present. On 29 June, three small pulli together with three eggs were seen, so probably the first young had hatched around 26 June. This means that the first egg was laid around 25 May. On 3 July, five pulli were at the nest, besides one unstarred egg. On 8 July, the egg was damaged, and it could be seen that it held a fully developed embryo. Four young were present that day, but on 18 July, only two large pulli were found about 50 m north of the nest. After this, the adults were seen a few times, but the young could not be found until a juvenile was seen at Kamelen on 14 August and again on 18 August. During the second half of August, snowy owls were seen regularly, but a juvenile was only identified on 21 August near Ugleelv and two on the lower slopes of Zackenbergfjeldet on 30 August.

On the sandy spit at the mouth of Kuhnelv near the peninsula, a nest with three pulli was found on 8 July. On 24 July, three large pulli were encountered 1500 m inland from the nest. Adults were seen in the area a few times later, whereas a juvenile was seen on 26 August.

Single snowy owls were seen in different places during the summer, and on Rødryggen east of Storsletten in northern Wollaston Forland one "small" and two larger juveniles were found on 2 August. They were all able to fly a few hundred metres, and hence, the eggs must have been laid already in mid May. Furthermore, one dead juvenile was found on Storsletten on 3 August, and one strongly flying juvenile was seen near Kuhnpasset on the same day.

Hence, 2001 turned out to be the best breeding season recorded so far for snowy owls in Wollaston Forland. Several young fledged, which is in accordance with the abundance of lemmings (see section 4.6 on Collared lemming population).

Common raven *Corvus corax*

One or two ravens were seen regularly during June, until five – probably a family – appeared on 23 June. During July and early August, singles or groups – of five and at one occasion six – were seen almost daily a.o. feeding on four musk ox carcasses. In the second half of August, up to nine were seen.

Year	Winter nests category 1	Winter nests category 2	Summer burrows	Animals seen
1995	285	821	–	–
1996	161	263	–	0
1997	342	109	710	1
1998	711	109	327	43
1999	305	57	403	9
2000	184	70	405	1
2001	318	22	869	11

Table 4.31. Annual numbers of recorded winter nests and summer burrows within the 2.08 km² census area in Zackenbergdalen 1995-2001. Category 1 denotes nests from the previous winter, category 2 are nests from earlier winters that were not recorded previously. One person (same effort each year) recorded the numbers of animals encountered within the 19 km² bird census area during June-July.

Arctic redpoll *Carduelis hornemanni*

Four times during June, single redpolls were recorded as the only ones this summer.

Lapland bunting *Calcarius lapponicus*

On 12 and 25 June, a single male Lapland bunting was seen.

Snow bunting *Plectrophenax nivalis*

The first 'just' fledged young was encountered on Zackenbergfjeldet on 8 July, but in the bird census area the first juvenile was not seen until 24 July. On 29 August three flocks totalling 100-150 individuals were seen at the research station.

4.6 Mammals

Thomas B. Berg

Observations on mammals were recorded by Hans Meltofte (31 May – 2 August) and Thomas B. Berg (2 July – 31 August). Most other Zackenberg personnel supplied additional random observations during the entire field season. The census area for collared lemming was surveyed for winter nests and summer burrows during 3 July – 20 August. Total numbers of musk oxen including age and sex data were censused once a week within the 40 km² musk ox census area during 3 July – 21 August. During the entire season, additional counts were made from a fixed elevated point at the station covering the area from Lindemansdalen along the shore-line to Lille Sødal north of Daneborg whenever weather conditions permitted.

The line transect Zackenberg – Store Sødal was walked by Thomas B. Berg and Claus B. Berthelsen during 18–20 July and Daneborg – Zackenberg was walked on 24 July by the same persons.

Four new arctic fox dens were recorded of which two were outside the valley proper (50 km²). All known dens within this area were checked regularly for occupation. All observations other than lemmings, foxes and musk oxen are presented in the section on "Other observations", where scientific names for all species are also given.

Collared lemming population

A total of 318 fresh winter nests and 869 active summer burrows were recorded within the 2.08 km² census area (Table 4.31). After the low phase in 2000, the number of winter nests is increased by

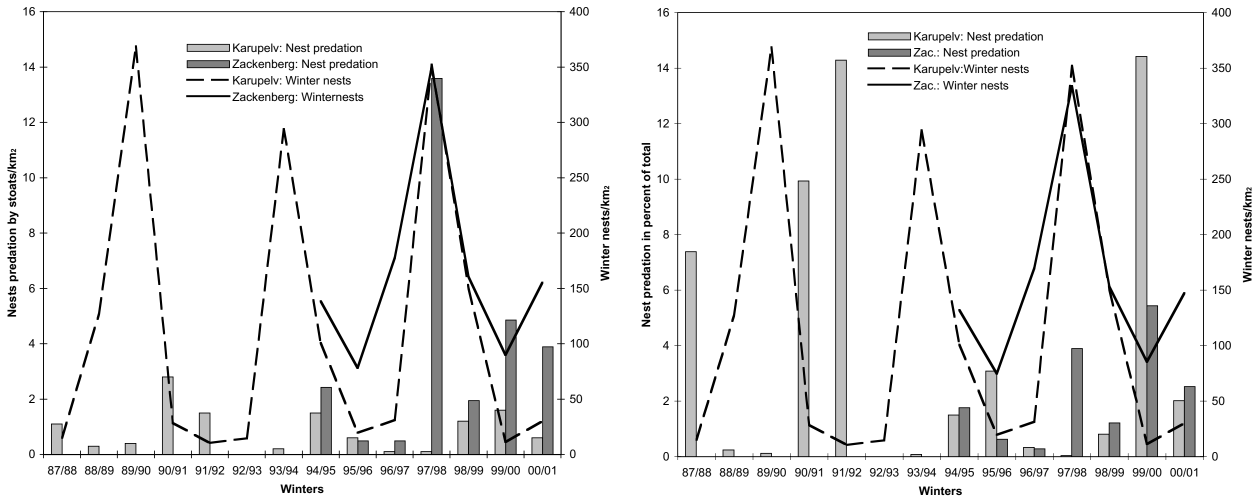


Fig. 4.5. Lemming winter nests (right axis) and stoat predation on lemming nests (left axis) at Karupelv, Traill Ø (10 km²) and within the census area in Zackenbergdalen (2.08 km²). Data include nests built from October to May. Nest predation by stoat is given both in actual numbers of depredated nests (A) and as per cent of total numbers of lemming nests (B). Data from Karupelv were kindly provided by Benoît Sittler (partly published in Sittler 1995 and 2000).

Section		Winter nests		Summer burrows	
		No.	No./km	No.	No./km
Store Sødal					
1996	150 km	2	0.013	1	0.007
1997	300 km	11	0.067	9	0.030
1998	150 km	21	0.140	6	0.040
1999	160 km	3	0.019	0	0.000
2000	160 km	1	0.006	0	0.000
2001	160 km	13	0.081	38	0.238
Daneborg-Zackenberg					
1997	50 km	22	0.440	21	0.420
1998	50 km	17	0.340	1	0.020
1999	50 km	1	0.020	0	0.000
2000	40 km	0	0.000	1	0.025
2001	40 km	24	0.600	50	1.250

Table 4.32. Records of lemming winter nests and active summer burrows obtained along the transects Zackenberg-Store Sødal (90 km) and Daneborg-Zackenberg (25 km). Nests and burrows were recorded within 3 m on each side of the two observers walking the transects, giving total length of 160 km and 50 km, respectively. Deviations from this appear from the table.

72%. The numbers of winter nests as well as summer burrows equal the numbers from the previous increase phase in 1997. The number of lemmings observed by Hans Meltofte during bird census in June and July (Table 4.31) was intermediate and equalled the decrease phase from 1999. The increase of the lemming population found in Zackenbergdalen was also apparent along the two line transects (Table 4.32). At Karupelv, the lemming population continued the low population density for the second year in succession (Fig. 4.5).

Eight lemming winter nests (3.7 / km^2 or 2.8% of total) were depredated by stoats during the winter as compared to 10 (5.4% of total) in 2000 (Fig. 4.5). At Karupelv, the figures decreased from 1.6 / km^2 (14.1% of total) to 0.6 / km^2 (2.0% of total). Comparing the two graphs in Fig. 4.5 it is clear that while the density of stoats at Zackenberg in most years is higher than at Karupelv, the proportion of winter nest taken over by stoats (in percent) fluctuates more at Karupelv than at Zackenberg. The reason for this is the delayed response by stoats to the lemming density at Karupelv (see also section 5.7).

The 29 fixed sample sites for predator casts and scats were checked on 26 August (Table 4.33). In general, the amounts of casts and scats were close to average.

Year	Skua casts	Owl casts	Fox scasts	Stoat scasts
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

Table 4.33. Numbers of casts and scats from predators collected from 29 permanent sites within the 2.08 km^2 lemming census area in Zackenbergdalen. The samples represent the period from mid August the previous year to August in the year denoted.

Musk ox population biology

The daily censuses of musk oxen in Zackenbergdalen and adjacent slopes (40 km^2) from a fixed point at the station showed remarkable differences from previous years. Before mid July, numbers recorded were consistently higher than in previous years (Fig. 4.6). Numbers in June 2001 averaged 32.10±17.33 SD compared to an average of 13.23±7.96 SD in June during 1996-2000. After an unusual minimum by mid August, numbers increased to a level comparable to the average for this part of the season. In total, the number of “musk ox days” within the 40 km^2 census area was the highest recorded so far (Table 4.34). These figures clearly illustrate the large variability in the regional distribution of musk oxen and stress the importance of long-term time series in order to analyse the year to year variation in the spatio-temporal use by musk oxen.

Maximum numbers of musk oxen recorded within the 40 km^2 census area on

Table 4.34. Accumulated numbers of ‘musk oxen days’ per month counted as one musk ox in one day within the 40 km^2 census area in Zackenbergdalen based on the daily counts from a fixed elevated point at the research station 1996-2001.

Month	1996	1997	1998	1999	2000	2001
June	445	290	522	361	478	923
July	445	1086	635	392	898	1257
August	2412	1432	1121	1292	1543	1689
Total	**3302**	**2807**	**2278**	**2045**	**2919**	**3868**

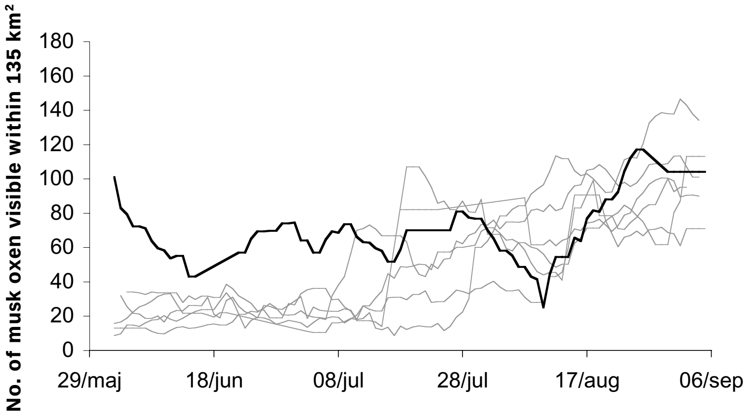


Figure 4.6. Numbers of musk oxen (one week running means) recorded daily during 2001 from a fixed elevated point at the research station (heavy line) compared to similar data from previous years (thin lines).

the weekly censuses were 81 individuals on 23 July and 95 on the last count (30 August) from the elevated point at the station. The maximum number of musk oxen recorded in one day within the entire visible area (~135 km^2) was 135 also on 23 July (see Table 4.35). During the transect week (18-25 July) a total of 160 animals were recorded within the 200 km^2 census area. Within the same days additional observations of 22 animals were made on Storsletten. Hence, the total number of musk oxen recorded during the transect week in 2001 was 182 animal, or exactly the same as it was in 2000, when Storsletten was covered by an aerial survey (see Caning and Rasch 2001: 41-43).

Two tables showing the age and sex distribution are presented. The first table (Table 4.35) is based on a total of 7-8 weekly censuses of musk oxen within the 40 km^2 census area. Table 4.36 tabulates all animals sexed and aged within the 200 km^2 line transect area in one week around mid July and illustrates the demography within this regional area (see text in Table 4.36). It appears that the number of calves born in 2001 (27) was the highest recorded within the 200 km^2 region since 1996, when a peak of 33 calves were counted at a single count in Zackenbergdalen and adjacent areas (135 km^2). In Table 4.37, details from the line trancect counts are presented, and in Table 4.38 they are compared to data from previous years.

Fig. 4.7 illustrates the relation between the average number of 3+ yr. old cows (three years or older) without a calf occurring inside the 40 km^2 census area in August and the average number of calves recorded the following year in August. 65% of 'these' cows had calves in 2001, which is almost as high as in 2000 (70%). The average number of cows with reproductive potential (3+ cows without a calf) inside the 40 km^2 area in 2001 was 66% of the total number of cows (3+ yr.), which is close to the average of 62% for the last five years. Based on the correlation between the number of cows without calves and the number of calves still alive in August the following year, the average number of calves recorded on the weekly censuses in August 2002 should be between four and eight. The result for 2001 fell inside the prediction made in 2000 (max. number predicted).

A total of four fresh musk ox carcasses (all adult males) were recorded inside the 40 km^2 census area (Table 4.39). Only one showed sign of having been eaten by wolf(s). Most likely, two of them died in May / June. The variation in the number of musk ox carcasses from year to year is presented in Table 4.40.

Arctic fox dens

Despite the intermediate number of lemming winter nests (the number of summer burrows peaked) 2001 showed a record number of arctic fox pups (Table 4.41). Four new dens (nos 9-12) were located (all active), of which two (nos 9 and 10) were within the 50 km^2 local area and the last two (nos 11 and 12) were on the slopes of Cardiocerasbjerg east of Kuhnelv. In total, five out of twelve dens had pups. Dens nos 1, 5 and 10 inside the area had a minimum of six (incl. one dark), four and three pups, respectively, while the two

Table 4.35. Sex and age distribution (mean no./census) of musk oxen in Zackenbergdalen as it appears from the weekly censuses 1 July – 31 August 1996-2001 (7-8 censuses per year). N is the total number of sexed animals within the 40 km² census area. Max gives the maximum number of musk oxen visible on one census within the visible area (~135 km²).

Year	Calf of yr.	F1	M1	F2	M2	F3	M3	F4+	M4+	Max	N
1996	12.57	7.71	7.71	2.14	6.43	3.71	1.00	17.14	11.00	153	493
1997	7.75	2.88	3.63	5.63	4.75	2.75	1.13	17.00	9.63	135	484
1998	2.75	0.88	0.88	3.38	3.75	2.38	2.75	12.13	12.13	94	328
1999	3.75	0.38	0.25	1.50	1.13	2.63	2.63	13.25	18.00	148	386
2000	15.13	3.00	3.50	1.13	0.38	2.50	1.88	24.25	19.50	124	648
2001	7.86	3.43	2.71	2.71	3.71	2.71	1.14	17.14	18.14	135	698

Year	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

Table 4.36. Sex and age distribution (actual numbers) of musk oxen based on total counts along the two line transects and the related census in Zackenbergdalen in 1997-2001. All counts were made within 16-25 July and covered an area of 200 km². It is assumed that no double counts were made within this period.

dens outside the area had a minimum of three and one, respectively. 16 pups were of the white phase and one of the dark.

Other observations

Collared lemming *Dicrostonyx groenlandicus*

In total, 17 adult and 2 juvenile lemmings were recorded in the field between 3 June and 31 August. Of these, 11 were recorded by one person (Table 4.31). Besides these recordings, a total of 40 specimens were caught live in traps ("Ugglan Special", see section 5.7). Over the season, three lemmings were observed taken by skuas, 11 by foxes (foxes seen with lemmings and dead lemmings buried with radio transmitters) and two presumably by stoats as the radio transmitter and lemming stomach was found side by side. Stoats are known for not eating the stomach. It was evident from those juveniles found that summer breeding took place and that litters were born at least in early June and in late July. (See also section 5.7).

Observations	Store Sødal	Zackenbergdalen	Daneborg-Zackenberg
M4+	7	25	6
M3	0	1	0
M2	1	1	0
M1	1	6	2
F4+	11	25	11
F3		4	3
F2	1	3	2
F1	1	4	2
Calf	7	15	7
Usp. 3+	10	0	0
usp yearling	0	0	1
Winter piles	887	–	18
Summer piles	177	–	105

Table 4.37. Musk ox data from the 90 km line transect through Store Sødal 18-20 July and the 25 km transect from Daneborg to Zackenberg on 24 July 2001 together with musk ox data from the total census in Zackenbergdalen on 23 July. Faeces piles of musk oxen were recorded by two observers giving total transect lengths of 180 km and 50 km, respectively. Only faeces piles within one meter from the transect were counted. F = female, M = male, 4+ = 4 years or more.

Polar bear *Ursus maritimus*

An apparently fresh track was found in wet soil on 26 July near Rødryggen south of Albrecht Bugt.

Arctic wolf *Canis lupus*

One adult female was recorded on 7 July trotting along the deltas and turning northwards towards Aucellabjerg, where she checked out and peed on fox dens nos 3 and 4. On 13 August a data logger, too big for an arctic fox to handle, were torn away from its fuse, and thus regarded as done by a wolf. Fresh wolf tracks were recorded in the area around the station hereafter until 18 August.

Arctic fox *Alopex lagopus*

A minimum of four adult foxes was recorded within the 50 km² main study area. An overview of fox records from each year 1995-2001 is presented in Table 4.42. The total number of fox records was the highest so far. This was partly the result of hunting activity close to the research station by the adult fox from den no. 1 probably caused by the presence of

Figure 4.7. Average numbers of calves during the weekly censuses in August in year t+1 plotted against the number of cows without calves in year t. The dashed line indicates the range of expected number of calves in 2002. The per cent values denote the snow cover in Zackenbergdalen on 10 June of the given year

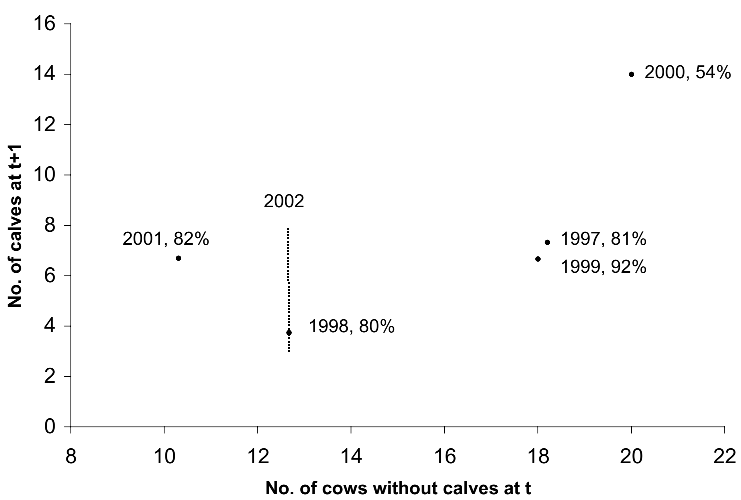


Table 4.38. Musk ox densities (animals/km²) in Store Sødal (92 km² in 1996-1998 and 125 km² in 1999 and on), the census area in Zackenbergdalen (40 km²) and in the coastal region between Daneborg and Zackenberg (37 km²) in mid/late July 1996-2001. The density of faeces piles (no. of piles/km walked) in Store Sødal (no./150 km in 1997-1998 and no./160 km from 1999 and on) and from Daneborg to Zackenberg (no./50 km in 1997-1998 and no./40 km in 1999 and on).

Year	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
Faeces piles/km				
1997 winter/summer	1.59 / 0.49	–	4.90 / 0.82	81
1998 winter/summer	1.55 / 0.39	–	1.14 / 0.68	80
1999 winter/summer	6.26 / 1.63	–	3.66 / 2.46	92
2000 winter/summer	2.33 / 0.38	–	0.90 / 0.22	54
2001 winter/summer	5.54 / 1.11	–	2.10 / 0.36	82

Table 4.39. Fresh musk ox carcasses recorded during the summer of 2001.

ID. no.	UTM East	UTM North	Sex	Estim. age	General remarks
01-1	515125	8264010	M	12+	No sign of wolf
01-2	513916	8266588	M	15+	Wolf faeces, no bone marrow
01-3	514057	8267336	M	12+	No sign of wolf, no bone marrow
01-4	512400	8268500	M	12+	No sign of wolf

Table 4.40. Fresh musk ox carcasses recorded during the field seasons 1995-2001. F = female, M = male. 'Thaw days' are number of days during October-April with positive temperatures, which may have caused ice crust on the snow.

Year	Snow cover 10 June (%)	Thaw days	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	5	13	7 / 1	0 / 1	0 / 2	1 / 1	
1996-1997	81	3	5	0 / 2		1 / 0	1 / 0	1
1997-1998	80	6	2	0 / 2				
1998-1999	92	5	1	0 / 1				
1999-2000	54	3	8	0 / 6	1 / 0			1
2000-2001	82		4	0 / 4				

Table 4.41. Numbers of known fox dens in use, numbers with pups and the total number of pups found at their maternal dens within the 50 km² fox census area in Zackenbergdalen. 'W' and 'D' denote white and dark colour phase pups, respectively.

Year	No. of known dens	No. of dens in use	No. of breed. dens	Total no. of pups
1995	2	0	0	0
1996	5	4	2	5W / 4D
1997	5	1	0	0
1998	5	2	1	8W
1999	7	3	0	0
2000	8	4	3	7W
2001	10	6	3	12W / 1D

the five juvenile arctic hares at the station. As it appears from the number of foxes recorded in the field during June-July 2001 (see Table 4.25), the number equalled the number found in 1996, 1999 and 2000.

Adult foxes were several times observed crossing Zackenbergelven despite high water level and strong current. It was obviously the adult female from den no. 1 that regularly visited the area east of the river during hunts. Caught lemmings were swallowed prior to river crossing while an arctic hare kitten was carried in the mouth during swimming.

On 2 August, one adult was seen heading north away from the maternal den (no. 1) together with three pups. Shortly hereafter the pups were left behind, whereupon no foxes were seen at the den anymore. No pups were seen at den no. 10 after 9 August. The last observation of pups at any den was at den no. 11 on 11 August, when 2-3 pups were recorded.

Arctic hare *Lepus arcticus*

One female gave birth to at least five kittens that stayed in close vicinity of the sta-

Year	White phase		Dark phase		Total number	Total number
	adult	juvenile	adult	juvenile	of records	of carcasses
1996	3	5	1		31W + 3D	
1997	2	1	1		17W + 5D	1W + 1D
1998	3	1	1	2	21W + 3D	1W
1999	3-4		1		18W + 1D	2W
2000	5-6	3			28W	2W
2001	3	4-5	1	1	54W +1D	1W

Table 4.42. Minimum number of individual foxes recorded in Zackenbergdalen (50 km², 1 June – 31 August) divided into colour phases (W = white; D = Dark) and age classes 1996-2001, excluding pups at dens. "Total number of records" gives records of all adults and those juveniles encountered in the field away from their maternal den. Also foxes visiting the research station are included.

tion and under the buildings the hole summer after having been encountered for the first time on 24 June. At least one, but most likely two kittens were taken by arctic foxes (most likely the same fox) on 28 and 29 June, respectively, and one large kitten was killed by a gyr falcon on 26 July. Another large kitten had one ear badly hurt probably by a fox or falcon on 24 July.

Daily records of arctic hares were made whenever weather permitted during 2 July – 30 August, when the east facing slope of Zackenberg mountain was searched by means of a 30 X spotting scope. As in 2000, the hares appeared within a well-defined area on the slope about 1000 meter wide and between 50 and 450 m a.s.l. The maximum daily count within this area was six animals (mean = 2.4) compared to 11 in 2000 (Table 4.43). Additional spotting scope records outside this area included only one in Oksebakkerne. An additional 20 records were made in the field during the field season. In total, a minimum of 15 individuals (incl. 5 kittens) was recorded during the field season.

One carcass of an adult hare was found on Bøllebakken on 1 August.

Walrus *Odobenus rosmarus*

The maximum number of walruses on Sandøen was recorded on 26 July, when 12 animals were hauled-out and eight were beached at the shore-line. On average 6.5 animals were recorded at visits to the island (see section 5.8).

During the waterbird censuses on 10 and 13 August, a lonely animal was recorded diving for food in front of the old delta. Two dives had durations of around six minutes.

Seals Pinnipidae

Resting seals on the fjord ice were recorded during the daily musk ox counts from 1 June until the fjord ice broke up in the inner part of Young Sund on 13 July. An average of 22 seals was recorded per count (Table 4.44). The maximum count of 57 seals was made on the last day of observation.

4.7 Lakes

Kirsten Christoffersen and Erik Jeppesen

The ice on the shallow lakes, Sommerfuglesø and Langemandssø, situated in Morænebakkerne started to melt in June, and a coverage of 50% is estimated to have occurred around 2 July and 8 July, respectively. Both lakes were totally free of ice, when sampling started in late July.

The lakes were sampled three times between 26 July and 18 August 2001. The water temperatures varied little due to the early ice-out and the mean water temperatures were 8.4°C in both lakes (Tables 4.45 and 4.46). The conductivity and pH of both lakes were comparable to measurements from previous years, with Sommerfuglesø being slightly more nutrient rich (Table 4.46). Total phosphourus concentrations were, however, higher than previously found and averaged 18.5 and 20.0 µg P/l in Sommerfuglesø and Langemandsø, respectively (Table 4.46). The

Table 4.43. Arctic hares appearing on the east facing slope of Zackenberg during the daily counts 1 July – 31 August 2000-2001. "Others" denote additional records in the field excluding the family at the research station in 2001.

Year	Average+SD	Range	Counts	Additional
2000	2.78 ± 2.90	0-11	16	22
2001	2.36 ± 1.71	0-6	22	17

Year	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

Table 4.44. Numbers of seals counted daily from a fixed point at the station from 1 June until the fjord ice broke up around mid July, 1997-2001. Counts were only made when visibility was good.

Lake	SS	SS	SS	LS	LS	LS
Date	26.7	8.8	18.8	26.7	8.8	18.8
Ice cover (%)	0	0	0	0	0	0
Temperature (ºC)	7.8	8.8	8.5	7.5	9	8.6
pH	6.6	ND	ND	6.5	6.4	6
Conductivity (µS/cm)	11	21	20	6	9	9
Chlorophyll a (µg/l)	0.72	0.82	0.47	1.57	1.45	1.35
Total nitrogen (µmg/l)	380	ND	310	230	360	440
Total phosphorous (µg/l)	26	ND	11	15	11	34

Table 4.45. Physico-chemical conditions and chlorophyll a concentrations in Sommerfuglesø (SS) and Langemandssø (LS) during July and August 2001.

total nitrogen concentration in Sommerfuglesø was comparable to the two previous years (1999-2000) but higher in Langemandsø than recorded before. The most likely explanation for the high nutrient levels is an increased run-off from the catchment area due to early melting of snow and ice (Christoffersen and Jeppesen 2002). The chlorophyll *a* concentration varied within the level found previously and averaged 0.67 and 1.46 µg/l in Sommerfuglesø and Langemandssø, respectively (Table 4.46). Thus, no obvious effects of the increased amount of total phosphorous were recorded.

The phytoplankton species composition included bluegreen algae (Nostocphyceae), dinoflagellates (Dinophyceae), chrysophytes (Chrysophyceae), diatoms (Diatomophyceae) and green algae (Chlorophyceae), as well as some forms that could not be identified (Table 4.47). The community biomass (expressed in units of biovolume) is dominated (94-95% of the total biomass) by chrysophytes in both lakes. The most important species in Sommerfuglesø were Chrysophyceae spp., Stichogloea spp. and *Dinobryon bacaricum* while Chrysophyceae spp., *Dinobryon bacaricum*, *D. boreale*, *Kephyrion boreale* and *Ochromonas* spp. dominated in Langemandssø. The remaining biomass in both lakes included several dinophyceans (*Gymnodinium* spp. and *Peridinium umbonatum*-group) as well as nanoflagellates (Sommerfuglesø) and green algae (Langemandssø).

Even though phytoplankton diversity varies from year to year, it seems that chrysophytes dominate in years with early ice-melt, while dinophyceans become equally important in a more cold year like 1999 (Table 4.48; Christoffersen and Jeppesen 2002). This trend is similar in both lakes.

Zooplankton was sampled in both lakes on 18 August. The zooplankton community in Sommerfuglesø included the cladocerans *Daphnia pulex*, *Macrothrix hirsuiticornis* and *Chydorus sphaericus*, the copepod *Cyclops Abyssorum alpinus*, as well as the rotifers *Polyarthra dolicopthera*, *Keratella quadrata* and *Conochilius* sp. (Table 4.49). In Langemandssø, where arctic char are present, only *C. sphaericus*, *C. abyssorum alpinus* and *P. dolicopthera* are found, but in much higher numbers than in Som-

Table 4.46. Average values for physico-chemical conditions in Sommerfuglesø (SS) and Langemandssø (LS) in 1999-2001 (July-August) compared to single values from mid-August 1997 and 1998. ND = no data.

Lake	SS	SS	SS	SS	SS	LS	LS	LS	LS	LS
Year	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001
Date of 50% ice cover	ND	9.7	18.7	24.6	2.7	ND	23.7	21.7	30.6	8.7
Temperature (ºC)	6.3	6.5	6.1	10.1	8.4	6.8	6.4	4.0	9.5	8.4
pH	6.5	7.4	6.7	5.8	6.6	6.5	7.0	6.3	5.5	6.4
Conductivity (µS/cm)	15	13	9.7	17.5	18	8	8.7	6.6	9.2	8
Chlorophyll a (µg/l)	0.84	0.24	0.41	0.76	0.67	1.04	0.32	0.38	0.90	1.46
Total nitrogen (µg/l)	ND	130	210	510	350	ND	80	120	290	340
Total phosphorous (µg/l)	4	9	11	10	19	8	7	7	11	20

Lake	SS	SS	SS	LS	LS	LS
Date	26.7	8.8	18.8	26.7	8.8	18.8
Nostocophyceae	0	0	0.001	0	0	0.001
Dinophyceae	0.044	0	0	0.084	0.025	0.012
Chrysophyceae	0.977	0.048	0.049	0.619	0.743	0.415
Diatomophyceae	0	0	0.002	0.002	0	0
Chlorophyceae	0	0	0	0.001	0.006	0
Total	**1.021**	**0.048**	**0.063**	**0.706**	**0.774**	**0.428**

Table 4.47. Biovolume (mm^3/l) of phytoplankton species in Sommerfuglesø and Langemandssø during July-August 2001

merfuglesø. These differences in biodiversity and density are similar to those of previous years and owe to the direct and indirect effects of the predation from fish (see also Caning and Rasch 2000). The early ice-out and the subsequent early rise in water temperature favour the reproduction potential of especially *Daphnia* and *Cyclops*.

Lake	**SS**	**SS**	**LS**	**LS**
Year	1999	2001	1999	2001
Nostocophyceae	0.008	0	0	0
Dinophyceae	0.036	0.013	0.406	0.039
Chrysophyceae	0.08	0.319	0.048	0.632
Diatomophyceae	0	0	0	0.001
Chlorophyceae	0.001	0	0.002	0.003
Others	0	0.003	0	0
Total	**0.125**	**0.335**	**0.456**	**0.675**

Table 4.48. Average biovolume (mm³/l) of phytoplankton species in Sommerfuglesø and Langemandssø in 1999 and 2001.

4.8 Acknowledgements

Peter J. Aastrup critically read the manuscript of chapter 4.

Taxon	**SS**	**SS**	**SS**	**SS**	**SS**	**LS**	**LS**	**LS**	**LS**	**LS**
	1997	1998	1999	2000	2001	1997	1998	1999	2000	2001
Cladocera										
Daphnia pulex	0.3	10.5	0.3	4.5	8.5	0	0	0	0	0
Macrothrix hirsuiticornis	0.1	0	0	0	0	0	0.2	0.2	0	0
Chydorus sphaericus	0.05	0	0	0	0.06	0	0	0	0.5	0.2
Copepoda										
Cyclops abyssorum alpinus (adult+copepodites)	0.8	0.5	0.5	0.2	0.6	3.3	2.9	4.1	22.0	13.6
Nauplii	5.7	1.3	6.5	0.7	1.4	5.2	3.8	6.4	3.1	4.4
Rotifera										
Polyarthra dolicopthera	171	90	184	65	74	316	330	274	168	248
Keratella quadrata group	5	3	17	0	0	4	28	34	0	0
Conochilus sp.	0.05	0	0	0	0	0	0	0	0	0

Table 4.49. Density (no/l) of zooplankton in Sommerfuglesø (SS) and Langemandssø (LS) in mid-August 1997-2001.

5 Research projects

5.1 Digital monitoring/ modelling of snow and vegetation coverage

Jørgen Hinkler

Since 1997, Remote Digital Cameras (RDC) have been used to monitor snow-cover in the Zackenberg area. An RDC is a standard digital camera placed in a weather-proof box equipped with a programmable trigger mechanism. Three RDC's are placed c. 480 m a.s.l. on the eastern slope of the mountain Zackenbergfjeldet. Each day all year round, they capture an image of the valley below. With a specially developed computer programme and a digital elevation model, these oblique images are transformed into so-called orthophotos. Another computer programme, which can detect pixels representing snow, converts the orthophotos to geocoded digital snow-cover maps.

The digital snow cover maps give a detailed picture of snow melt-off in the area. A snow-cover depletion model based on the snow-cover maps, temperature and snow depth measurements was developed (Fig. 5.1 A). The model calculates snow cover depletion in the central part of Zackenbergdalen. If one satellite or air photo and daily temperature records are available for a given melting season, snow cover depletion can be modelled for this season. Modelled snow-cover depletion curves for 12 different melting seasons in Zackenbergdalen are shown in Fig. 5.1 B.

In 2001, a pilot study on multispectral vegetation monitoring in Zackenbergdalen was initiated. The idea is to use an automated Remote Multispectral Digital Camera (RMDC) to monitor vegetation growth / biomass production and the duration of different growing seasons. These factors form a useful basis for the understanding of relations between vegetation, snow cover, and fluxes of e.g. carbon dioxide and methane. During the 2001 season, capabilities of multispectral image analyses were tested. A Dycam multispectral Agricultural Digital Camera (ADC) was installed at the roof of one of the houses at Zackenberg Station, taking daily photographs of the western slope of the mountain Aucella. The ADC-images were recalculated to Normalized Difference Vegetation Index (NDVI)-images. NDVI is a greenness index, which is proportional to the amount of chlorophyll in plants. The index is defined as the difference between near infrared and red reflectance relative to the total amount of reflectance in both these parts of the electromagnetic spectrum.

During the beginning of the growing season dominated by intense snow melt, NDVI increases dramatically until it reaches a maximum around 10 July. Afterwards it ceases gradually as day length (amount of solar radiation) and mean daily temperatures decrease (Fig. 5.2).

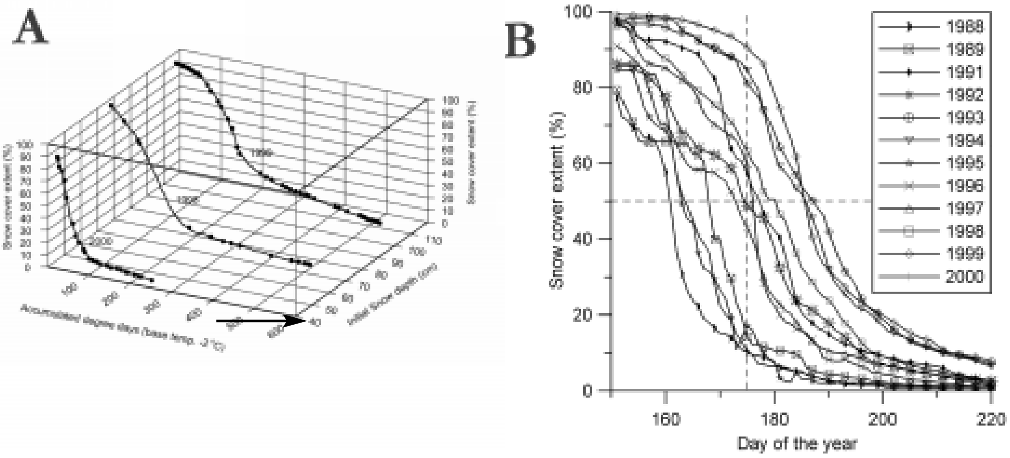


Fig. 5.1. A: Snow depletion modeling; all possible snow-cover depletion curves can be found in a 'depletion space' of accumulated temperatures, initial amount of snow, and snow-cover extent.
B: Interpolated snow-cover depletion curves for 12 different melting seasons.

Currently an RMDC to be installed at the same location as the RDC's is under development. With this system, it will be possible to give quantitative estimates of biomass production in Zackenbergdalen derived from multispectral orthophotos.

5.2 Near-surface soil CO_2 dynamics within a permafrost-affected soil

Bo Elberling and Jens Søndergaard

Microbial soil respiration is known to occur in frozen soils resulting in elevated soil and snow CO_2 concentrations as well as CO_2 effluxes during winter. In addition, releases of CO_2 from soil have been observed in relation to initial soil thawing. Up to a 10-fold increase in the CO_2 release upon thawing (burst events) has been reported (Goulden *et al*. 1998). It is unclear to which extent winter respiration contributes to such burst events and whether seasonal trends in soil CO_2 release over the year can be assumed to be a result of steady state soil CO_2 production.

Field activities in Zackenberg have been carried out in 2001 (June-August) as part of the larger project, "Quantification and modelling of gas behaviour and weathering processes in the unsaturated zone", financed by Danish Natural Science Research Council. Within this framework, activities in Zackenberg aim to evaluate seasonal controls of subsurface CO_2 concentrations and dynamics within three fairly well-drained tundra heath sites (*Dryas*, *Cassiope* and *Salix*).

The 2001 field work

CO_2 effluxes, temperatures, water contents and pore gas compositions in soil were monitored from the first snow melt in June 2001 and the following three months. Soil CO_2 effluxes (microbial and root respiration) were measured by means of a LiCor infrared gas analyser (LiCor 6400-09 Soil CO_2 Flux Chamber, LiCor, Lincoln, USA). The CO_2 analyser (non-dispersive infrared analyser) was attached to a portable chamber, functioning as a dark and closed soil-flux chamber. During measurements of 2-3 min the soil-flux chamber was placed on top of open columns (9 cm long and 10 cm inside diameter) installed in the ground. Absolute values of both sample and reference mole fractions (CO_2 and H_2O) were measured continuously. The CO_2-efflux was calculated based on a linear increase (R^2 > 0.95) in chamber CO_2 concentrations over time.

In addition, a detailed monitoring program evaluating daily variations in CO_2 effluxes was performed during two weeks prior to soil thawing in June 2001. At this site snow was removed and effluxes were monitored during *in-situ* thawing of the upper 0-20 cm of the soil (Fig. 5.3).

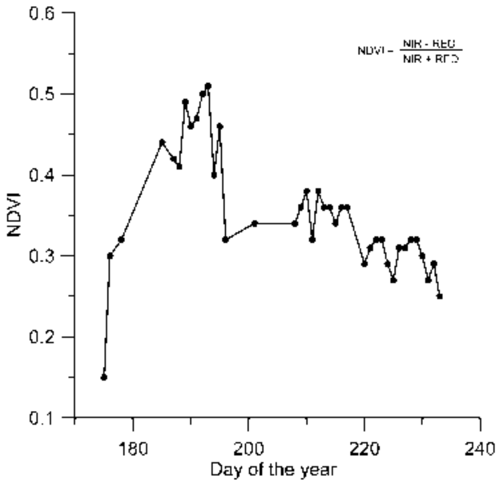


Fig. 5.2. Maximum NDVI values on the western slope of the mountain Aucellabjerg during the 2001 growing season.

Results and discussion

Temporal trends of observed soil CO_2 effluxes during the growing season were highly correlated to near-surface temperatures (Fig. 5.4). Based on measurements after the initial soil thawing in 2001 (after 24 June) more than 80% of the variation in soil CO_2 effluxes could be explained by near-surface soil temperature variations. Short-term observations indicated that also daily variations in soil CO_2 effluxes are primarily controlled by soil temperatures. High rates at the end of the season were consistent with a heavy precipitation event. Variations in CO_2 effluxes during

Fig. 5.3. Soil CO_2 efflux measurements during rapid soil thawing in early June 2001 (Photo: Bo Elberling).

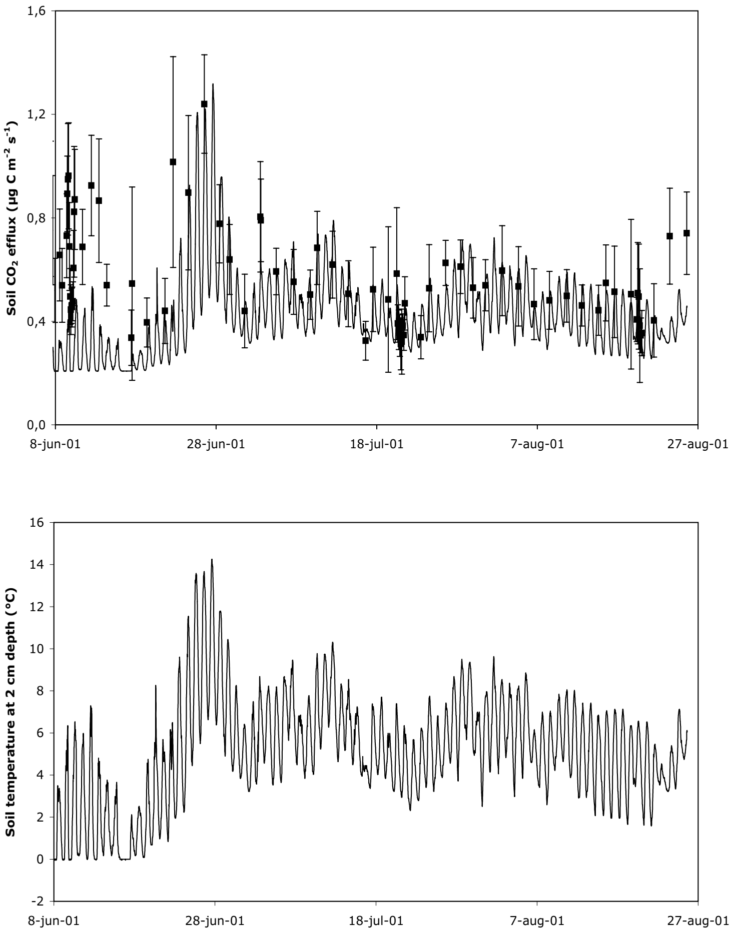


Fig. 5.4. Soil CO_2 efflux (A) and ground temperature at 2 cm below the surface (B) at the Cassiope site. The CO_2 efflux is simulated using the observed soil temperature and an exponential function. The model result is shown as s solid line (A).

rapid soil thawing could not be explained solely by changes in temperature. Results indicated that about 75% of the total efflux observed during 24 hours could be explained by on-going respiration. Over the same period the active layer was observed to increase about 2-3 cm in thickness. Using a simple mass balance for the day, the remaining 25% could be explained by the release of CO_2 from the thawing soil observed to contain more than 10% CO_2 in the air-filled pore space. As these high CO_2 concentrations are almost two orders of magnitude higher than measured by the end of August 2000 just prior to ground freezing, the majority of soil CO_2 is considered being produced within the frozen soil and released upon soil thawing. These observations are at the moment being further related to results of laboratory manipulations of water availability and temperatures and used to simulate and evaluate seasonal and vegetation-specific controls on soil respiration.

5.3 Global Change effects on unicellulars and plants

Louis Beyens, Ivan Nijs, Andy Van Kerckvoorde, Pieter Ledeganck, Koen Trappeniers, Fred Kockelbergh, Sofie Mertens and Ivan Impens

This project started in 1998 and involves a study on global change effects on unicellulars and plants. The objectives of the overall project are explained in the ZERO 4th Annual Report 1998 (Rasch 1999). We present here a short summary of the fieldwork in 2001, followed by some results from fieldwork done in previous seasons.

The 2001 fieldwork

The fieldwork in the summer of 2001 focused on the influence of a heat spell on the carbon balance in a tundra ecosystem. Three of six small grassland plots were exposed to infrared radiation (FATI-system) (Nijs *et al.* 1996, 2000) during 8 days to increase the surface temperature by 8.5°C. CO_2-flux data were collected every two days, using dynamic closed chamber techniques. We observed in this preliminary experiment of extreme disturbances on the C-budget e.g. an increase of the soil respiration and a significant increment of the photosynthesis. The effects disappeared nearly without delay when we turned off the heaters. To explain and model trends in the above ground fluxes we measured chlorophyll content and recorded digital images of the plots to monitor changes in 'greening' and cover during and after the heating. Point quadrat methods were also used to detect shifts in species composition. From the fluorescence measurements during the experiment we learned that the species in the heated plots were less stressed than their counterparts in the control plots. Further investigation will have to point out to what extent climatic extremes can be compared to physiological extremes.

Ecology and community structures of unicellulars: results from previous fieldseasons

Testate amoebae

The testate amoebae data lists of the previous years, presented in the previous ZERO Annual Reports, were put together. In the three different habitats (soils, terrestrial mosses and waterbodies) 77 different taxa, belonging to 19 genera, were observed. The aquatic samples harboured a higher number of taxa compared with soil or terrestrial mosses. About one third of the taxa was found exclusively in aquatic samples, but these taxa contributed only 9% of the total abundance in the water samples. Taxa occurring in the 3 major habitats made up about a third of the number of taxa. This group of taxa becomes extremely important when considering the contribution in abundance for each habitat type. The major TWINSPAN-clusters represented the three major habitats (Fig. 5.5). *Assulina muscorum* and *Corythion dubium* occurred typically in terrestrial mosses. *Plagiopyxis callida* and *P. declivis* were restricted to the soils. *Difflugia globulosa* and *D. penardi* showed preferences for aquatic samples.

When comparing our taxa list with the list of all testate amoebae taxa ever found in the Arctic (Beyens and Chardez 1995), eight taxa were recorded for the first time: *Centropyxis sacciformis* Hoogenraad, *C. deflandriana* Bonnet, *Difflugia acuminata* Ehrenberg, *D. pristis* Penard, *Difflugiella crenulata* Playfair, *Euglypha strigosa* f. *heterospina* Wailes, *Heleopera rosea* Penard and *Sexangularia minutissima* Penard. An interesting biogeographic observation is the occurrence of *Cyphoderia perlucidus* Beyens and Chardez in water samples from Zackenberg. This taxon is only known from arctic regions: it was found in Edgeøya (Beyens and Chardez 1986), Devon Island (Beyens *et al.* 1991) and in Victoria Island (Beyens and Chardez 1995). The record in Zackenberg marks an intermediate geographic position between these former observations.

Using weighted-averaging regression, a predictive model for the F-value of the mosses has been developed. The optima and tolerances for the different taxa are shown in Fig. 5.6.

	*0		*1
	*00	*01	
	[illegible]	[illegible]	A1, A2, A3, A4, A5, A6, C1, C2, C3, C4, C5, C6, F1, F2, F3, F4, F5, F6, S1, S2, S3, S4, S5, S6, V1, V2, V3, V4, V5, V6, M451, M458, M469, ZM01, ZM02, ZM03, ZM04, ZM05, ZM18, ZM28
Achnanthes helvetica	0,50	0,12	0,00
Achnanthes marginulata	6,77	6,82	0,03
Achnanthes minutissima var. *minutissima*	7,41	1,45	0,10
Achnanthes petersenii	5,84	2,82	0,02
Achnanthes pusilla	1,85	0,02	0,00
Achnanthes subatomoides	1,23	0,07	0,00
Brachysira zellensis	2,33	0,03	0,00
Caloneis aerophila	0,09	0,36	2,31
Caloneis arctica	0,42	4,80	0,23
Cymbella falaisensis	2,27	1,40	0,00
Cymbella paucistriata	0,96	2,74	0,07
Cymbella cesatii	0,16	0,82	0,01
Diadesmis contenta	0,39	0,26	2,77
Diadesmis contenta f. *biceps*	0,19	0,45	13,88
Diadesmis perpusilla	1,42	5,22	11,87
Eunotia arcus	0,87	0,05	0,00
Eunotia fallax	1,00	13,54	6,95
Eunotia praerupta	0,30	0,45	1,82
Eunotia praerupta var. *bidens*	0,00	1,33	0,24
Fragilaria capucina var. *vaucheriae*	5,20	0,88	0,16
Fragilaria pinnata var. *pinnata*	10,50	0,64	0,02
Hantzschia amphioxys	0,01	0,08	3,71
Luticola mutica	0,02	0,09	1,17
Navicula atomus	0,00	0,00	9,10
Navicula cryptocephala	0,59	1,18	0,07
Navicula gandrupii	0,14	1,99	0,20
Navicula pseudoimmeloides	0,01	1,44	0,00
Nitzschia alpina	2,36	0,06	0,00
Nitzschia perminuta	8,67	13,21	6,52
Pinnularia balfouriana	5,12	1,50	0,10
Pinnularia borealis	0,06	0,12	12,40
Pinnularia borealis var. *thuringiaca*	0,02	0,05	1,14
Pinnularia curticostriata	0,02	0,27	9,10
Pinnularia divergens var. *decrescens*	0,07	1,30	0,00
Pinnularia obscura	0,28	1,02	7,15
Pinnularia sinistra	0,01	1,22	0,07
Stauroneis anceps	0,39	1,36	0,11
Tabellaria flocculosa	11,32	2,69	0,21

Fig. 5.5. The major TWINSPAN clusters showing the mean relative abundance of the important and most differentiating testacean taxa.

Diatoms

In the three different habitats (soils, terrestrial mosses and waterbodies) 244 different taxa, belonging to 32 genera, were observed. Comparable with the testate amoebae, the aquatic samples harboured a higher number of taxa compared with soil or terrestrial mosses. About half of the taxa were found exclusively in aquatic samples. However, these taxa contributed to merely 13% of the total abundance in the aquatic samples. Only a few number of taxa were exclusively restricted to soil habitats or terrestrial mosses. Taxa common to the three major habitats made up about a quarter of the total number of taxa. This group became extremely important when considering the contribution to the total abundance for each habitat type. A TWINSPAN classification revealed three major divisions. The first cluster grouped all soil samples together with the driest terrestrial mosses and was characterised by *Diadesmis* spp., *Hantzschia amphioxys*, *Navicula atomus*, *Pinnularia borealis*, *P. curticostriata* and *P. obscura*. The second cluster contained water and most terrestrial moss samples and was typified by *Caloneis arctica*, *Eunotia fallax* and *Nitzschia perminuta*. The third cluster contained

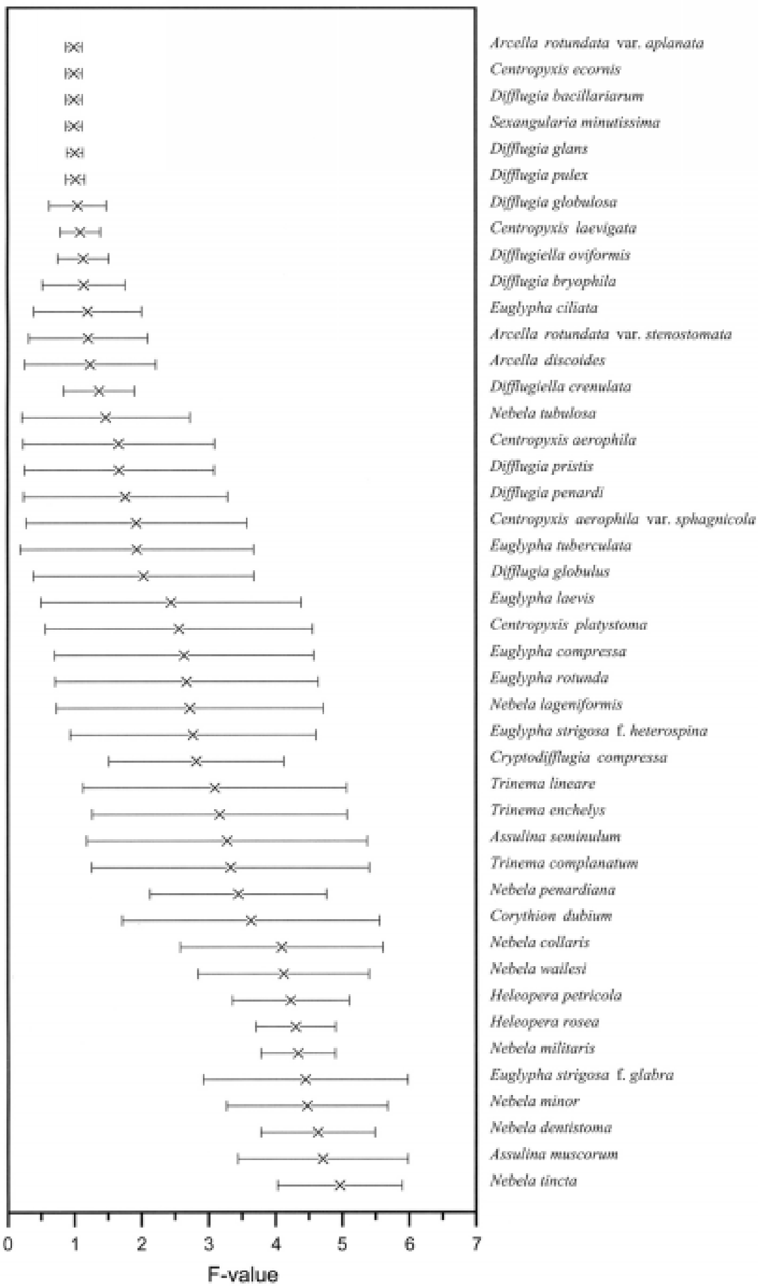


Fig. 5.6. WA optima and tolerance of the different testacean taxa according to F-value.

mainly water samples. Two terrestrial moss samples were included in this cluster. *Achnanthes minutissima*, *A. petersenii*, *F. pinnata* var. *pinnata* and *Tabellaria flocculosa* characterised this cluster. Not surprisingly tychoplanktonic taxa as *Fragilaria* spp. and *Tabellaria flocculosa* differentiate this cluster. Other characterising taxa were *Achnanthes minutissima* and *A. petersenii*. However, a clear differentiation of the different habitat types was not observed.

Using weighted-averaging regression, a transfer function was made for the F-value of the moss samples. The moss samples included the terrestrial mosses (F-value III-VIII) and the aquatic ones (F-value I-II). 80 moss samples were used in the regression. The optima and tolerances for the different taxa are shown in Fig. 5.7.

Palaeoecology

A total of seven peat and soil cores were analysed. As stated in the previous ZERO report, the analysed diatom and testacean assemblages revealed a shift in humidity conditions, changing from a wetter environment in the oldest layers of the core, which were dated at 5,790 ± 35 years BP, to rather dry conditions in the younger layers.

When plotting the diatom composition of the samples in the lower part of core 5 as passive samples in the DCA-analysis of our recent aquatic samples, they all clump next to the recent samples showing a higher pH (Fig. 5.8). Whether the testate amoebae assemblage found in the lower part of core 5 is characteristic for alkaline conditions is not clear for the moment. An assemblage with high abundances of *Difflugia globulus* and *Centropyxis platystoma* was never observed in our analysis of the recent samples. Beyens *et al.* (1991) associated *Centropyxis platystoma* with high pH values in waterbodies having a pH varying between 6.8 and 9.4. However, Laminger (1972) found high abundances (abundance of 68%) in a waterbody with pH 7. Schönborn (1966) mentioned a high importance of *Difflugia globulus* (under the name *D. globulosa*) in samples from alkaline waterbodies in Spitsbergen. Also Dallimore *et al.* (2000) noted the importance of *Difflugia globulus* in alkaline conditions. Based on species composition of testate amoebae and diatoms the palaeo-environment between 5,790 BP and 5,595 BP at the locality of core 5, being the western side of the airstrip at Zackenberg station, was probably an alkaline pool or marsh with a relatively high conductivity.

5.4 Effects of UV-B radiation on arctic perennial plants

Teis N. Mikkelsen, Helge Ro-Poulsen and Linda Bredahl

Emissions of certain gaseous pollutants, like the CFCs, have reduced – especially in polar regions – the stratospheric ozone layer which protects the earth's surface from incoming UV-B radiation. This radiation band is injurious to DNA and can influence growth, development and lifecycle of organisms. Although biological repair mechanisms exist, these mechanisms have energetic costs and mutations may remain as errors in the repair processes. The combination of different processes can lead to a variety of adverse effects on plants and may interact with other factors, making it difficult to attribute to UV-effects specifically. Little is known about the effects of ambient UV-B radiation on terrestrial organisms in a natural environment. This project seeks to identify and quantify some effects of UV-B radiation on the performance of plants under field conditions and on the interactions with microclimate.

The experimental investigation was initiated in the beginning July 2001. A set of aluminium frames covering 47x60 cm was installed 20 cm above the ground on two slopes facing south approximately 500 m south from the station. The plant cover was dominated by *Salix arctica*, *Vaccinium uliginosum*, *Cassiope tetragona* and *Dryas* spp. Four types of treatments were applied: UV-A and UV-B absorption (transparent Lexan®), UV-B absorption (transparent Mylar® type D), no UV absorption (transparent Teflon®, control) and no filter (filter control) (Fig. 5.9). The treatments were replicated four times at each slope. The plots were exposed to the treatments from 10 July to 17 August. During the treatment period the following parameters were studied: Photosynthesis at saturated light level (1,200 µmol photons / m^2 / s), photosynthesis at saturated light level and saturated CO_2 concentration (1,500 µmol CO_2 / m^2 / s), photosynthetic response curves in relation to light, temperature and CO_2 concentrations, chlorophyll fluorescence induction kinetics, relative chlorophyll content, specific leaf area (SLA), relative content of flavonoids (UV-B absorbing pigments) and species composition. Micrometeorological measurements were conducted at each slope. In each plot air and soil temperatures were measured, soil water content was measured in four plots at each slope and photosynthetic active radiation (PAR), relative humidity and temperature were measured 20 cm above the ground.

Besides absorbing different proportions of short wave solar radiation, the transparent filters affect the temperature conditions underneath. The results show that the different types of foils increase the average air / soil temperature with 0.0 / 0.4

Fig. 5.7. WA optima and tolerance of the different diatom taxa according to F-value.

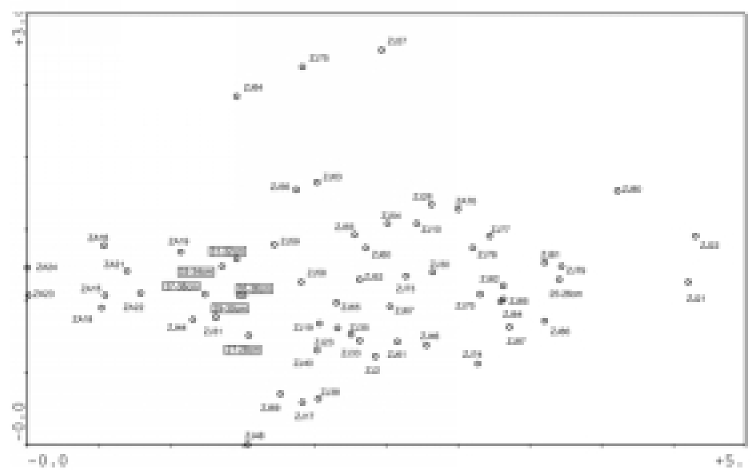


Fig. 5.8. DCA-ordination diagram of the recent aquatic samples. The samples of the lower part of core 5 (27-28 cm, 29-30 cm, 31-32 cm, 33-34 cm, 35-36 cm, 37-38 cm) were plotted as passive samples (boxed labels).

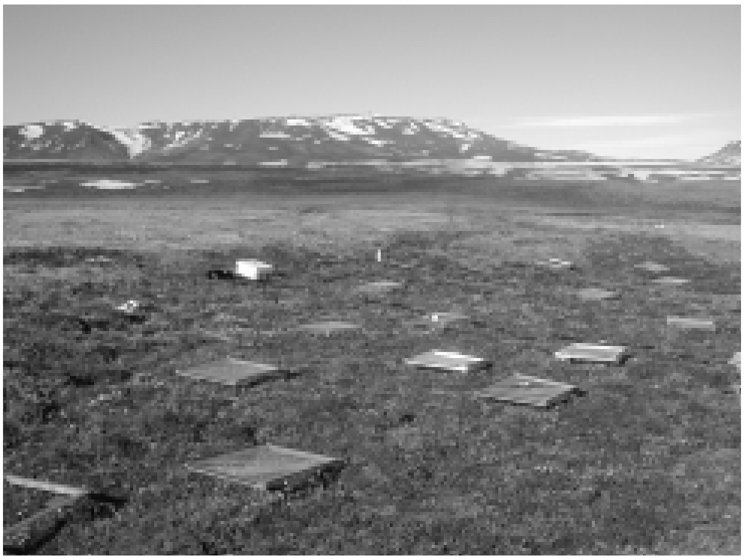


Fig. 5.9. A section from one of the selected slopes. The transparent filters absorb different quantities of UV radiation.

°C (Teflon®), 0.2 / 0.5 °C (Mylar®) and 0.5 / 0.5°C (Lexan®). This artefact should be compared to the average air / soil temperature in the control, which was 4.9 / 3.5 °C.

Photosynthetic response curves for *Salix arctica* outside the treatments shows a light saturation from around 1200 µmol photons / m^2 / s (Fig. 5.9 a) and a temperature optimum at 10 °C (Fig. 5.9 b). A close relation between inhibition of chlorophyll fluorescence (F_v / F_m) and accumulated photosynthetic active radiation was found (R^2=0.61, Fig. 5.12). F_v / F_m reflects the current state of photosystem II (PS II) and a reduction in PS II indicates a decrease in photosynthetic potential. For the treatments, only preliminary data are available (data analysis is ongoing). If the Mylar® treatment (removal of UV-B) is compared to the Teflon® treatment (control) an increase is seen for F_v / F_m and this indicates a lower stress level on the photosynthesis.

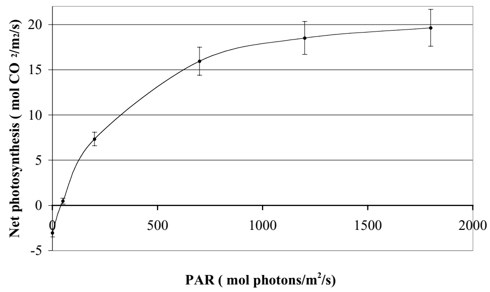


Fig. 5.10. Average light-photosynthesis response curve on Salix arctica from 16 plants.

5.5 Altitude distribution of vascular plants on Clavering Ø, Northeast Greenland, 74° N. A comparison between 1931-32 and 2001

Fritz Hans Schwarzenbach

The Danish botanist Poul Gelting wintered 1931-32 at the former scientific station Eskimonæs on Clavering Ø. He studied the altitude distribution of vascular plants from sea-level to the altitude limit of higher plants (1,250 m) in the area from Eskimovig (east of Eskimonæs) to Granatdal (WSW of the station). He concentrated his work mainly on the surroundings of Eskimonæs and on the Rustplateau. The results are published by Gelting (1934, pp. 239-245) with the data summarized in a comprehensive and well commented table. Many details – as well as the highest records of each species in the area between Eskimovig and Granatdal – are included in the texts on the individual species.

My own study was done between 28 July and 15 August 2001, concentrating the field work on the sub-area “Eskimonæs” where Gelting had found the highest limit of vascular plants at an altitude of 1,250 m. The altitude distribution of plants at higher levels (530-1,320 m) was studied

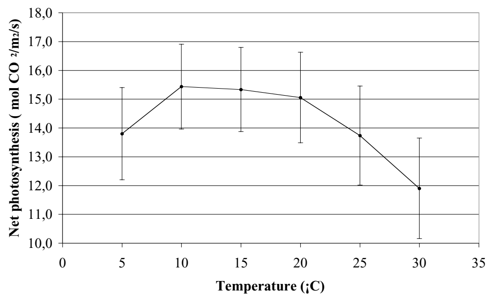


Fig. 5.11. Average temperature-photosynthesis response curve on Salix arctica from 16 plants.

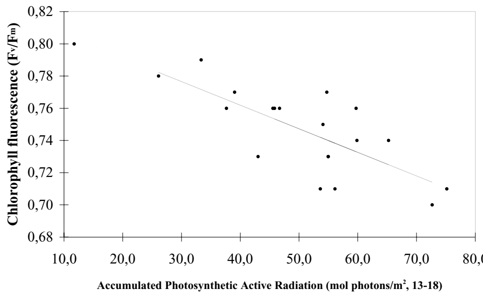


Fig. 5.12. Correlation between chlorophyll fluorescence (Fv/Fm) and accumulated photosynthetic active radiation.

during a stay in a camp at 620 m (31 July to 8 August). The remaining days were used for excursions at lower altitudes between Eskimonæs, and the slopes east of Granatdal.

The vegetation of twelve sites between the coast and the highest summit reached during the summer, 1,320 m, were studied in detail. The topographical position was determined by GPS and altimeter. The places were photographed. Some of these sites were marked by little cairns on top of striking boulders. The selected plots represent typical types of vegetation at different altitudes. All species found in the vicinity of the marked points were noted. No phytosociological analysis could be done due to lack of time.

The twelve sites were selected to serve as a base for further studies in the future.

Gelting had based his study on lists of species he had found walking to and fro through the area noting all species within each of the 13 belts of 100 m between the coast and the maximum altitude reached by vascular plants (1250 m). The same method was used for the survey of 2001. In addition, the altitude was recorded whenever a species was observed for the first time descending from higher to lower levels. This simple method gives a reasonable estimate of the altitude limits. Alltogether, the study of the summer 2001 includes c. 1400 records (species, altitude, site).

Gelting found 132 species (according to the taxonomy of his time) in the area between Eskimovig and Granatdal. The number of species observed during the summer 2001 is around 120, as some critical species have to be determined by specialists of the Greenland Herbarium in Copenhagen. Most of the species not retrieved by the author are rare. They are either restricted to the coast (e.g. *Chrysosplenium tetrandrum*) or were found around ponds or in mires below 150 m (e.g. *Pleuropogon sabinei*, *Calamagrostis neglecta*).

On the other hand, the occurrence of the following rare species could be confirmed: *Cardamine pratensis*, *Cerastium regelii* (only at 30 m), *Matricaria inodora*, *Minuartia rossii*, and *Saxifraga hieracifolia*. In addition, three species which had been found by Gelting only at very low levels were observed at high altitudes: *Cochlearia groenlandica* (880 m), *Erigeron compositu* (1320 m), and *Saxifraga hirculus* (930 m). Further, *Epilobium arcticum* (840 m) could be added to Gelting's list.

The altitude distribution of vascular plants has changed since 1931-32. The most interesting observation is the shift of the altitude limits of a considerable number of species. Gelting found no species of higher plants above 1250 m. He lists three species at a site of 1250 m, and five more species at 1225 m. On the other hand at least 28 species were observed within the altitude range from 1225 m to 1320 m in the summer 2001. More details will be published after the analysis of the new data.

5.6 Pervasive influence of the North Atlantic Oscillation in muskox – *Salix* feedback dynamics

Mads C. Forchhammer

Ecological responses to inter-annual as well as decadal fluctuations in large-scale climate, such as the North Atlantic Oscillation (NAO) (Hurrell 1995) have been explored primarily through direct climatic influence on separate trophic levels. However, a recent study (Post *et al.* 1999) reveals that indirect climatic forcing through the biological interactions between trophic levels may play an even more important role in determining how community and ecosystems respond to perturbations in climate.

This study, which is financed by the Aalborg Zoo and the Danish Polar Center, focuses on the long-term ecological effects of indirect climatic effects mediated through interactions between the muskox (*Ovibos moschatus*) and one of its important forage species (*Salix arctica*).

Whereas long-term population data on the muskox population in Wollaston Forland exist from previous sources (Forchhammer *et al.* 2002), the field campaign at Zackenberg in 2001 aimed at collecting long-term data on inter-annual growth of *Salix*. In total, 105 individual plants were collected and their sampling sites described (Fig. 5.13). Preliminary tree-ring analyses show that annual growth dynamics of *Salix* can be made over a period of 17 (Fig. 5.14 a) to 63 years, hence making it possible to analyse up to 40 years of muskox-*Salix* dynamics, retrospectively.

Combining ecological theory with statistical modelling of time series provides the basis for simultaneous evaluation of the

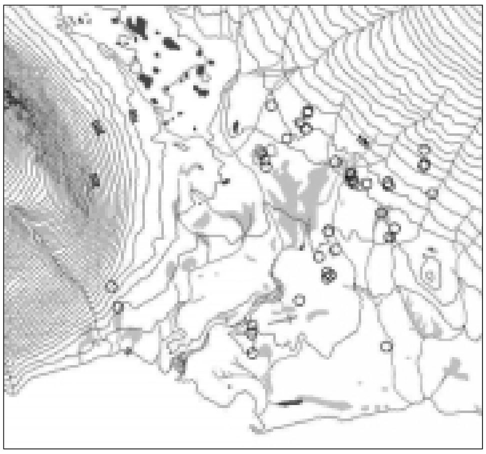


Fig. 5.13. Map of Zackenbergdalen with all the sites sampled in 2001.

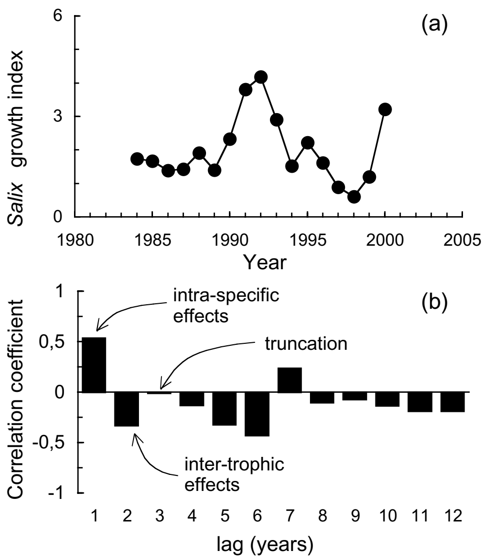


Fig. 5.14. (A) 17-year time series of annual growth of a Salix plant as measured by annual tree-ring width adjusted for age. (B) Partial autocorrelation function (PACF) displaying the temporal lagged partial influence (correlation) of previous years growth on present year growth. The truncation point between 2 and 3 years lagged influence in the PACF indicate a two-dimensional time series structure suggesting a combined influence of intra-specific (1-year lag) and inter-trophic (2-year lag) factors.

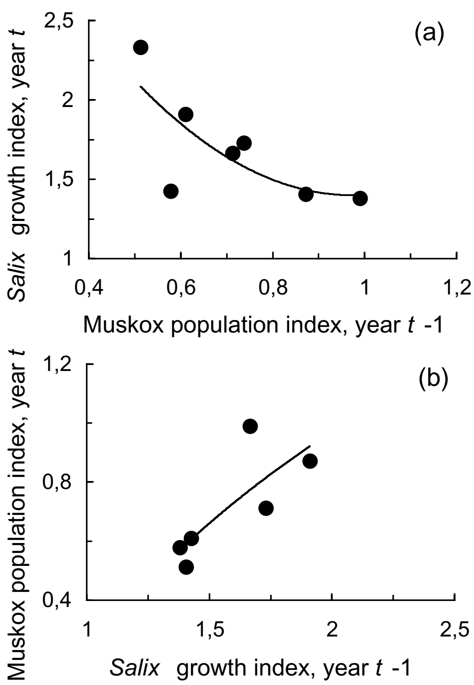


Fig. 5.15. Relationship between (A) current year (t) growth of Salix and last-year (t-1) muskox abundance and (B) current year (t) muskox abundance and last-year (t-1) growth of Salix.

relative importance of biological and climatic (direct as well as indirect) effects over longer time span (Forchhammer 2001). For example, the large variability in inter-annual growth seen for the 17-year old *Salix* individual in Fig. 5.14 a can best be explained by a two-dimensional time series structure and, hence, by a combination of intra-specific (competitive) and inter-trophic (plant-herbivore) interactions (Fig. 5.14 b). The same has been demonstrated previously for inter-annual changes in the abundance of muskoxen in Wollaston Forland (Forchhammer *et al.* 2002).

Since the muskox-*Salix* system apparently can be characterised by lagged, non-linear feedback dynamics (Fig. 5.15 a,b), the direct influence by the NAO demonstrated on both *Salix* growth dynamics (Fig. 5.16) and muskox abundance (Forchhammer *et al.* 2002) may potentially be channelled through from *Salix* to muskox and / or vice versa. The relative importance of these indirect climatic effects will be determined by further analytical modelling (Forchhammer 2002) integrating all the data collected in this study as well as comparative data from other localities within the geographical range of muskoxen in Greenland.

5.7 Collared Lemming Project – Zackenberg

Thomas Bjørneboe Berg

After a low density of lemming winter nests in 2000, the lemming population has

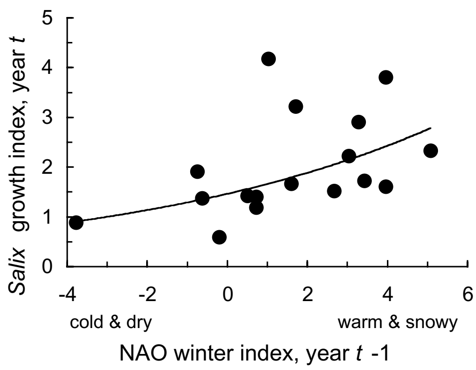


Fig. 5.16. The influence of the NAO on growth of Salix arctica*: high NAO winters (warm and snowy) were followed by increased annual growth of* Salix*, whereas low NAO winters (dry and cold) depressed annual growth of* Salix.

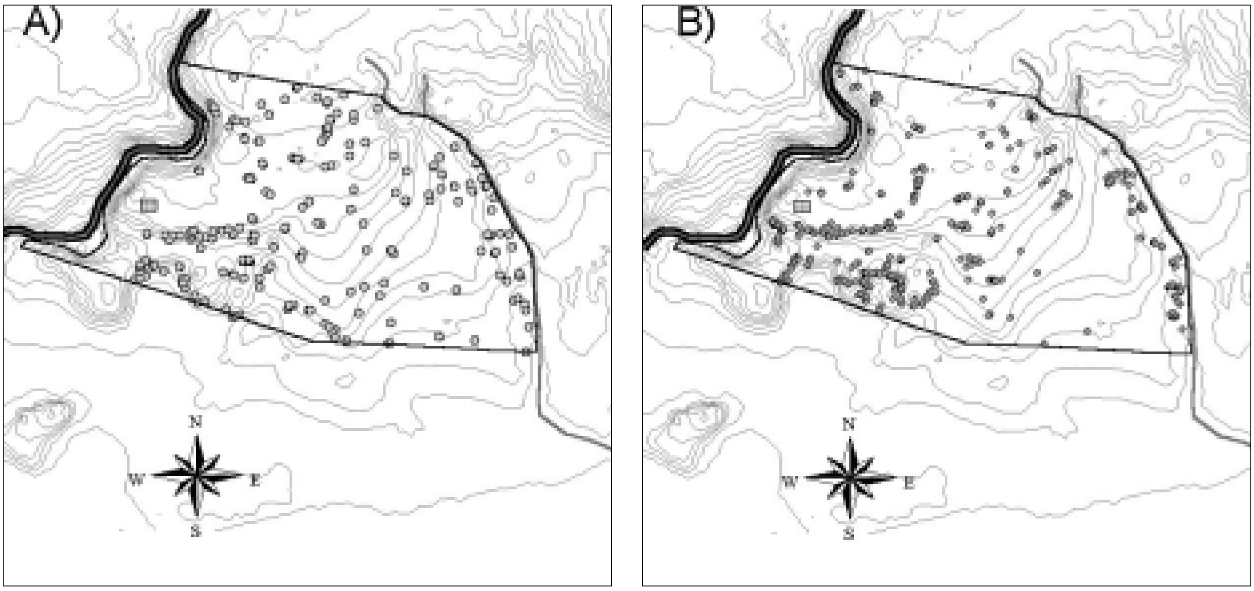


Fig. 5.17. (A) Spatial distribution of 318 winter nests build during winter 2000-2001 and recorded during summer 2001. (B) Positions of 869 summer active burrows. The western thick line is Zackenbergelven and the eastern thin line is Kærelv. The 2.08 km² lemming census area is fenced by the solid line. Zackenberg Station is marked by a square.

initiated its increase phase towards an expected winter peak in the coming winter 2001 / 2002. The situation equalled the one in 1997. The number of active summer burrows peaked in 2001, a year before the expected maximum of winter nests, as was the case in 1997. While the use of summer habitats were within the same areas as last year, the use of winter habitats were expanded. The actual positions of winter nests and summer burrows are shown in Fig. 5.17.

The major part of this summer's fieldwork focused on summer burrows, their physical structure, vegetation descriptions and sampling of selected plant species around burrow entrances. During summer lemmings spend most of their time in close vicinity of their summer burrow entrances and may hence affect the vegetation heavily within three meters from the burrow. Samples of *Dryas*, *Salix*, *Poa* and *Kobresia* were made within one meter as well as beyond six meters. Analysis of phenol content is expected to show higher levels of phenols close to the burrow than beyond six meters from the burrows as grazing induce production of chemical plant defences. Results from feeding experiments conducted in 2000 (Caning and Rasch 2000:55-56) showed that simulated grassing increased the phenol content in the *Dryas*, *Salix*, and *Vaccinium* (Berg 2003a) and that lemming fed on female *Salix* and *Dryas* leaves had a preference for those leaves that contained the least amount of phenol.

Four enclosures of 1 m² were set up in four different vegetation compositions. One lemming was placed within each enclosure two to three times during the summer. The lemmings were starved for four hours prior to the experiment in order to empty their guts and were provided with a nest box as shelter. During summer lemmings defecate in their summer burrows to minimise the smell in the open that may attract predators. After roughly 34 hours the lemmings were removed and their faeces collected from the nest box. Faecal as well as phenol analyses are in progress.

For the first time, according to the literature, the sub-terrain life space of collared lemming has been investigated (Berg 2003b). 383 summer burrows were analysed by means of a three-meter long optic fibre scope. About five percent of the burrows were too curvy for the fibre scope to penetrate to the end. Roughly 300 meter of subterrain corridors were examined. Mean length of corridors being around 75 cm. 21 percent of the burrows contained a nest made of grass. None of the burrows showed any attempt by the lemming to make food storage although leaves of *Dryas*, *Salix*, *Vaccinium*, *Empetrum*, *Cassiope*, and unspecified grasses were observed in the corridors. Around 33 percent of the burrows contained piles of faeces.

40 lemmings were caught within the area of the 383 summer burrows using "Ugglan special" live traps. They consisted of 18 reproductively active adults (10 males, 8 females) and 22 subadults (9 males, 13 females). Additional seven juveniles (two litters of three and four respec-

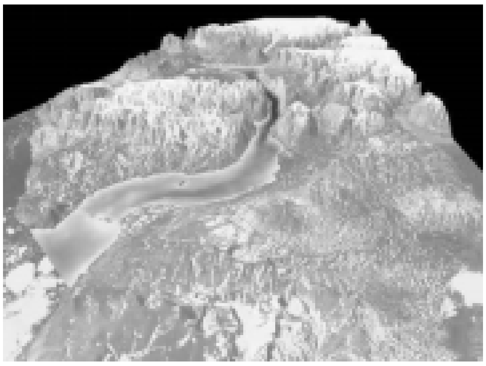


Fig. 5.18. Digital elevation model of the Young Sund – Tyroler Fjord fiord system.

tively, born around mid July) were recorded, but sex determination was too uncertain. Of these 40 animals, 27 were radio collared using 2.5-gram radio transmitters from BioTrack. Four animals were still alive by the end of August, six were killed by fox (all males), between two and four presumably by stoat (all females), two died in the trap and 13 had an unknown fate of which long-tailed skuas probably have taken their share. Thus the survival rate has been at least 15 percent during this increase phase (summer peak) compared with 5 percent in the peak year 1998 (summer crash) when 27 animals were radio collared within the same area (Rasch 1999:51-53).

5.8 Marine studies in Young Sund

After the conclusion of the CAMP project (Changes in Arctic Marine Production) in April 2001, the people involved decided to continue the marine work by other means of funding this year. Besides the walrus work that is funded until 2003, we managed to initiate new projects in Young Sund that will continue until 2003 as well. Furthermore, a proposed long-term marine monitoring program (MarineBasic) has been applied for, and we are certain that this program will ensure and stimulate continued marine research in the area. The fieldwork this year focused on:

- Bathymetry
- Hydrography
- Microbial mats
- Bivalves
- Walrus
- Film activities

Bathymetry of Young Sund

Søren Rysgaard, Michael Stjernholm, Torben Vang, Egon Frandsen and Jan Damgaard

An important goal of the marine studies is to model the carbon cycle in Young Sund. However, a prerequisite for hydrodynamic modeling is to know the bathymetry of the fjord. The outer part of the fjord and an area near Zackenberg has been mapped previously, although the grid-size was relatively coarse (see previous ZERO Annual Reports). This year we surveyed the bottom topography of the remaining part of Young Sund, and improved data cover in previously mapped areas. Especially the outer part of the fjord around the sill was mapped in great detail. The survey was performed from a rubber dinghy using a combined echo sounder and GPS receiver (Lowrance LC X-15 MT 50 / 200 kHz 35° / 12°). Data were recorded continuously while sailing along pre-defined transects. The total distance was 850 km and a total of 200,000 data points were collected. The bathymetric map of Young Sund was constructed after data quality control and correction for tidal amplitude.

Our data were integrated with topographical data from GEUS and a Landsat TM satellite image to construct the map of the entire area (Fig. 5.18). The fjord covers a surface area of 390 km^2, is 90 km long and 2-7 km wide. The average depth in Young Sund is around 100 m and the maximum depth of 360 m is found in Tyroler Fjord. A sill of 40-50 m that greatly influences the hydrography in the fjord (see later) is found in the outer part of the fjord. It is likely that Young Sund is representative of numerous fjords along the East Greenland coast and that ancient retreat of glaciers were responsible for the creation of the sills. The data set was used to estimate the drainage basin area of Young Sund (Fig. 5.19). The area was found to be 3,109 km^2 although there is some uncertainty regarding the exact position of the border at the margin of the Greenland Ice Sheet inside the fjord. Further work is needed in order to determine the exact area. As freshwater input to Young Sund plays a very important role in the circulation and hydrographic regime of the fjord, it is important to obtain a valid estimate of the total freshwater input to the fjord in the future.

Hydrographic and oceanographic measurements in Young Sund

Torben Vang, Bjarke Rasmussen, Anders Windelin, Egon Frandsen, Jan Damgaard, Peter B. Christensen and Søren Rysgaard

A comprehensive hydrographic study of Young Sund was accomplished during the summer of 2001. Young Sund is a deep sill fjord with significant buoyancy input in the form of freshwater from the melting of snow and ice in the catchment area and the melting of sea ice. The buoyancy input tends to drive an estuarine circulation in which lighter water is moved seaward over heavier water moving towards the freshwater sources. This stratification competes with stirring by tides and wind stress in controlling the structure of the water column. The tidal range is c. 1 m. The aim of the study was to identify and quantify the dominant oceanographic processes and dynamics within Young Sund and to establish a carbon and nutrient budget for the area between the island Basaltø and the mouth of the fjord.

The study consisted of four different elements:

- Continuous measurements of water level, salinity, temperature, current velocity and direction at two stations.
- Daily CTD-profiles (0-100 m), water sampling (1, 5, 10, 15, 20, 30, 50 m) at two stations.
- Hourly CTD-profiles (0-100 m), water sampling (1, 5, 10, 15, 20, 30, 50 m) at two stations during a tidal period
- Salinity and temperature mapping (CTD profiles 0-100 m), along and across Young Sund

Continuous measurements of water level, salinity, temperature, current velocity and direction at depths of 5 and 25 m were carried out at two positions with Aanderaa RCM 9 current meters. One was placed at the mouth of the fjord near the small island Sandøen and another was placed about 30 km upstream near Zackenberg. Additional measurements were made with an Aanderaa DCM 12 current profiler near Sandøen. This instrument, an ADCP, continuously measured the current velocity and direction as well as the water levels at 6 water depths.

Unfortunately, drifting sea ice collided with one set of RCM 9 instruments resulting in loss of data from the position near Sandøen. CTD data and water levels from the DCM 12 instrument compensate the lost data to a satisfactory level. The data from the continuous measurements are the basic input in our tidal model. The daily and hourly CTD-profiles and water samplings were mainly made at two stations. One near Sandøen and the other near the island Basaltø. These data, combined with a tidal model, make it possible to determine the carbon and nutrient fluxes for the outer area of Young Sund during the summer of 2001. The idea is to compare this mass balance estimate of carbon flux in the outer region of Young Sund with previous, independent measurements of carbon fluxes made by the CAMP project. Mapping of salinity and temperature revealed the complex oceanographic structure of Young Sund. Some effects of the buoyancy input are evident on the salinity map (Fig. 5.20)

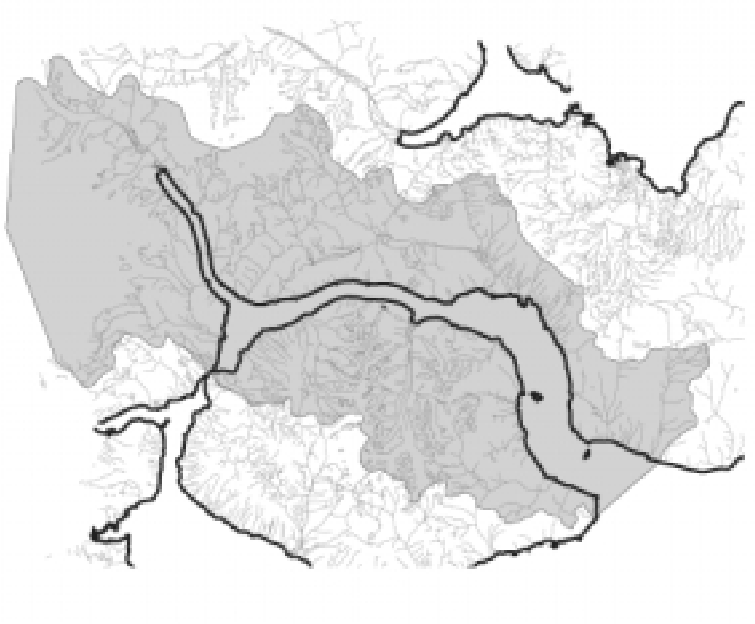


Fig. 5.19. Catchment area of Young Sund.

A unique microbial mat from the high Arctic

Ronnie Nøhr Glud and Søren Rysgaard

During August 2001, a newly discovered microbial mat observed in the area of Young Sund was investigated. The mat grew on dead *fucus* that had accumulated in a small lagoon with bottom-water temperatures between 4 and 7 °C. The inlet of a small creek resulted in a variable but distinct salinity gradient and mat growth was observed at salinities of 4-28‰. The mat was between 0.2 and 1.5 cm thick and extremely fluffy, with a complex 3D structure of voids, channels and chimneys. Thus, the hydraulic permeability was high

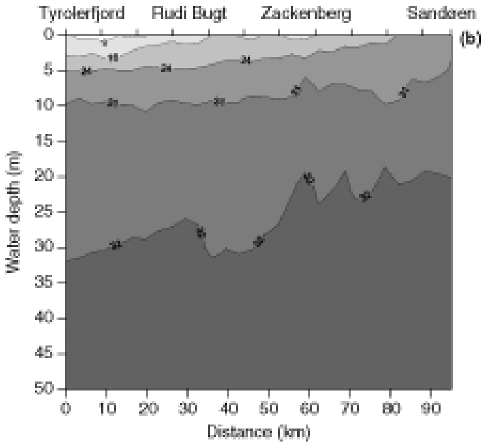


Fig. 5.20. Salinity along Young Sound. The horizontal and vertical resolutions of measurements are 2 km and 20 cm, respectively.

and partial pressure differences resulted in a complex convective solute transport. Along with wave action, this structure caused highly unstable gradients of O_2, H_2S and pH to be maintained within the mat as resolved by detailed *in situ* microelectrode mapping (Fig. 5.21). The structure thereby ensured that the mat was not diffusion limited and could grow to the extreme thickness (for a non-phototrophic mat) and the exclusion of better known chemolithotrophic gradient living microbes, which were expected for the habitat.

We succeeded in growing the mat in the laboratory, where more detailed analyses were performed. The dominant organism is a so-called iron-oxidizing bacterium, an aerobe heterotroph, probably related to the genus *sphaerotilus* (belonging to the proteobacteria beta-group). The mat mainly consisted of iron-encrusted bacterial sheets embedded in TEP. Most sheets were empty, but some contained rows of active bacteria – endospore formation was observed by electron microscopy. At present, molecular analyses are being performed in order to identify the bacterium and to investigate the phylogenetic relationship.

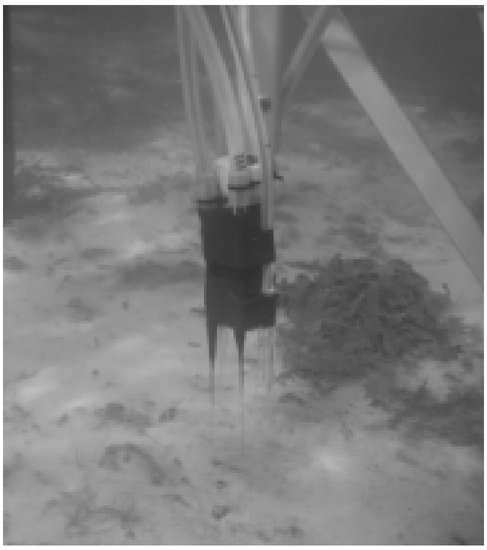


Fig. 5.21. In situ microelectrode mapping in the newly discovered microbial mat (Photo: Søren Rysgaard).

The role of benthic and pelagic microalgae as food sources for bivalves

Mikael K. Sejr, Ronnie N. Glud, Torben Vang, Peter B. Christensen and Søren Rysgaard

Through previous studies of growth and production of dominant bivalves, their annual carbon demand has been estimated. To complement these studies we wished to investigate which groups of primary producers fuelled this production. Ice algae and benthic and pelagic microalgae are all potential food sources for bivalves. Since the annual contribution from ice algae is small, we focused on estimating the relative importance of pelagic and benthic algae. Benthic diatoms are abundant in Young Sund but are only available to feeding bivalves if they are kept in suspension, for instance by tidal currents.

Using hydrographic equipment we continuously monitored turbidity, current velocity, temperature and salinity at a depth of 20 m during a period of two days. This was done at 10 cm and 110 cm above the sea floor. During this period, water samples were collected 10 cm above the bottom at 2-h intervals. These samples represented the potential body of water filtered by bivalves and were analyzed for chlorofyll *a* content, amount of suspended organic and inorganic matter together with size distribution of particles. Additionally, benthic algae collected on the sediment surface and in the water column 10 m above the sediment were used as a reference for the algae found in stomach samples of mussels. Further analyses will provide information on their relative importance.

Walrus studies

Erik W. Born, Mario Acquarone, Søren Rysgaard, Michael Sejr, Göran Ehlmé, Nette Levermann and Thorsten Møller

Walruses are important consumers of the benthic invertebrate fauna in Young Sund. Hence, in order to be able to determine the

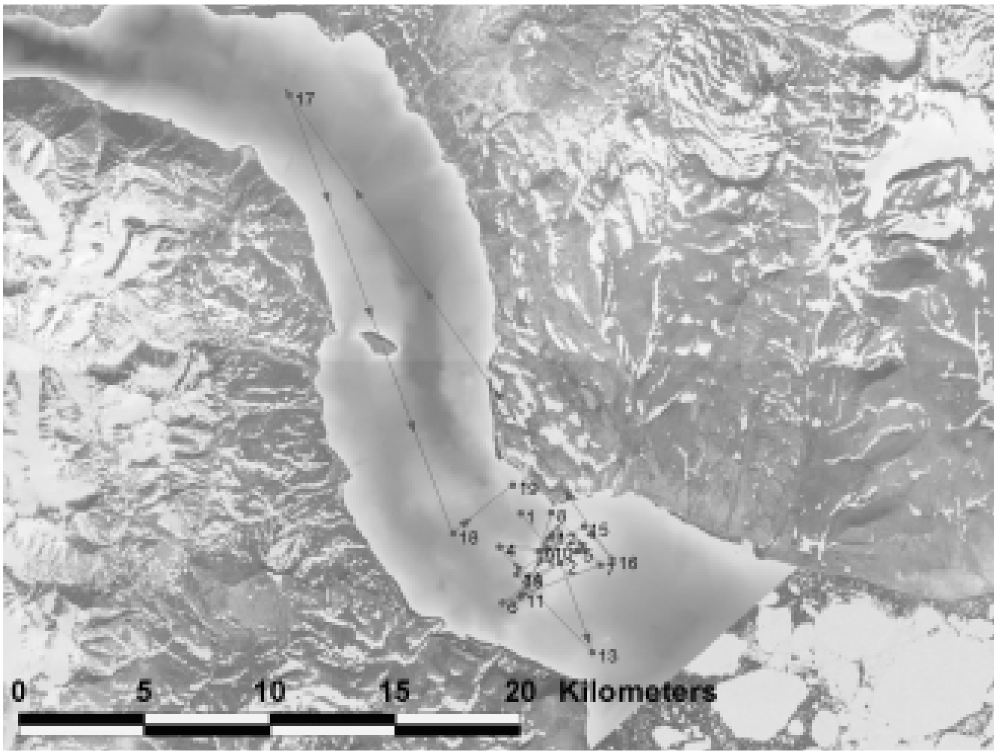


Fig. 5.22. Track of adult male walrus (1226 kg) during an entire feeding cycle that included a 74-h trip at sea followed by a 23-h rest on land.

flow of energy in the marine ecosystem of the area, the ecological role of walruses must be determined quantitatively. The walrus study, which was initiated in 1999 (Rasch 1999; Caning and Rasch 2000), has several goals some of which were pursued during the 2001 field season:

1. To determine the energy expenditure, area use and activity of individual walruses.
2. To determine the number of walruses feeding in the Young Sund study area during the open-water period.
3. To determine the quantity of food ingested by individual walruses in Young Sund.

Determination of the energy expenditure, area use and activity of individual walruses

In order to fulfill the first objective, walruses were immobilized by use of etorphine HCl (reversed with diprenorphine HCl) at the terrestrial haul-outs at Sandøen in Young Sund and Lille Snenæs in Dove Bugt and fitted with satellite transmitters as was done in previous years. Between 24 and 28 July, satellite-radios (SPOT-2 and ST-10; Wildlife Computers, Seattle) were attached to the tusks of four adult male walruses (total body weight: 900 to 1400 kg). One of these walruses had also been studied in 1999 and 2000 (Fig. 5.22). The information collected by the transmitters in the 2001 season and in previous seasons allows calculation of the amount of time spent at the mollusk banks, and of diving and feeding activity in the area.

Between 3 and 18 August, nine male walruses with body masses ranging from 800 to 1,600 kg were immobilized at Lille Snenæs. SPOT-2 satellite tags and MK7 time-depth recorders (Wildlife Computers) were attached to seven of these animals. Four of these walruses were also studied in 2000 where body water contents and turnover rates were determined by use of deuterium water. In 2001, deuterium water metabolism was studied in two individuals. Furthermore, two of the animals that had also been studied in 2000 were treated with doubly labeled water. After the first injection and subsequent equilibration of the injectate with the body fluids while the animals lay prone on the beach, they dived into the water. They both returned to the beach and were immobilized again for blood sampling. One animal was recaptured once, whereas the other was recaptured twice. From the turnover of doubly labeled water in these two animals, the energy-expenditure of free-living walruses will be estimated. The data from three seasons (1999-2001) on movement, diving activity, area use, and isotope-water studies will be processed during 2002 for reporting at the beginning of 2003.

Observations of swimming and diving walruses at Daneborg

Between 26 July and 20 August, systematic observations were made of walruses within a distance of about 4 km from Daneborg. The purpose was (1) to obtain systematic data for quantification of walrus predation in the Young Sund study area, and (2) to keep track of individual walruses and identify the circumstances in which it would be possible to dive along with them to collect data on foraging activity

Observations were made from a post situated 45 m a.s.l. on the mainland (74° 18.443 N – 20° 13.006 W) about 400 m from the shore-line (Fig. 5.23). Track was kept of all walruses that appeared within the study areas, and their diving and swimming behavior was noted systematically. The locations of sites where walruses surfaced and dived were determined by use of a theodolite (Wild GST 20) according to methods described in e.g. Würsig *et al.* (1991). In order to obtain a representative picture of walrus foraging activity within the study area it was attempted to cover all hours of the diurnal cycle. Hence, a total of 4-6 2-hours watches were kept around the clock according to a "rolling" schedule to ensure that all hours were surveyed twice during the study period. Observations were usually suspended when the sea-state exceeded Beaufort 2, as it was no longer considered possible to detect and observe walruses reliably at any distance. A Svarowski binocular telescope (30 x and 75 x magnification), a (Kowa SN-1) Svarowski nonocular telescope (30-60 x magnification) and hand-held binoculars (7 x magnification) were used during the observations.

Observations were also made regularly on Sandøen of the walruses on haul-out. Walruses on land, ice and at the shore were counted (mean=6,7; sd=4,9; number of days=20; days with 0 animals on the beach were not included). ID-photos were taken of every individual and physical characteristics were defined and described for later use in an ID-catalogue and for estimation of the number of walruses using Sandøen and Young Sund.

Fig. 5.23. Observation post for swimming and diving walruses at Daneborg (Photo: Søren Rysgaard).

Determination of the quantity of food ingested by individual walruses in Young Sund

Fig. 5.24. Göran Ehlmé in close contact with feeding walrus (equipped with satellite transmitter). Göran is the one with camera (Photo: Søren Rysgaard).

Between 31 July and 7 August 2001, we succeeded in diving with walruses on 10 occasions to study their feeding activity during entire dives averaging 5.8 min (SD = 0.7; range: 5-7 min) in length (Fig. 5.24). These dives were made between 10 and 24 h on four different days, by six different adult male walruses as judged from body and tusk size. The walruses dived 200-350 m from the coast at an average depth of 9.7 m (SD=3.7; range: 5.8-15.9 m). Comparison of diving and surfacing behavior in study animals and undisturbed walruses revealed no differences (two-way ANOVAs, P>0.05, n=115 below; Mann-Whitney U-test, P>0.05, n=104 surface), and hence, the feeding behavior of the walruses was thought to be unaffected by the presence of the divers. The diver marked the exact location of a feeding patch by placing a block of lead attached to a streamer that reached to the surface. After a foraging dive, we usually waited ~10 min to let the sediments that had been stirred up by the walrus settle after which we dived once more to collect all bivalves (living and dead) at that feeding patch. Hence, the records of the recent foraging dive were sampled less than about 20 min after its termination. In the field laboratory the shells of newly predated bivalves could easily be distinguished from older shells because they still had some soft parts attached (~ 2-3% of total) that had not yet been cleaned completely by amphipods and other scavengers.

The shells of *M. truncata, H. arctica* and *S. groenlandicus* were collected at the feeding patches. On average, 53.2 bivalves were consumed per dive of which 71.8% were *M. truncata*, 20.7% *H. arctica* and 7.5% *S. groenlandicus*. This corresponds to 149.0 g (SE= 18.9; range: 62-253 g) shell-free dry matter during each dive – or 583 g wet weight (ww) bivalve biomass (range: 242-1000 g). When adjusting for differences in energy contents and the different proportions of the three species in the individual dives, a walrus obtained an estimated average of 2,575.5 kJ (SE=325.2; range: 1,071.8-4,377.2 kJ; n=10) during each dive.

Film activities

Lars Ø. Knutsen and Göran Ehlmé

This year an initiative was taken to produce a documentary film from Young Sund with facts and reflections on "climate warming". Our intention was to present complicated material in an easily understandable way in order to reach a broader audience. This initiative will support the scientific observations as well as producing photographic material for public broadcastings in Denmark, Norway and Sweden in the years 2002-3.

6 Disturbance in the study area

Hans Meltofte

Research zone	May	June	July	Aug.	Sept.	Total
1	1	150	142	115		408
1b		7	24	14		45
1c (20.6-10.8)		1	5			6
2			6			6
ATV-trips		1	4	4		9

Table 6.1. 'Person-days' and trips in the terrain with an ATV (all terrain vehicle) allocated to the research zones in the Zackenberg study area 31 May – 31 August 2001. Visits by boat in the goose protection zone (1c) count one each. ATV trips to the climate station are not included.

Surface activities in the study area

The number of 'person-days' (one person in one day) spent in the terrain in the main research zone 1 (Table 6.1) was the lowest since the first full season in 1996. The number of visits in zone 1b, the 'low impact study area', and in zone 1c, the 'goose protection area', were in the same order of magnitude as in the last few years. However, on 8 July two persons with two dogs visited the base of the peninsula. Again on 24 July, a boat with three persons visited the same place. This was probably the reason why the entire coast off Zackenbergdalen was devoid of moulting pink-footed geese this year (see section 4.5).

Four of the trips with the Argo all terrain vehicle were along the 'road' to Tørvedammen, but two trips in July and three in August went to the coast at the delta of Zackenbergelven. In this connection, a new 'road' was established over the plateau south of the research station, but it soon appeared that it harmed the vegetation so much that it was abandoned again.

Aircraft activities in the study area

Also the number of fixed-wing aircraft take-off and landings in 2001 (Table 6.2) was lower than any year since 1995. Only one helicopter passed over the valley this year.

Table 6.2. Number of flights with fixed-winged aircraft and helicopters, respectively, over the study area in Zackenbergdalen 31 May – 31 August 2001. Each ground visit of an aircraft is considered two flights.

Type of aircraft	May	June	July	Aug.	Sept.	Total
Fixed-wing	1	4	12	24		41
Helicopter				1		1

Discharges

As in previous years, combustible waste (paper etc.) was burned at the station, while plastics, cans, bottles etc. were flown out of the area. Solid but biologically degradable toilet and kitchen waste was poured through a grinding mill into Zackenbergelven from 11 July onwards, including an amount left over from 2000. During storage of the waste in June, July and August, a total amount of about 500 g 'Vera-flue-safe' was added as a killing agent against fly maggots. 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 and solid waste let into Zackenbergelven equalled about 950 'person-days'.

Manipulative research projects

East of Teltdammen, on the first plateaux south of the research station (UTM-zone 27: 512,921 mE, 8,264,564 mN), three plots of 40x50 cm were radiated with infrared heaters during 13–21 July, so that the upper soil temperatures were raised 8.5°C. At the end of the season, these plots together with three control plots were harvested (see chapter 5.3).

At two sites on the slopes south of the research station (site 1: UTM-zone 27: 8,264,000 mN, 512,700 mE. Site 2: UTM-zone 27: 8,263,800 mN, 513,000 mE), 40 plots measuring 0.3 m^2 each, were shaded from UV-radiation during 10-17 July, and plant material was sampled during the same period (see chapter 5.4).

South of Teltdammen and the airstrip, leaves (less than 20 g per sample) from *Salix*, *Dryas*, *Kobresia* and *Poa* were sampled around 25 lemming summer burrows in early August within UTM-zone 27: 8,265,250±150mN, 512,900±300mE. Four 1 m^2 enclosures for one lemming each were established for 12 days south of Teltdammen in late July within UTM-zone 27: 8,264,330±100mN, 512,700±50mE (see chapter 5.7).

Take of organisms

51,421 arthropods were collected as part of the BioBasis monitoring programme (see section 4.4). 100 individuals of arctic willow *Salix arctica* were collected from scattered places in the valley (see section 5.6).

7 Zackenberg-Daneborg publications 2001

Vibeke Sloth Jakobsen

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8 Personnel and visitors

Aka Lynge

Research

Zackenberg

Claus Bang-Berthelsen, M.Sc. student, National Environmental Research Institute, Denmark (BioBasis, 31 May – 31 August).

Thomas Bjørneboe Gomes Berg, Ph.D. student, National Environmental Research Institute, Denmark (BioBasis, 30 June – 31 August).

Linda Bredahl, University of Copenhagen, Botanical Institute (UV-B radiation, 2 July – 21 August).

Bo Elberling, University of Copenhagen, Institute of Geography (permafrost, 5-19 June).

Mads C. Forchhammer, University of Copenhagen, Zoological Institute (muskoxen, 20-31 August).

Jørgen Bille Hansen, Asiaq (ClimateBasis, 24 July – 6 August).

Jørgen Hinkler, Ph.D. student, National Environmental Research Institute, Denmark (Digital monitoring, GeoBasis, BioBasis, 19 June – 14 July).

Jens-Peter Kleist, Asiaq (ClimateBasis, 24 July-6 August).

Fred Kockelberg, University of Antwerp, Department of Biology (Global change effects, 2-24 July).

Hans Meltofte, D.Sc., National Environmental Research Institute, Denmark (BioBasis Manager, 31 May – 2 August).

Sofie Mertens, University of Antwerp, Department of Biology (Global change effects, 2-24 July).

Teis Nørgaard Mikkelsen, Risø Research Center (UV-B radiation, 2-14 July).

Ivan Nijs, University of Antwerp, Department of Biology (Global change effects, 2-24 July).

Morten Rasch, Scientific Manager, Danish Polar Center, GeoBasis (5-19 June, 21-31 August).

Helge Ro-Poulsen, University of Copenhagen, Botanical Institute (UV-B radiation, 8-21 August).

Fritz Schwarzenbach, Schweiz (botany, 24 July – 16 August).

Elisabeth Schwarzenbach, Schweiz (botany, 24 July – 16 August).

Jens Søndergaard, M.Sc. student, Institute of Geography, University of Copenhagen (GeoBasis, BioBasis, 5 June – 27 August).

Daneborg

Mario Acquarone, National Environmental Research Institute, Department of Arctic Environment (marine ecology, 21 July – 1 September).

Peter Bondo Christensen, National Environmental Research Institute, Department of Marine Ecology (marine ecology, 4-22 August).

Egon Frandsen, National Environmental Research Institute, Department of Marine Ecology (marine ecology, 23 July – 22 August).

Jan Damgaard Nielsen, National Environmental Research Institute, Department of Marine Ecology (marine ecology, 23 July – 22 August).

Torben Vang, Vejle County (marine ecology, 23 July – 22 August).

Ronnie N. Glud, Marine Biological laboratory. University of Copenhagen (marine ecology, 4 – 22 August).

Mikael Sejr, Institute of Biological Sciences, University of Aarhus (marine ecology, 23 July – 22 August).

Göran Ehlmé, Water Proof Diving International AB, (marine ecology, 23 July – 22 August).

Lars Øivind Knutsen, CineNature AB, (marine ecology, 23 July – 22 August).

Erik W. Born, Greenland Institute of Natural Resources (marine ecology, 21 July – 1 September).

Søren Rysgaard, National Environmental Research Institute, Department of Marine Ecology (marine ecology, 23 July – 22 August).

Nette Levermann, Greenland Institute of Natural Resources (marine ecology, 21 July – 1 September).

Torsten Møller, Kolmården Djurpark (marine ecology, 21 July – 1 September).

Logistics

Zackenberg

Karin H. Christiansen, Cook, Danish Polar Center (19 June – 31 August).

Aka Lynge, Logistics Manager, Danish Polar Center (31 May – 31 August).

Henrik Philipsen, Logistician, Danish Polar Center (5-19 June, 24 July – 31 August).

Charlotte Sigsgaard, Logistician, Danish Polar Center (31 May – 5 June).

Ole Aagaard, Logistician, Danish Polar Center (9 July – 31 August).

Others

J. Raae Andersen, Consultant Engineer (21-27 August).

Kirsten Eriksen, Danish Polar Center (24 July – 6 August).

Knud Falk, Danish Polar Center (21-27 August).

Jens Gregersen, Artist (19 June – 2 July).

Erik Thomsen, Photographer (19 June – 2 July).

Liselotte Tvede, Danish Polar Center (24 July – 6 August).

Further contributors

Kirsten Christoffersen, Ph.D., Freshwater Biological Laboratory, University of Copenhagen (BioBasis).

Helle I.Ø.J. Hansen, M.Sc. student, National Environmental Research Institute, Denmark (BioBasis).

Erik Jeppesen, D.Sc., National Environmental Research Institute, Denmark (BioBasis).

Sten B. Pedersen, M.Sc., National Environmental Research Institute, Denmark (BioBasis).

Henrik Søgaard, Ph.D., Institute of Geography, University of Copenhagen (BioBasis).

Mikkel P. Tamstorf, Ph.D., National Environmental Research Institute, Denmark (BioBasis).

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