Zackenberg Ecological Research Operations

4th Annual Report, 1998

Danish Polar Center
Ministry of Research and Information Technology
1999

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ISBN: 87-90369-31-9
Editor: Morten Rasch
Layout: Special-Trykkeriet Viborg a-s and Morten Rasch

Impression: 800
Paper: 80 g recycled
Printing: Special-Trykkeriet Viborg a-s

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Cover photo: Adult male collared lemming caught by an ermine during snow melt in early June.
Photo: Niels Martin Schmidt.

Citation: Rasch, M. (ed.) 1999: Zackenberg Ecological Research Operations, 4th Annual Report, 1998.
Danish Polar Center, Ministry of Research and Information Technology, Copenhagen.

Executive summary

The establishment of a new administrative structure and a more permanent economic basement for ZERO (Zackenberg Ecological Research Operations) was finalised late in 1998, with the signing of contracts between Greenland Field Investigations, Institute of Geography (University of Copenhagen), National Environmental Research Institute and Danish Polar Center.

During the summer of 1998, 30 scientists from 8 different countries worked at Zackenberg, while 9 scientists from two different countries worked at the branch in Daneborg. The total number of person days at Zackenberg and Daneborg was 1474.

The Daneborg branch of Zackenberg Station was reconditioned in 1998 by Danish Polar Center in co-operation with scientists from National Environmental Research Institute. The station now holds room for 25 persons, a large laboratory and a mess room.

The first part of the 1998 field season was generally colder and more dry than the same period in 1997. July and August were however warmer and much more wet than in 1997. The total precipitation in the period June and August exceeded 100 mm w.e. Heavy rain in mid August caused extremely high water discharge in Zackenbergelven.

The snow cover in early spring was more extensive than in 1997, and the amounts of snow accumulated in river beds and on lakes and ponds etc. were significantly larger. Hence, the start of running water in the rivers and formation of open water in lakes and ponds and on the fjord was somewhat delayed, although the average disappearance of snow and ice was rather similar to the previous years. The effect of this on the biological processes was that flowering on average occurred a little later than in 1997, and that a few species of birds bred a little later than in previous years. Total amounts of flowering was extremely low in several species, and a number of arthropod genera had a poor season, but the breeding birds generally performed well, and the lemming population peaked. Muskoxen occurred in somewhat reduced numbers, and the percentage of new born calves was the lowest recorded since 1995.

Most of the research projects at Zackenberg in 1998 were continuing work started before 1998. Two larger projects were however initiated in 1998. A Belgian research group started a project examining the effect of increased air temperature on unicellulars and plants, and a Danish research project constructed a 100 m long snow fence to examine the effects of increased snow cover on active layer development and processes.

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1 Introduction

Morten Rasch

After the very busy 1997 field season at Zackenberg Station with the completion of dry and wet laboratories, official opening by the Danish Minister of Research and Information Technology and the Greenland Minister of Health, the Environment and Research, and visit by the Danish Parliaments Finance Committee we expected that the 1998 field season would be more calm. This did not happen mainly due to large research activity (see section 2 and 5), restoration of the Daneborg facility (see section 2.5) and problems with the electrical power production (see section 2.3). We have now realised that Zackenberg Station is and probably always will be a very busy place during the field season.

1.1 The new structure for ZERO

The work with the establishment of a new structure and more permanent economic basement of ZERO (Zackenberg Ecological Research Operations, encompassing research, monitoring and logistics at Zackenberg Station and the facility in Daneborg), which was initiated in 1997 (see Meltofte and Rasch 1998, section 1.2), was finalised in 1998 with the signing of contracts between Greenland Field Investigations, Institute of Geography (University of Copenhagen), National Environmental Research Institute and Danish Polar Center and the signing of a Memorandum of Understanding by all participants in the ZERO work. The entrance of the new cooperation was celebrated with a reception at Danish Polar Center 15 December 1999.

In future, Danish Polar Center operates Zackenberg Station and runs in cooperation with Institute of Geography (University of Copenhagen) a GeoBasis programme. For the leadership of Zackenberg Station, Danish Polar Center has employed a station manager.

The BioBasis programme is financed by the Ministry of Environment and Research and operated by National Environmental Research Institute.

The new Climate Basis programme, including meteorological, hydrological and hydrographical monitoring, is operated by the Greenland Field Investigations and financed by the Greenland Home Rule.

The ZERO committee with representatives of the Zackenberg partners, experts in natural science from University of Copenhagen and the station staff coordinates the activities at Zackenberg.

1.2 Two Zackenberg scholarships

At the official opening of Zackenberg Station in 1997, the Danish Minister of Research and Information Technology, Jytte Hilden, granted for the period 1998 – 2000 in cooperation with the Greenland Minister of Health, the Environment and Research, Marianne Jensen, two scholarships to Greenland students or young scientists for one month study at Zackenberg Station. In 1998, the scholarships were given to the biology student Nanette Hammeken Arboe (University of Copenhagen) and the Ph.D. student Nanna Høegh (University of Aalborg). The stay at Zackenberg Station turned out as a great success for both scholarship holders. Abstracts relating to their research projects at Zackenberg are given in section 5.4.5 and section 5.3.

1.3 The Zackenberg study area

The Zackenberg study area comprises the catchment basin (514 km^2) of the river Zackenbergelven. The station is located in the valley Zackenbergdalen at the lower reach of Zackenbergelven (74°30'N, 21°00' W. UTM Zone 27; 8,264,500 m N; 512,500 m E). The nearest settlement is the military outpost Daneborg c. 20 km southeast of Zackenberg. The Zackenberg Study area has been described in detail in previous annual reports (Meltofte and Thing 1996, 1997, Meltofte and Rasch 1998).

2 Logistics

Morten Rasch

In 1998, Zackenberg Station was open from 26 May to 2 September (99 days). During this period thirty scientists, seven logisticians and seven other visitors worked from the station (see section 8.1.1, 8.2.1 and 8.3). The Daneborg branch of the Zackenberg Station was used in the periods 25 May – 16 June and 3 – 25 August by nine scientists and 2 logisticians (see section 8.1.2 and 8.2.2). The total number of person days in 1998 on Zackenberg and the Daneborg branch was 1474. The same numbers for previous years are: 105 (1991), 250 (1992), 0 (1993), 210 (1994), 321 (1995), 1422 (1996) and 1462 (1997).

2.1 Transportation

Opposite to previous years, the runway at Zackenberg Station was almost free of snow when the first plane arrived on 26 May. The total number of planes landing at Zackenberg in 1998 was 25 (see section 6.). 15 landings were related to renewal of station personnel, and 10 landings were related to transport of cargo and fuel from Daneborg. Landings in relation to cargo and fuel transport were limited to two days in August.

Helicopters were used for sling operations of scientific equipment to and from Store Sødal and for transportation of a new generator from Daneborg to Zackenberg (Fig. 2.1).

Tranportation of heavy equipment inside the Zackenberg study area was performed with the All Terrain Vehicle purchased in 1997. The vehicle exerts no impact when the terrain surface is snow covered. When snow cover disappears, the vehicle does however damage the vegetation, especially during wet periods. In 1997, the use of the vehicle was therefore limited to a traffic corridor and suspended when the terrain was wet. In 1999, attempts will be made to concentrate all transport of heavy equipment inside the study area to the period before major snow melt.

Fig. 2.1. Sling operation with a 14.4 kW generator (weighing 600 kg) for a scientific project at Zackenberg. Photo: Morten Rasch.

2.2 Accommodation

As in previous years, Canadian Weatherhaven shelters were used for accommodation of scientists. The shelters have a limited lifetime, and they have always been considered as temporary and rather rough accommodation facilities. The need for more and improved space for accommodation, workshop, storage and indoor social life was emphasized in 1998. Attempts are therefore being made to find funding for a new 129 m^2 accommodation building with 9 double rooms, small kitchen and living room, and a 60 m^2 combined generator, workshop and toilet building (see also section 2.3).

2.3 Electrical power production

Experiences from the 1995-1998 field seasons have revealed that the amount and quality of the electrical power at Zackenberg Station is insufficient. In 1998, the inexpedient power production led to damage of expensive scientific equipment, and in late August, the main generator burned down. A new and more sufficient 14.4 kW generator has been bought, and a renewal of the electrical wire system at Zackenberg is planned for the 1999 field season. Further, attempts are being made to find means for erection of a new generator building with two 14.4 kW generators, workshop and improved toilet facilities.

2.4 Telecommunication

In 1998, as in previous years, telecommunication from Zackenberg to the world outside NE Greenland was based on satellite telephone with handset, fax and E-mail. E-mail is the most used means of communication. The technology behind E-mail communication through satellite link is however still at a pioneer stage, and due to system lability and low baud rates the price for transmission of one E-mail is therefore c. 25 DKK.

2.5 Restoration of the Daneborg facility

Due to continuously increasing activity at the Daneborg branch of Zackenberg Station since 1994, it was decided by Danish Polar Center in cooperation with the marine ecology research group from the National Environmental Research Institute (led by Dr. Søren Rysgaard, see section 5.10) to restore the building 'Kystens Perle' in 1998. Danish Polar Center provided means for the restoration. The first two weeks of August, the renovation was prepared by the marine ecology group by pulling down walls, roofs, floors, etc. Due to harsh weather conditions during August, the carpenter was delayed, and the renovation had to be completed in a week. Through the combined efforts of members from the marine group, a logistician from Danish Polar Center, a carpenter and with help from the SIRIUS dog sledge patrol and members of Det Nordøstgrønlandske Kompagni, NANOK, the construction of a new laboratory, dining room, sitting room, bedrooms and repair of the roof was achieved (Fig. 2.2 and 2.3). Now, the station has room for 25 scientists. Hopefully, there will be enough time and financial support to complete the renovation next year.

Fig. 2.2. The restored kitchen and dinning room at the Zackenberg Station facility in Daneborg. Photo: Søren Rysgaard.

3 Zackenberg Basic

The GeoBasis and Climate Basis programmes

The purpose of the GeoBasis and Climate Basis programmes is to collect data on the dynamics of physical and geomorphological parameters at Zackenberg. The programmes were originally initiated as one GeoBasis programme in 1995 (see Meltofte and Thing 1996). In 1998, the original GeoBasis programme was divided into a GeoBasis (operated by Institute of Geography, University of Copenhagen) and a Climate Basis programme (operated by ASIAQ, Greenland Field Investigations). Climate Basis operates the climate station, the hydrometric station and the hydrographic station. GeoBasis takes care of geomorphological monitoring, monitoring of water quality in rivers and soils and active layer monitoring.

Location of GeoBasis and Climate Basis test sites and specifications of GeoBasis and Climate Basis installations have been described in earlier Annual Reports (Meltofte and Thing 1996, 1997, Meltofte and Rasch 1998).

Data collected by the GeoBasis programme can be ordered from Institute of Geography, University of Copenhagen (e-mail:mr@geogr.ku.dk), while data collected by the Climate Basis programme can be ordered from ASIAQ, Greenland Field Investigations (asiaq@greennet.gl).

3.1 The meteorological station

Carsten Bøcker

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

The reason for moving the radiation sensors was that the vegetation in the nearest surroundings of the meteorological station had suffered from intense traffic in the area. The resulting change of the terrain surface is expected to have changed the albedo of the surface.

In the 1998 field season, no major changes to the station was conducted. The sensors were calibrated and checked by ASIAQ – Greenland Field Investigations. Carsten Bøcker (ASIAQ) performed all data processing on climate data from 1997/98.

Most precipitation at Zackenberg falls as snow. The meteorological station is equipped with both a tipping bucket and a Belfort precipitation gauge. Neither of these sensors measures snow precipitation very accurate. Therefore, they are supplemented by a snow depth sensors (Sonic Range), and a digital camera in order to verify the spatial distribution of snow.

3.1.1. Meteorological data from 1997

In the design of the meteorological station at Zackenberg it was originally planned to transfer data from Zackenberg to the Danish Polar Center in Copenhagen once every week throughout the year. Unfortunately, it has not yet been possibly to conduct the automatically data transfer from Zackenberg to the Danish Polar Center. Data from the autumn and winter 1997/1998 were therefore not collected until the beginning of the field season 1998.

Data from 1997 represent the second full calendar year of climate registrations from Zackenberg. The variations during 1996 of selected climatic parameters are given in Figs. 3.1 and 3.2. In Table 3.1 statistics of measured wind speed and direction are presented, while Table 3.2 shows a summary of all measured climatic parameters.

Table 3.1 Wind statistics, Zackenberg 1997. Calm is defined as wind speeds below 0.5 m/s.

Direction	Observations	Frequency	Main Speed	Max Speed
N	5200	10.1	3.9	26.2
NNE	1998	3.9	3.5	19.5
NE	1489	2.9	2.8	19.4
ENE	1557	3	2.2	12.9
E	2630	5.1	2.2	8.3
ESE	3749	7.3	2.3	10.3
SE	3730	7.2	2.5	18.1
SSE	2102	4.1	2.3	16.2
S	1711	3.3	2.5	9.9
SSW	1131	2.2	2.3	11.5
SW	1005	2	2.2	12.2
WSW	1288	2.5	2.5	15.9
W	1388	2.7	2.6	16.9
WNW	1883	3.7	2.9	15.9
NW	4115	8	3.9	25.1
NNW	14355	27.9	5.1	25.8
Calm	2121	4.1		

In 1997, the mean air temperature measured 2 m above terrain was -10.1° C, the maximum temperature was 21.3° C (mid August) and the minimum temperature was -36.2° C (mid January). The period with frequent temperatures above 0° C started in the end of May and ended in mid September.

The total amount of precipitation measured in 1997 was 148 mm w.e. This value is probably too low. Data indicate that practically no precipitation occurred in January to May, probably due to frozen precipitation gauges. Data from 1998 indicate that the precipitation gauges are inappropriate for mea-

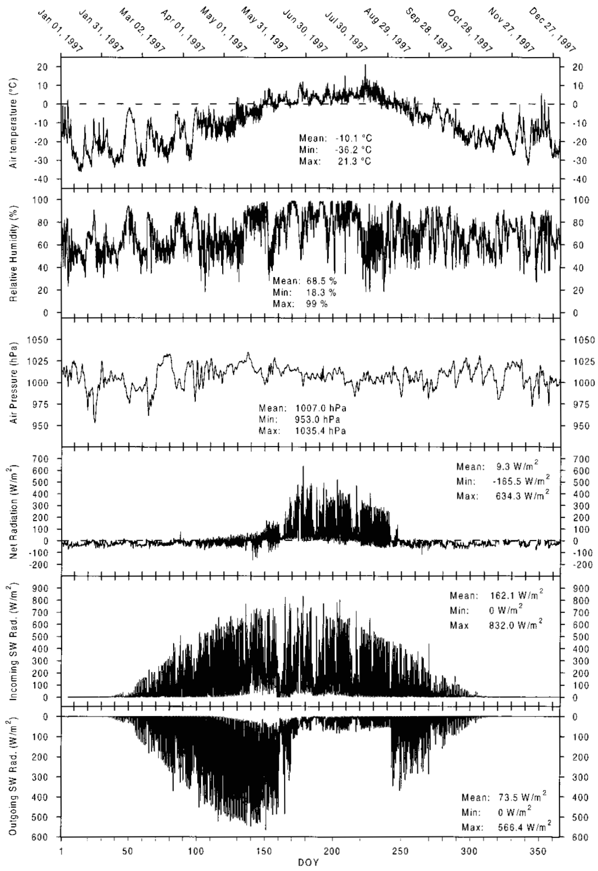


Fig. 3.1 Variation in 1997 of selected climate parameters. From above: Air temperature, relative humidity, air pressure, net radiation, incoming shortwave radiation and outgoing shortwave radiation. All parameters are measured two metres above terrain.

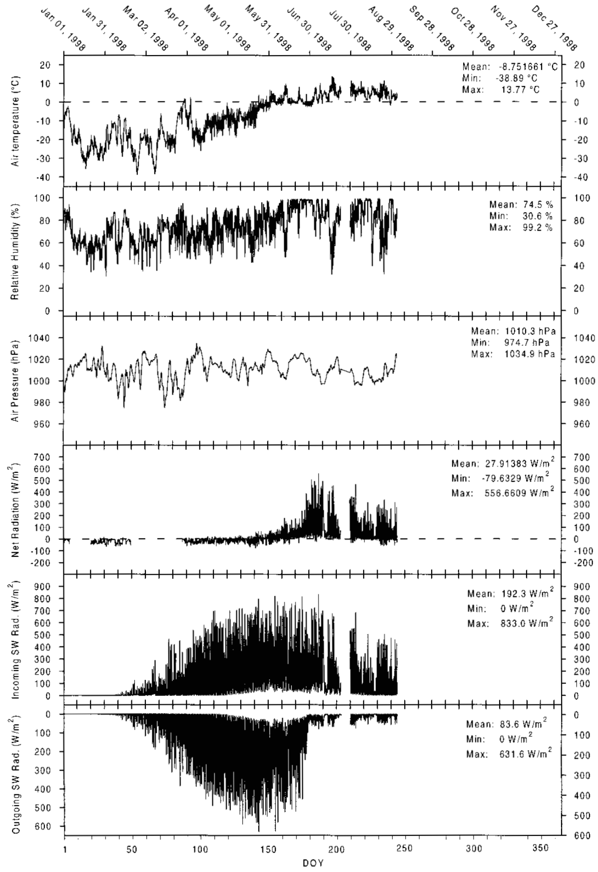


Fig. 3.3 Variation of selected climate parameters in 1998. From above: Air temperature, relative humidity, air pressure, net radiation, incoming shortwave radiation and outgoing shortwave radiation. All Parameters are measured two metres above terrain.

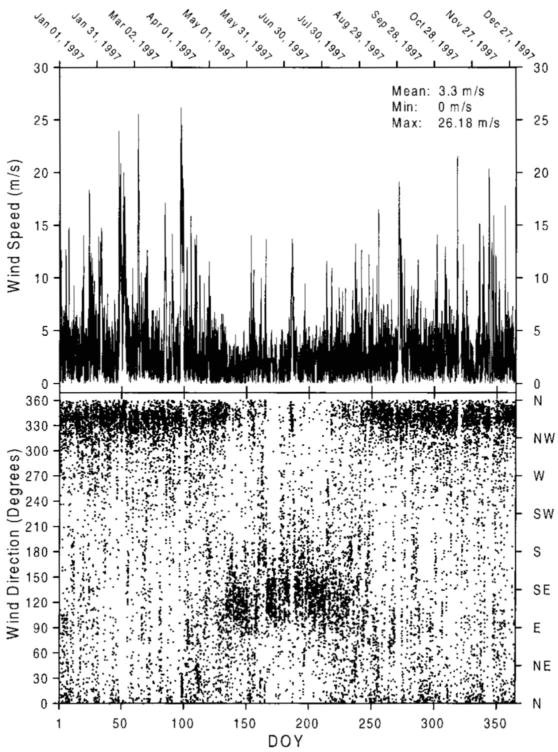


Fig. 3.2 Variation in wind speed and wind direction in 1997. Parameters are measured 7.5 metres above terrain.

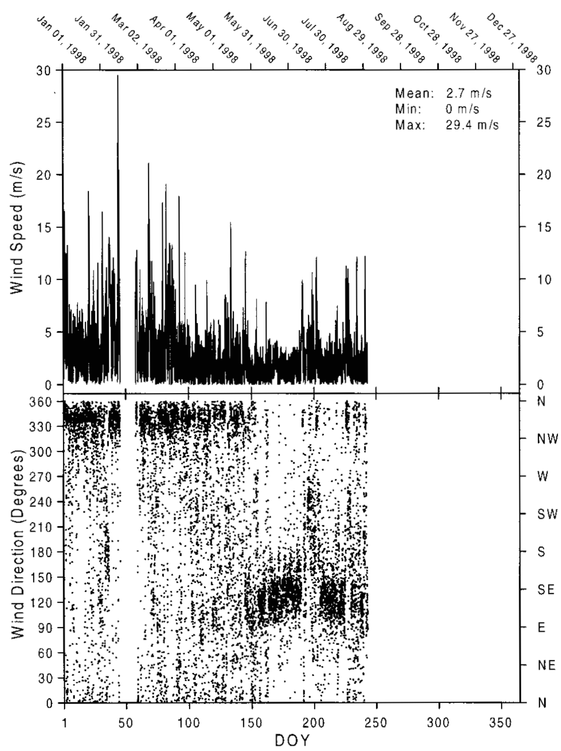


Fig. 3.4 Variation in wind speed and wind direction in 1998. Parameters are measured 7.5 metres above terrain.

Table 3.2 Summary of selected climate parameters.

Parameter	Mean	Max.	Min.
Air temperature, 2 m above terrain (°C)	-10.1	21.3	-36.2
Air temperature, 7.5 m above terrain (°C)	-9.3	21.1	-34.6
Relative air humidity 2 m above terrain (%)	68.5	99.0	18.3
Relative air humidity 7.5 m above terrain (%)	66.3	99.8	16.2
Air Pressure (hPa)	1007.0	1035.4	953.0
Incoming shortwave radiation (W/m^2)	162.1	832.0	0.0
Outgoing shortwave radiation (W/m^2)	73.5	566.4	0.0
Net Radiation (W/m^2)	9.0	634.0	-165.0
Wind Velocity, 2 m above terrain (m/s)	3.0	22.5	0.0
Wind Velocity, 7.5 m above terrain (m/s)	3.4	26.2	0.0
Precipitation (mm w.eq.), total	148.0		
Ground temperature, 0 cm below surface (°C)	-8.2	16.6	-26.2
Ground temperature, 2.5 cm below surface (°C)	-8.2	24.0	-25.5
Ground temperature, 5 cm below surface (°C)	-7.6	16.4	-24.8
Ground temperature, 10 cm below surface (°C)	-7.0	13.6	-23.8
Ground temperature, 20 cm below surface (°C)	-8.4	7.5	-24.2
Ground temperature, 40 cm below surface (°C)	-9.0	3.1	-22.3
Ground temperature, 60 cm below surface (°C)	-7.1	2.7	-17.3
Ground temperature, 80 cm below surface (°C)	-6.8	1.2	-15.4
Ground temperature, 100 cm below surface (°C)	-8.2	-0.7	-16.1
Ground temperature, 130 cm below surface (°C)	-8.6	-2.4	-14.5

surements of snow precipitation. During the period January – March 1998, the gauges measured no precipitation. During the same period, the snow depth sensor registered a snow accumulation of 0.475 m.

The mean air pressure in 1997 was 1007 hPa. During the summer the air pressure was rather stable. During the winter the air pressure was much more variable and often below 980 hPa.

The relative humidity during the summer of 1997 was higher than during the rest of the year. Mean relative humidity was 68.5 %. Episodes of foehn with rapid rises of air temperature and declining relative humidity, occurred in March and April.

The mean net radiation in 1997 was 9.3 W/m^2. During the winter, the net radiation was consistently negative. In the spring, the snow gradually became wetter resulting in a gradual decrease in albedo and a positive net radiation. Later, when snow melted away, the net radiation increased instantly as a result of the increased albedo (Fig. 3.1).

Mean wind speed at 2 and 7,5 m above ground was respectively 3.0 and 3.4 m/s. The highest wind speed was measured at 26.2 m/s. The wind speed fluctuated more during late autumn, winter and early spring than during summer.

The dominant wind direction was south-easterly during summer and northerly during winter. The dominant wind direction during summer is probably caused by warm-up of the terrain surface after snow melt (Fig. 3.2).

3.1.2 Meteorological data from 1998

The variation of selected climatic parameters from 1 January to 1 September 1998 is shown in Figs. 3.3 and 3.4. For comparison with observations from previous years, monthly mean values from September 1996 to August 1998 of selected meteorological parameters are given in Table 3.3. In Table 3.4 monthly mean values of ground temperatures at the meteorological station for the same period are given.

Table 3.3 Monthly mean values of selected climate parameters, September, 1996 – August 1998.

Year	Month	Air Temperature		Relative humidity		Air Press.	Net Rad.	Shortwave Rad.		Wind Velocity		Wind Dir.
		°C 2.0	°C 7.5 m	% 2.0	% 7.5 m	hPa 0.0	W/m2	W/m2 In	W/m2 Out	m/s 2.0	m/s 7.5 m	(0-360°) 2.0
1996	Sept	-1.5	-0.9	68.4	66.2	1008.2	3	No data	31.8	2.9	3.4	224.7
1996	Oct	-11.4	-10.3	63.3	60	1007.2	-30	31.6	20.3	3.8	4.4	281.7
1996	Nov	-13.3	-12.4	54.9	52	1004.7	-30	1.3	0.4	3.3	3.8	264.7
1996	Dec	-22.2	-2.1	61	59	1017.4	-26	0.3	0.2	2.5	2.8	260.6
1997	Jan	-22.4	-21.3	56.8	54.2	1001.4	-28	0.3	0.3	3	3.4	243.3
1997	Feb	-20.8	-19.9	62.6	59.9	998.2	-23	16.6	10.1	4.7	5.4	282.5
1997	Mar	-19.2	-17.7	63.6	60.4	1005	-21	112.9	80.4	6.2	4	265
1997	Apr	-13	-11.8	63.9	60.3	1011.2	-17	203.3	155.2	4	4.6	226.6
1997	May	-6.3	-5.7	74.6	73.5	1017.5	-1	250.4	230.6	1.6	1.8	185.2
1997	Jun	2.4	2.6	76.2	74.9	1013.7	88	215.8	107.4	2	2.4	154.6
1997	Jul	3.7	3.4	84.6	84.8	1007.5	130	224.7	23.1	2.4	2.7	155.2
1997	Aug	5	5	67	66.1	1002.6	74	174.2	20.7	2.5	2.8	162.8
1997	Sept	-3.8	-3.2	71	68.9	1002.9	-21	124.8	73.4	3.1	3.6	234.9
1997	Oct	-11.3	-10.3	67.8	65.4	1011	-29	39.1	19.6	3	3.4	250.9
1997	Nov	-18	-16.9	66.6	64.6	1010.4	-20	2.2	0.8	2.7	3.2	268.2
1997	Dec	-17.4	-16	66	63.6	1001.8	-24	0.4	0.3	3.4	3.8	233.6
1998	Jan	-21.3	-20	62.2	59.4	1012.9	-23	0.3	0.3	3.4	3.9	151.9
1998	Feb	-19.7	-19	66.7	64	1005.4	-29	15.9	8.6	5.3	6.7	245.9
1998	Mar	-17.5	-16.6	69.4	66.5	1004.2	-10	96.9	63.1	5.6	4.5	228.3
1998	Apr	-13.1	-12.1	69.7	68.2	1016.2	-18	220.3	162.1	1.9	2.1	197.4
1998	May	-6.5	-6.2	76.1	75.7	1012.5	-8	282.5	229	1.9	2.2	138.9
1998	Jun	0.9	0.8	87.5	87.3	1016.9	51	269.2	172.3	1.4	1.6	171.2
1998	Jul	4.7	4.4	81.5	80.9	1008.2	126	204.4	20.1	2.1	2.4	161.4
1998	Aug	4.6	4.5	83.8	83.8	1004.4	64	123	12.3	2.1	2.4	137.6

Table 3.4 Monthly mean values of ground temperatures, September, 1996 – August 1998.

Year	Month	0 cm	-2.5 cm	-5 cm	-10 cm	-20 cm	-40 cm	-60 cm	-80 cm	-100 cm	-130 cm
1996	Sept	-1.2	-0.9	0.0	1.0	-0.1	-0.7	0.9	1.0	-0.8	-2.3
1996	Oct	-1.0	-9.3	-8.4	-7.3	-7.9	-6.6	-3.0	-1.9	-3.1	-3.1
1996	Nov	-15.5	-15.3	-14.5	-13.7	-14.5	-13.6	-9.7	-8.1	-8.9	-7.5
1996	Dec	-19.9	-19.7	-1.9	-18.1	-18.9	-17.8	-13.6	-11.9	-12.6	-11.0
1997	Jan	-21.1	-20.6	-2.0	-19.2	-20.0	-19.2	-15.5	-14.0	-14.8	-13.3
1997	Feb	-17.6	-17.5	-16.8	-16.1	-17.2	-17.2	-14.7	-13.9	-14.9	-14.1
1997	Mar	-16.9	-16.8	-16.1	-15.4	-16.5	-16.4	-14.0	-13.2	-14.3	-13.7
1997	Apr	-14.5	-14.5	-13.8	-13.1	-14.4	-14.8	-12.9	-12.4	-13.6	-13.5
1997	May	-11.9	-12.1	-11.4	-10.7	-12.1	-12.8	-11.3	-11.1	-12.4	-12.6
1997	Jun	1.9	1.6	1.8	1.7	-0.9	-3.2	-3.1	-4.3	-6.4	-8.5
1997	Jul	7.6	7.7	7.8	7.7	4.6	1.2	-0.9	0.1	-1.9	-4.2
1997	Aug	4.7	5.7	5.4	5.7	3.7	1.7	2.0	1.0	-0.9	-3.0
1997	Sept	-0.8	-1.1	-0.1	0.8	-0.3	-0.9	0.8	0.9	-0.9	-2.6
1997	Oct	-3.6	-3.7	-2.8	-1.9	-2.8	-2.7	0.6	-0.4	-1.8	-2.7
1997	Nov	-12.6	-12.7	-11.9	-1.1	-11.8	-1.1	-7.4	-6.0	-7.0	-6.0
1997	Dec	-14.1	-14.2	-13.4	-12.6	-13.6	-13.2	-10.1	-9.0	-10.0	-9.0
1998	Jan	-15.2	-15.2	-14.4	-13.6	-14.6	-14.2	-11.2	-10.2	-11.2	-10.3
1998	Feb	-15.0	-15.1	-14.4	-13.6	-14.7	-14.7	-12.2	-11.3	-12.4	-11.6
1998	Mar	-14.3	-14.5	-13.7	-13.0	-14.1	-14.2	-11.9	-11.2	-12.3	-11.8
1998	Apr	-12.6	-12.8	-12.0	-11.3	-12.5	-12.9	-11.0	-10.5	-11.7	-11.6
1998	May	-10.5	-10.6	-9.9	-9.2	-10.6	-11.3	-9.8	-9.6	-10.9	-11.1
1998	Jun	-1.1	-1.4	-0.9	-0.7	-2.7	-4.5	-4.4	-5.2	-7.0	-8.5
1998	Jul	7.6	7.8	7.7	75.8	4.3	0.7	0.9	-0.1	-1.9	-4.4
1998	Aug	5.8	5.8	6.3	6.5	4.4	2.1	2.4	1.0	-0.9	-2.9

Table 3.5. Statistics (annual mean, annual maximum and annual minimum) on time series from the Tiny-Tag/TinyTalk dataloggers operated by GeoBasis

Purpose	Datalogger	Type	Position Easting (m)	Northing (m)	Elevation (m a.s.l.)	1996 Mean °C	Minimum °C	Maximum °C	1997 Mean °C	Minimum °C	Maximum °C
Active layer temperature profile	P1, 0 cm	TinyTag	512,388	8,263,490	20	-7.7	-37.6	29.9	-9.8	-40.7	30.7
	P1, 10 cm	TinyTag				-10.5	-32.6	15.0	-9.6	-39.1	19.1
	P1, 50 cm	TinyTag				-6.7	-25.2	7.3	-9.0	-29.4	8.8
	P1, 118 cm	TinyTag				-5.9	-15.6	-0.1	-8.1	-18.3	-0.1
Active layer temperature profile	P2, 0 cm	TinyTag	512,713	8,264,257	23	-5.6	-30.5	34.1	-7.8	-29.4	25.9
	P2, 10 cm	TinyTag				-6.1	-24.6	12.4	-8.4	-25.7	12.8
	P2, 70 cm	TinyTag				-6.0	-19.1	2.3	-8.1	-19.6	2.3
	P2, 155 cm	TinyTag				-6.5	-14.6	-1.4	-8.6	-16.4	-1.8
Active layer temperature profile	P3, 0 cm	TinyTag	515,917	8,268,224	ca. 400	-6.2	-31.5	25.2	-9.6	-36.3	23.4
	P3, 10 cm	TinyTag				-5.9	-27.5	18.1	X	X	X
	P3, 66 cm	TinyTag				-5.5	-20.3	6.9	-8.7	-23.3	6.5
Active layer temperature profile	P4, 0 cm	TinyTag	516,936	8,269,597	ca. 820	-8.5	-33.7	27.0	-10.6	-39.1	27.4
	P4, 10 cm	TinyTag				-8.0	-28.4	16.3	-10.5	-33.7	14.9
	P4, 85 cm	TinyTag				-7.6	-18.9	1.9	-10.4	-22.5	1.1
Active layer temperature profile	P5, 0 cm	TinyTag	509,964	8,267,457	ca. 259	X	X	X	-9.2	-36.0	20.4
	P5, 75 cm	TinyTag				X	X	X	-8.9	-22.4	11.0
	P5, 135 cm	TinyTag				X	X	X	-8.6	-21.7	11.3
Active layer temperature profile	P6, 0 cm	TinyTag	513,068	8,263,921	11	X	X	X	-10.1	-37.6	19.1
	P6, 10 cm	TinyTag				X	X	X	-9.9	-25.7	10.6
	P6, 30 cm	TinyTag				X	X	X	-6.0	-23.3	15.6
	P6, 60 cm	TinyTag				X	X	X	X	X	X
Air temperature in Moraenebakkerne	T1	TinyTag	511,090	8,268,397	85	-7.3	-33.6	21.6	-9.8	-37.2	23.6
Air temperature in Store Sødal	T2	TinyTag	509,105	8,269,215	129	-7.8	-35.0	20.6	-10.3	-39.1	21.6
Air temperature on Aucellabjerg	T3	TinyTag	518,023	8,269,902	965	-8.9	-36.0	19.8	-10.4	-37.6	17.7
Water temperature in Zackenbergelven	V1	TinyTag	512,654	8,264,548	?	-2.5	-11.9	8.4	-5.1	-11.8	20.2
Water temperature in Gadekæret	V2	TinyTag	512,978	8,264,538	?	-10.8	-23.8	15.9	-8.0	-27.4	19.4
Air/snow temperature in snow patch	S1, Plateau	TinyTalk	512,209	8,264,467	29	X	X	X	-12.0	-37.3	26.5
	S1, Slope	TinyTalk			25	X	X	X	-5.2	-11.5	20.5
	S1, Snow	TinyTalk			23	X	X	X	-5.2	-9.5	26.6
	S1, Below	TinyTalk			16	X	X	X	X	X	X

The first quarter of 1998 (*i.e.* January to March) was generally warmer, more windy and with higher air pressure than in the previous years. January was the coldest month of 1998 with a mean monthly air temperature of -21.3° C. The air temperature and air pressure of April and May 1998 were very similar to the conditions in 1997. The wind speed was however significantly lower.

During the beginning of the 1998 field season, the weather conditions at Zackenberg were not as warm as in 1997, and the spring was therefore delayed. July and August were warmer than in 1997. The period between early June and mid July was rather dry, often with 100 % cloud cover and/or fog. From mid July until the end of the field season it was more rainy. During this period the total amount of precipitation exceeded 100 mm w.e. Heavy rain in mid August caused extremely high discharge in Zackenbergelven. The warmest day in 1998 was 16 July 1998 with a maximum air temperature of 13.3° C measured 2 meter above terrain. In 1997, the maximum temperature was 21.3° C.

3.2 TinyTalk/TinyTag dataloggers

Morten Rasch

GeoBasis operates 30 TinyTag/TinyTalk temperature dataloggers measuring soil temperature profiles (six sites), air temperature near terrain surface (nine sites) and water temperature (2 sites). Position, purpose, interval between measurements and period of operation for all dataloggers are given in Table 3.2.1. in Meltofte and Rasch (1998). All dataloggers were tapped in 1998, and no serious operational failures were observed. Table 3.5 shows annual mean, maximum and minimum for 1996 and 1997 from all TinyTag/TinyTalk dataloggers operated by GeoBasis at Zackenberg.

3.3 The hydrometric station

Mogens Brems Knudsen and Morten Rasch

The hydrological measurements in Zackenbergelven were initiated 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 of which 106 km^2 is glacier covered.

In the 1998 field season, the hydrometric station was moved because its earlier location was inappropriate. Every year the station was buried in a large snow patch which caused damage to the equipment and hampered the data collection in late spring and early summer (Meltofte and Rasch 1998).

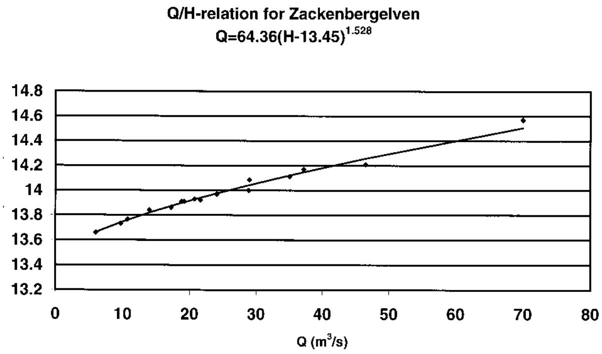


Fig. 3.5. Water level – discharge relation curve for Zackenbergelven at the hydrometric station, 1995-1998. The coefficient of correlation for the curve is 0.99.

At the station, the water level is logged automatically with a sonic range sensor. This sensor uses sound to determine the distance from a fixed point (the sensor) to the water surface. The signal is then transformed to a water level, which is again transformed to discharge, using a relation between water level and discharge (a Q/H-relation) based on manual measurements.

The discharge and water level have been measured in the field seasons of 1995, 1996, 1997 and 1998. The function describing the relation between water level and discharge is shown in Fig. 3.5. The high correlation coefficient indicates that the cross profile at the hydrometric station is stable.

In 1998, automatic measurements of river water discharge were processed by Mogens Brems Knudsen (ASIAQ, Greenland Field Investigations). All work relating to manual measurements of river water discharge, sediment transport and river water chemistry was carried out by Morten Rasch (26 May – 15 June and 14 August – 2 September) and Steen Birkelund Pedersen (15 June – 14 August).

3.3.1 River water discharge

In 1998, the river started to run on 10 June. At 15:00 this day, the river was observed running in Morænebakkerne. From here, the river worked its way through the snow deposit in the river bed (Fig. 3.6). Later this day, at 22:00, the river was running at the hydrometric station. At this time, the hydrometric station was still buried in snow (the hydrometric station was excavated on 12 June). First automatic observations of water discharge occurred on 23 June. In the intervening period, the data collection was hampered because of large amounts of snow and ice in the river leading to erroneous measurements of water level.

The river water discharge in Zackenbergelven during the summer of 1998 is shown in Fig. 3.6. Peak discharge occurred on 22-23 July and again on 16-17 August. Both peaks were due to heavy rain. The first period (22-23 July) followed a 20 mm rain fall. The rain started in the evening of 21 July, and the next day the water level in the river was rising quickly. The next peak in river discharge (16-17

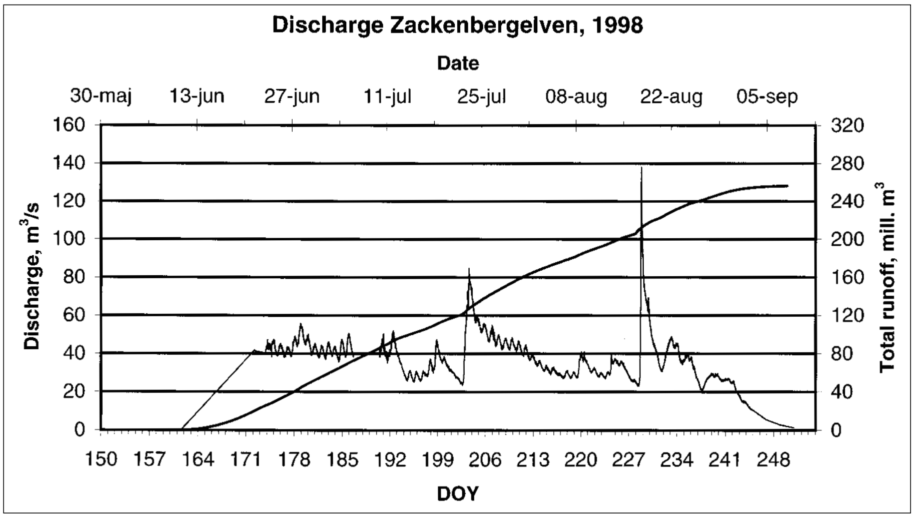


Fig. 3.6. Variation of river water discharge at 15 minute intervals in Zackenbergelven.

August) occurred almost one month later. This peak was much higher than the one in July (Fig. 3.7), though the amount of rain was almost the same as in July (c. 25 mm). The difference in magnitude of the two peaks is probably due to the fact that in July rain occurred after a period of rather fine weather with only small amounts of precipitation, whereas in August rain fell on two occasions prior to the very heavy rain that caused the extreme high river water discharge on 16-17 August.

In periods with no or little rain there is a clear diurnal variation in the river water discharge. The minimum discharge is at midday, *i.e.* out of phase with temperature. This indicates a melt water travel time of 12 hours + n · 24 hours in the catchment.

The total amount of water drained from the catchment in the 1998 field season was 256 mill. m^3. With a drainage basin area of 514 km^2 this corresponds to a total water loss of nearly 500 mm w.e. from the area in 1998, compared to a loss of 340 mm w.e. in 1997. The precipitation measured from 1 October 1996 to 30 September 1997 was 140 mm, whereas in the hydrological year of 1998 (1 October 1997 to 30 September 1998), the total amount of precipitation was 284 mm. This is far less than the observed run off. The discrepancy might be the result of the rain gauge not measuring all precipitation during the winter. In the period January – March 1998, the precipitation gauge registered almost no precipitation. In February the snow depth sensor registered an increase in snow depth of c. 40 cm.

3.3.2 Suspended sediment

In 1997, water samples for determination of suspended sediment content and loss on ignition determined organic matter content in Zackenbergelven was collected twice every day. Data from 1997 have now been processed. During 97, the suspended sediment content varied between 4 mg/l and 1,914 mg/l with a mean of 112 mg/l, while organic matter content varied from 2.7 mg/l and 26.8 mg/l with a mean of 8.6 mg/l. Major fluxes of sediment were related to flood events, especially the flood event between 5 and 10 July (see Fig. 3.3.1.2 in Meltofte and Rasch 1998). The total transport of respectively suspended sediment and organic matter during 1997 were 29,444 t and 1,644 t.

Due to the experiences from 1997, the interval for collection of water samples for determination of suspended sediment and organic matter content was reduced to twice every week. However, during the flood between 16 and 22 August water samples were collected twice every hour. When the flood reached maximum on 16 August, the sediment concentration in Zackenbergelven was 46,925 mg/l. Data from 1998 have still not been fully processed. However, preliminary results indicate that the sediment content ranged between 7 mg/l and 46,925 mg/l, and that the majority of the sediment came during the flood event between 16 and 22 August. During these seven days, the sediment transport was 105,013 t which is 3.6 times as much as during the entire year of 1997. This demonstrates specifically the geomorphological importance of extreme events and in general the importance of long time series for the understanding of ecosystem dynamics.

Fig. 3.7. Zackenbergelven, 16 August 1998. The width of the river is approximately 3 times larger than under normal circumstances at this time of the year. Photo: Hanne Hvidtfeldt Christiansen.

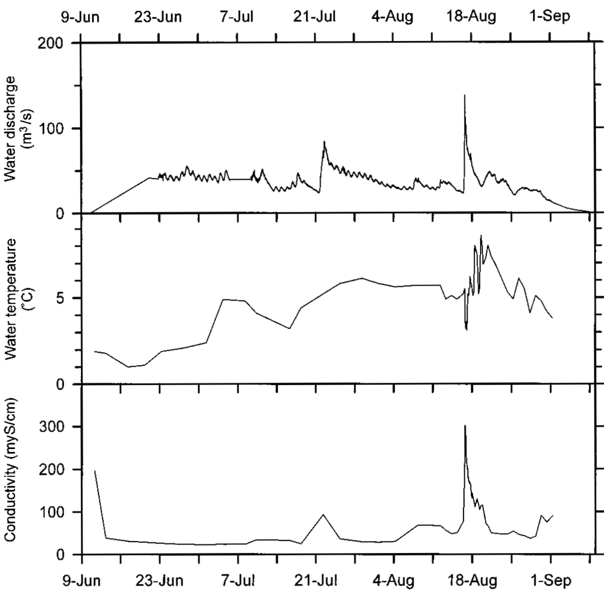


Fig. 3.8. Variation of temperature and conductivity in Zackenbergelven during the summer of 1998.

3.3.3 Water chemistry, pH and conductivity

In 1998 conductivity, pH and temperature was measured twice every week during the period 11 June – 1 September. Figure 3.8 shows the variation of conductivity and temperature in 1998. Besides, water samples were taken for determination of Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+}, Cl^{-}, NO_3^{2-}, SO_4^{2-} and HCO_3^{-} concentrations. Chemical analyses of water samples from 1998 are being processed at the moment. The chemical analyses of water samples from 1997 were finished early in 1999. Table 3.6 shows the variation in concentrations of the different ions measured in 1997.

Table 3.6 Variation of different ions in Zackenbergelven during 1997.

Cl meq/l	NO_3 meq/l	SO_4 meq/l	HCO_3 meq/l	Na meq/l	Mg meq/l	K meq/l	Ca meq/l	Fe meq/l	Mn meq/l
0.020-0.224	0.003-0.132	0.0575-0.800	0.0002-0.0007	0.023-0.204	0.035-0.230	0.012-0.074	0.096-0.798	0.001-0.042	0.002-0.002

3.4 Landscape Monitoring

Morten Rasch

The landscape monitoring at Zackenberg is mainly based on monitoring photos of different dynamic landforms, *i.e.* ice wedges, debris islands, free rock faces, rock glaciers, talus slopes, avalanche tracks and coastal spits and cliffs. Besides, active layer depth is measured at two sites, soil water chemistry is measured at two sites, ice wedge growth rate is measured at two sites, cross shore changes of the shore line is measured at six sites and salt marsh accretion is measured at two sites.

3.4.1 Monitoring photos

All the 24 photo monitoring sites (see section 3.4.1 in Meltofte and Rasch 1998) which are included in the GeoBasis programme were visited in 1998 and pictures were taken. Time series of photos are still too short for observation of geomorphological changes.

In August 1997, a digital camera was installed c. 500 m a.s.l. on the eastern slope of the mountain Zackenberg (see section 3.4.1 in Meltofte and Rasch 1998). The camera took pictures of the lower part of Zackenbergdalen twice every week in the period 22 August – 26 December 1997. Thereafter, the camera went out of power, and photographing was not resumed before 21 June 1998. The time series from the autumn and early winter of 1997 shows the changes in distribution of the first snow cover in Zackenbergdalen (Fig. 3.9), while the time series

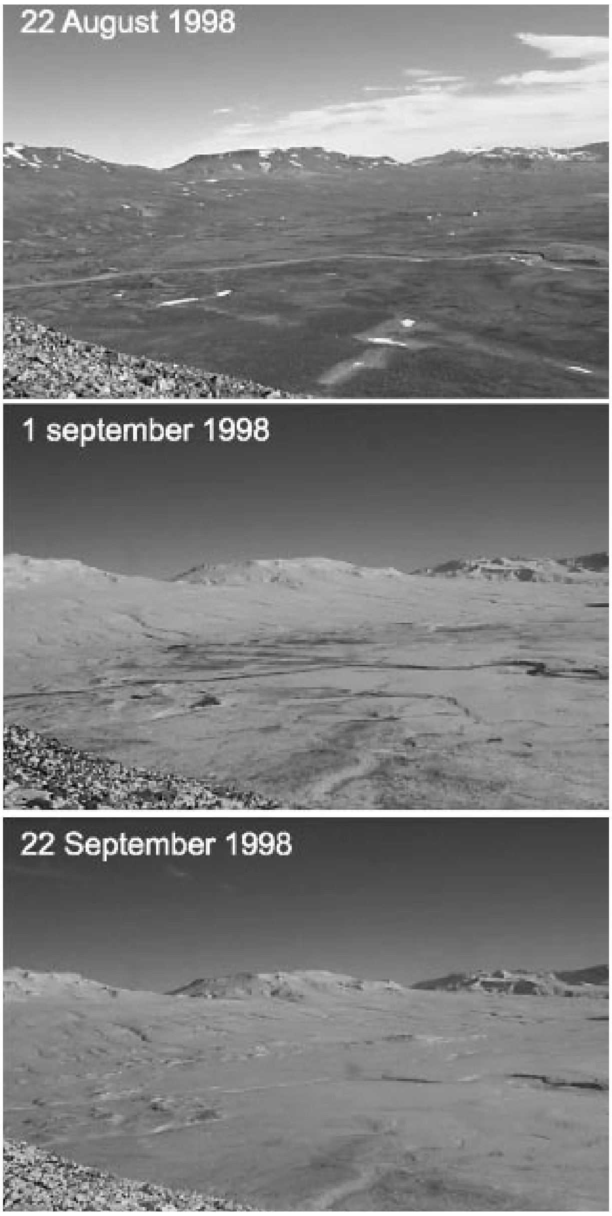


Fig. 3.9. Examples of autumn pictures from the digital camera on Zackenberg, 1998.

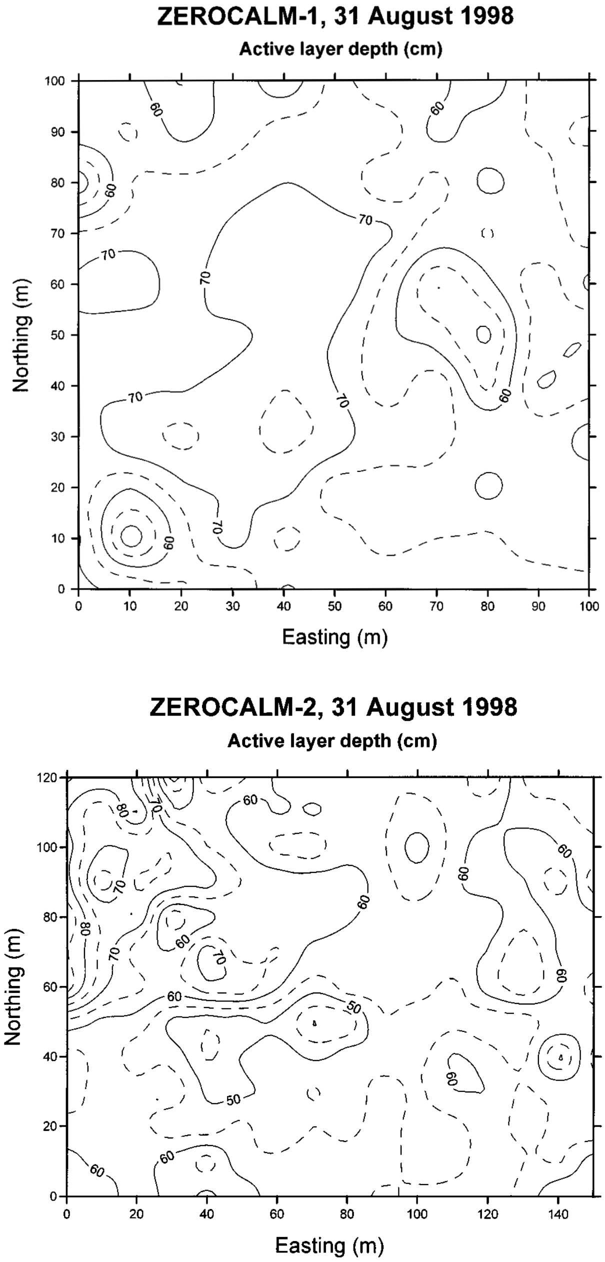


Fig. 3.10. Maximum active layer depth in the two ZEROCALM grids at Zackenberg.

from early summer 1998 shows the melting of the snow. A research project in cooperation between Institute of Geography (University of Copenhagen) and Danish Technical University is developing a method for automatic mapping of snow-cover based on pictures from the digital camera (see section 5.7).

3.4.2 Active layer depth

Two plots (ZEROCALM-1, ZEROCALM-2) for measurements of active layer depth were established in 1996 by Hanne Hvidtfeldt Christiansen (Institute of Geography, University of Copenhagen) as a part of a research project (see section 5.1.12 in Meltofte and Thing 1997). Since then registering of active layer depth has been performed once every second week during the field season in cooperation between GeoBasis and Hanne. Data on maximum active layer depth in the two plots are reported once every year by GeoBasis to CALM (Circumpolar Active Layer Monitoring Programme) under ITEX (International Tundra Experiment) and IPA (International Permafrost Association) together with soil temperature data measured near the plots (see section 3.2).

ZEROCALM-1 (121 measuring points in a 100 x 100 m^2 grid) is situated near the climate station on a horizontal and well-drained *Cassiope* heath. In 1998, maximum active layer depth measured on 31 August was 0.659 m (SD = 0.061 m). In the preceding years the same figures were: 16 August 1996, 0.601 m (SD = 0.054 m); 21 August 1997, 0.617 m (SD = 0.06 m).

ZEROCALM-2 (208 measuring points in a 120 x 150 m^2 grid) is situated c. 500 m south of the runway on a southerly sloping *Eriophorum* fen. In this plot the maximum active layer depth measured on 31 August was 0.595 m (SD = 0.088 m). In the preceding years the same figures were: 16 August 1996, 0.607 m (SD = 0.077 m); 21 August 1997, 0.574 m (SD = 0.098 m).

Maps of active layer depth in ZEROCALM-1 and ZEROCALM-2 are shown in Fig. 3.10.

3.4.3 Soil water chemistry

In 1998, water samples for determination of soil water chemistry (Na, K, Mg, Fe, Mn, Cl, NO3 and SO4) in the active layer were collected in duplicate at two sites (each with suction probes at eight different levels) every fourteen days throughout the field season. The purpose of the measurements has been described in Meltofte and Rasch (1998). Water samples from 1998 are now being processed in the laboratory at Institute of Geography, University of Copenhagen.

3.4.4 Coastal geomorphology

In 1998 the coastal monitoring comprised tide measurements at one site photographic, monitoring at 10 sites, surveying of cross shore profiles at two sites, registering of coastal cliff retreat at four sites and measurements of salt marsh accretion at two sites.

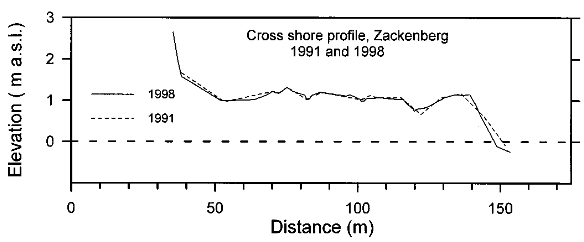


Fig. 3.11. Cross shore profiles (1991 and 1998) from the coast immediately south of Zackenberg Station. Notice, that no significant changes of the cross shore profile has occurred since 1991

Due to hardware problems tide measurements in 1998 were of bad quality and difficult to calibrate. Since the establishment of the tide gauge in 1996, there have been several problems with the equipment mainly due to sea-ice cutting the cables or foxes chewing the cables. Despite this, the measurements from the tide gauge has allowed construction of a tide prediction table, and tide predictions for Zackenberg are now published by Farvandsvæsenet in their publication 'Tidevandstabeller, Grønland'. Due to the recurrent problems with the tide gauge it has been decided to terminate the tide measurements.

The two cross shore profiles have been measured in 1992, 1995, 1996, 1997 and 1998. Locations of the profiles are shown in Fig. 3.4.4.1 in Meltofte and Rasch (1998). Profiles from 1992 and 1998 are shown in Fig. 3.11. No significant changes of the profiles have occurred since 1992.

Coastal cliff recession is measured along the shore-line immediately south of Zackenberg Station (see Fig. 3.4.1.1 in Meltofte and Rasch 1998). The mean coastal cliff recession along the shore line since 1996 is 0.4 metres (0.2 metres per year).

3.5 General observations on ice conditions

Hans Meltofte

Due to large quantities of snow, that had accumulated on ponds and in river beds, the ice melt on the ponds and running water in the rivers had a slow start in 1998. This also apply to formation of open water in the fjord, though the final break up of fjord ice was rather similar to 1997.

3.5.1 The fjord

On 26 May, when we flew up to Zackenberg, the ice edge towards the polynya in the mouth of Young Sund was situated about 1 km south of Sandøen, and the islet was almost totally covered in ice and snow. Even in early July, an ice-bridge remained between the mainland and the islet.

As in 1997, open water did not start to form off the delta of Zackenbergelven until the last days of June. On 3 July, the open water stretched about 500 m out from the delta. Even on 12 July, only small open water areas had developed off the outlets of the rivers in the southeastern part of the valley, whereas the open water off Zackenbergelven covered about 1 km^2 at that time. Already two days later, the fjord ice had broken up off Zackenbergdalen, but the ice in the outer part of the fjord did not brake until 22 July. During August pack ice entered Young Sund periodically.

3.5.2 Lakes and streams

When we arrived at Zackenberg on 26 May, all ponds and lakes were covered in snow and ice. Melt water started to appear in the snow on a few ponds during the last days on the month, and on 2 June the ponds north of the runway ("Gadekæret") were about 10 % ice free. On 9 June, the western pond was more than 90 % ice free and the eastern 60 % ice free. On 12 June almost all ice had disappeared. The ponds south of the runway ("Sydkærene") started to thaw on 4 June, but the last ice here did not disappear before 19 June. This is 1-2 weeks later than in 1997. New ice on the ponds appeared already on 22 August.

The ice on Lomsø broke up on 11 July, as compared to 30 June in 1997, but the last ice disappeared already by 16 July.

Water started to run upon the snow in Aucellaelv on 6 June, but the remaining rivers in research zone 1A did not start to run until 11-13 June due to large quantities of snow in the river beds. This may also have been the main reason for Zackenbergelven not starting to run until 10 June, or 1-2 weeks later than in the two previous years.

4 ZACKENBERG BASIC

The BioBasis programme

From 1998, the BioBasis programme at Zackenberg is carried out by the National Environmental Research Institute (NERI), Department of Arctic Environment, Ministry of Environment and Energy, Denmark. It is financed by the Danish Environmental Protection Agency, Danish Fund for Environment and Disaster Relief (MIKA), Ministry of Environment and Energy, Denmark. Evaluations presented in this report do not necessarily mirror the opinions of the Environmental Protection Agency.

Details on methods and sampling procedures are presented in a manual (Meltofte *et al.* 1998), which is available from NERI (mel@dmu.dk).

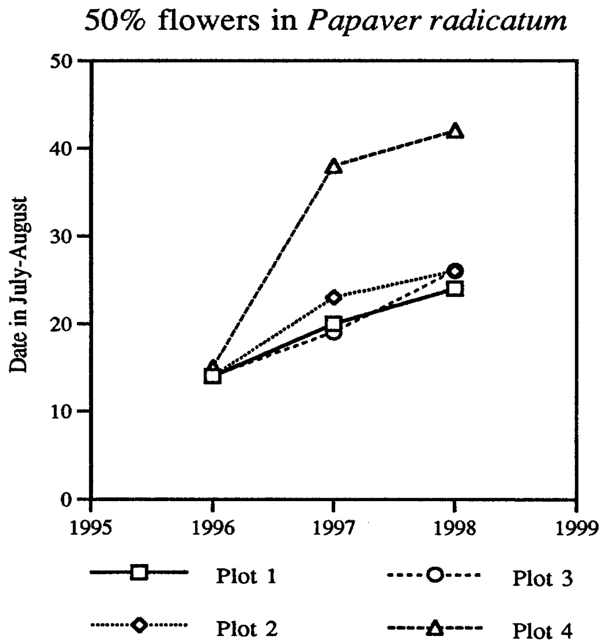


Fig. 4.2. Extrapolated dates of 50 % flowers (50/50 ratio of buds/open flowers) in four Papaver radicatum *plots, 1996-98. Dates are number of days after 31 May.*

4.1 Vegetation

Hans Meltofte

ITEX study plots were sampled by BioBasis assistant Niels Martin Schmidt between 27 May and 12 August, and by BioBasis assistant Thomas B. Berg during the rest of the season.

A vegetation map of research zone 1A was published this year (see section 7.2).

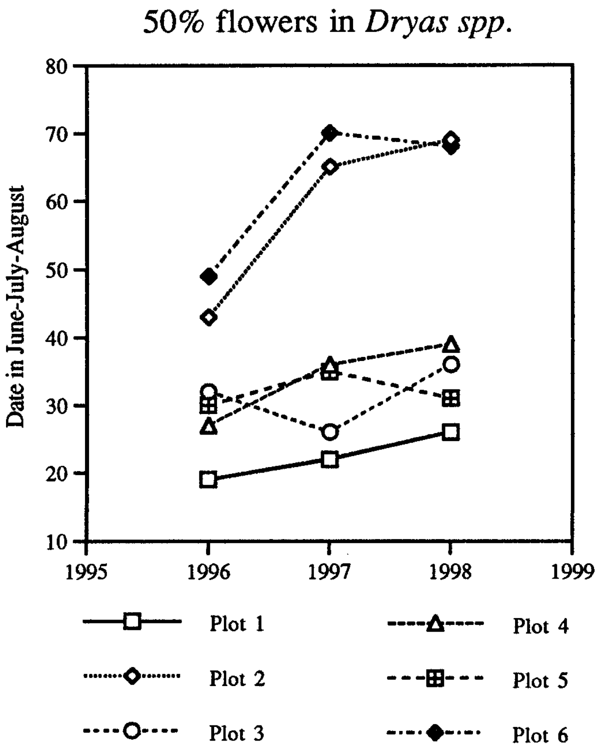


Fig. 4.1. Extrapolated dates of 50 % flowers (50/50 ratio of buds/open flowers) in six Dryas spp. *plots, 1996-98. Dates are number of days after 31 May.*

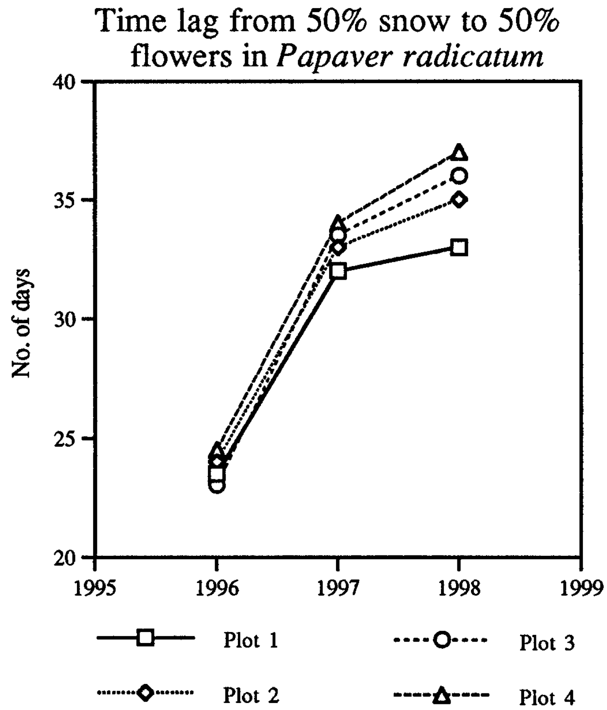


Fig. 4.3. Time lag from 50 % snow cover to 50 % flowers (50/50 ratio of buds/open flowers) in four Papaver radicatum *plots, 1996-98.*

4.1.1 ITEX reproductive phenology

The snow cover was more extensive in the early part of the 1998 season, than in the previous year, but in spite of large individual variation among the plots, the average snow melt in the study plots did not differ much from the previous years (Table 4.1 and section 4.1.3).

Flowering was as late or even later than in 1997, but maybe these years were closer to average than the particularly early 1996 season (Table 4.1 and Figs 4.1-2). Accordingly, the time span between snow melt and flowering was generally similar to or a little larger than in 1997, as it is illustrated by *Papaver radicatum* in Fig. 4.3.

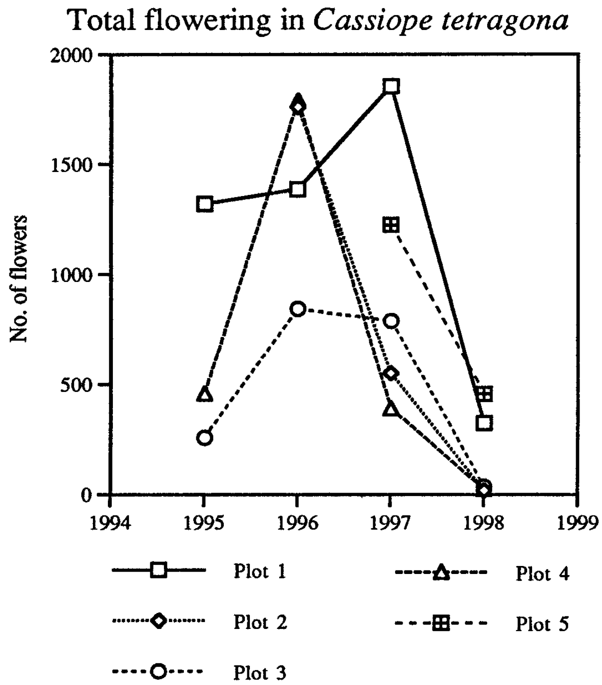


Fig. 4.4. Total number of flowers in five Cassiope tetragona *plots, 1996-98.*

Table 4.1. Extrapolated dates of 50 % snowcover and 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 ITEX study plots in 1996, 1997 and 1998, respectively. Extrapolations based on samples of less than 50 buds/flowers are given in brackets.*

Plot no.	1996 50% snow	1996 50% flowers	1997 50% snow	1997 50% flowers	1998 50% snow	1998 50% flower
Cassiope 1	14.6	2.7	9.6	6.7	13.6	6.7
Cassiope 2	19.6	6.7	21.6	20.7	27.6	(21.7)
Cassiope 3	15.6	9.7	21.6	18.7	20.6	(19.7)
Cassiope 4	20.6	15.7	15.6	15.7	20.6	(21.7)
Cassiope 5					11.6	20.7
Cassiope 6			?	28.7	6.7	(31.7)
Dryas 1	<3.6	19.6	<27.5	22.6	23.5	26.6
Dryas 2	26.6	13.7	27.6	4.8	4.7	8.8
Dryas 3	6.6	2.7	<27.5	26.6	7.6	6.7
Dryas 4	1.6	27.6	3.6	6.7	13.6	(9.7)
Dryas 5	6.6	30.6	31.5	5.7	4.6	1.7
Dryas 6	21.6	19.7	4.7	9.8	5.7	(7.8)
Dryas 7					2.6	30.6
Dryas 8					30.5	25.6
Papaver 1	20.6	14.7	18.6	20.7	21.6	24.7
Papaver 2	20.6	14.7	20.6	23.7	21.6	26.7
Papaver 3	21.6	14.7	15.6	19.7	20.6	26.7
Papaver 4	21.6	15.7	4.7	7.8	5.7	11.8
Salix 1	<3.6	6.6	<27.5	6.6	<27.5	12.6
Salix 2	14.6	21.6	20.6	29.6	23.6	10.7
Salix 3	7.6	20.6	8.6	25.6	12.6	(28.6)
Salix 4	20.6	29.6	5.6	23.6	21.6	2.7
Saxifraga 1			<27.5	31.5	<27.5	5.6
Saxifraga 2			<27.5	2.6	<27.5	7.6
Saxifraga 3	?	5.6	<27.5	1.6	27.5	9.6
Silene 1	<3.6	20.6	<27.5	24.6	<27.5	21.6
Silene 2	<3.6	23.6	<27.5	29.6	<27.5	1.7
Silene 3	?	30.6	<27.5	26.6	27.5	23.6
Silene 4	24.6	26.7	28.6	10.8	20.6	20.8

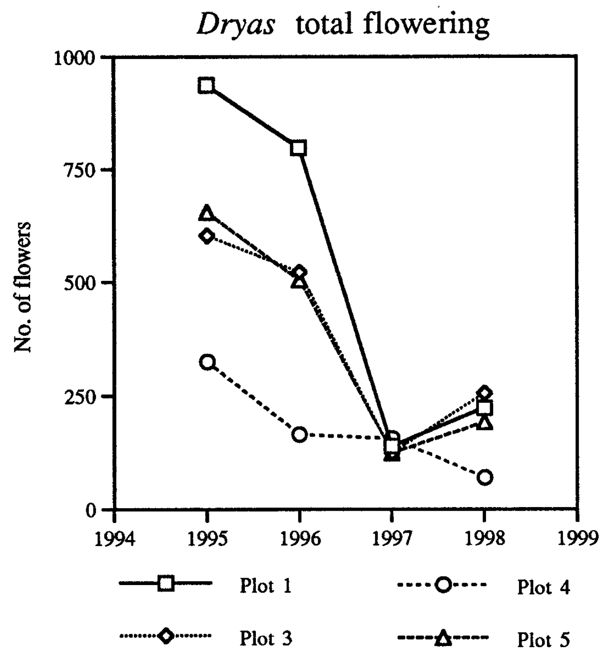


Fig. 4.5. Total number of flowers in four early flowering Dryas spp. *plots, 1996-98.*

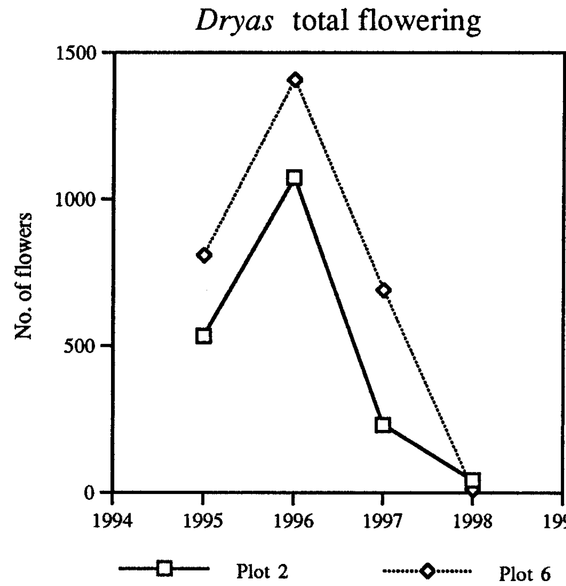


Fig. 4.6. Total number of flowers in two late flowering Dryas spp. *plots, 1996-98.*

4.1.2 ITEX quantitative flowering

Numbers of flowers produced in 1998 were significantly lower in most plots than in any of the preceding seasons (Table 4.2). This especially applies to *Cassiope tetragona* (Fig. 4.4), but also to most *Salix arctica* plots. In *Dryas*, three of the four exposed and early flowering plots recovered a little from the very poor 1997 season (Fig. 4.5), while the two late flowering plots 2 and 6 held exceedingly few flowers this year (Table 4.2 and Fig. 4.6). Only *Saxifraga oppositifolia* and *Silene acaulis* flowered to a 'normal' extent (Table 4.2).

Table 4.2. Area size and total number 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 ITEX plots in 1995, 1996, 1997 and 1998, respectively. 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 (m^2)	1995	1996	1997	1998
Cassiope 1	2	1321	1386	1855	322
Cassiope 2	3		1759	550	19
Cassiope 3	2	256	844	789	35
Cassiope 4	3	456	1789	391	24
Cassiope 5	2.5			1224	455
Cassiope 6	2				
Dryas 1	4	(936)	(797)	138	223
Dryas 2	60	534	1073	230	42
Dryas 3	2	603	522	123	255
Dryas 4	6	(325)	(164)	155	69
Dryas 5	6	(654)	(504)	123	191
Dryas 6	91	809	1406	691	10
Dryas 7	12			787	581
Dryas 8	12			391	240
Papaver 1	105	302	337	265	190
Papaver 2	150	814	545	848	316
Papaver 3	90	334	238	289	266
Papaver 4	91	196	169	192	80
Salix 1 mm.	60		807	959	63
Salix 1 ff.		520	1096	1349	149
Salix 2 mm.	300		790	1082	132
Salix 2 ff.		617	1376	1909	455
Salix 3 mm.	36	239	479	412	32
Salix 3 ff.		253	268	237	38
Salix 4 mm.	150		1314	831	509
Salix 4 ff.		1073	1145	642	709
Saxifraga 1	7		(1010)	141	163
Saxifraga 2	6		513	387	432
Saxifraga 3	10		529	322	288
Silene 1	7		(251)	403	437
Silene 2	6		493	524	440
Silene 3	10		348	211	127
Silene 4	1	466	270	493	312
E. scheuz. 1	10		395	423	257
E. scheuz. 2	6		537	344	172
E. scheuz. 3	10		392	545	482
E. scheuz. 4	8		260	755	179
E. triste 1	10		0	3	1
E. triste 2	6		98	59	21
E. triste 3	10		0	0	0
E. triste 4	8		0	0	0

Table 4.3. Date of 50 % snowcover in the three plant community study plots and in the four Eriophorum *plots (see section 4.1.2).*

Plot no.	1996	1997	1998
Vegetation 1	13.6	30.5	6.6
Vegetation 2	<3.6	22.6	24.6
Vegetation 3	20.6	20.6	20.6
Eriophorum 1		14.6	19.6
Eriophorum 2		14.6	20.6
Eriophorum 3		27.6	21.6
Eriophorum 4		25.6	22.6

4.1.3 Snow melt in 400 m^2 plant community study plots and Eriophorum plots

The snow melt in the three plant community study plots and in the four Eriophorum plots was generally in accordance with the other ITEX study plots (see section 4.1.1). Exposed plots carried more snow than in 1997, while the average snow melt was similar to the previous year (Table 4.3).

4.2 Arthropods

Niels Martin Schmidt

In the 1998 season, yellow pitfall traps and window traps were operated in the same way as in 1997 (see Meltofte and Rasch 1998). Each pitfall trap station held eight yellow pitfalls and the window trap station held two window traps. The liquid in all traps contained only water, salt (NaCl) and detergent (Tween 20).

Sampling was performed by Niels M. Schmidt (27 May to 12 August) and by Thomas B. Berg (19 to 26 August). Sorting was done by Niels M. Schmidt with assistance from Peter K. Kristensen and Jacob Leonhard. Sorted samples are kept in 70 % alcohol at the Zoological Museum, University of Copenhagen.

4.2.1 Pitfall traps

All pitfall traps were put in place at the end of the 1997 season and could be activated as soon as the ground was snow free. The first traps were opened on 27 May, and all traps were open on 13 July. They all remained open until 26 August. On six occasions (10 and 24 June, 5 and 9 August) traps were destroyed by Arctic foxes and the content was lost. On five occasions (24 June, 22 and 29 July, 5 August) a fox, and on one occasion (17 June) a lemming had defecated in the traps, but unlike last year this did not lead to a significant increase in the number of *Cyclorrhapha* larvae in the traps. On four occasions (1 and 8 July, 19 and 26 August) a total of four pitfalls were contaminated with large amounts of soil

Table 4.4. Total number of arthropods caught at the five pitfall trap stations in 1998. 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 and 1997 are given for comparison. Note that 1996-data should be doubled to allow comparison, and that Lycosidae *juveniles and adults were not separated in 1998.*

Date	03.6	10.6	17.6	24.6	01.7	08.7	15.7	22.7	29.7	05.8	12.8	19.8	26.8	T1998	T1997	T1996
No. of active stations	2	2	2	2	4	4	5	5	5	5	5	5	5	5	5	5
No. of trap days	39	81	112	105	209	224	280	280	280	252	280	266	280	2702	2797	1512
COLLEMBOLA	13	83	349	282	910	877	1798	859	778	417	1884	603	227	9090	11597	2794
HETEROPTERA																
Nysius groenlandicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	20
Aphidoidea	0	0	0	0	9	34	2	12	20	52	12	18	28	187	12	3
Coccoidea	0	0	0	0	0	0	1	0	1	1	0	0	0	3	503	102
THYSANOPTERA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
LEPIDOPTERA																
Lepidoptera larvae	0	0	0	4	2	6	3	3	3	4	2	7	7	41	60	47
Colias hecla	0	0	0	0	0	1	0	0	3	3	8	4	1	20	24	48
Clossiana sp.	0	0	0	0	0	0	0	0	5	11	14	13	20	63	255	494
Lycaenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Plebeius glandon	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1
Noctuidae	0	0	0	0	0	0	0	0	0	0	2	2	1	5	65	35
DIPTERA																
Nematocera larvae	0	4	1	0	0	2	3	5	1	2	8	26	9	61	39	26
Tipulidae	0	0	0	0	0	0	0	0	2	0	0	2	0	4	6	10
Trichoceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Culicidae	0	0	0	0	0	0	4	0	5	11	0	0	2	22	18	1
Chironomidae	0	1	33	430	397	588	360	364	208	38	23	36	15	2493	4157	1728
Cecidiomyiidae	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0
Mycetophilidae	0	1	3	0	18	32	332	175	845	469	2028	441	48	4392	2360	325
Empididae	0	0	0	0	0	0	0	1	4	0	2	1	1	9	5	5
Cyclorrhapha larvae	0	0	1	4	2	2	0	2	0	1	1	1	2	16	55	7
Phoridae	0	0	0	0	1	1	0	2	19	1	1	15	12	52	83	55
Agromyzidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Syrphidae	0	1	5	0	0	2	2	0	11	2	3	0	6	32	75	42
Tachinidae	0	0	0	0	0	0	0	0	0	0	0	0	4	4	17	0
Calliphoridae	2	0	0	0	0	2	3	2	7	10	7	6	9	48	43	22
Muscidae	0	0	3	35	121	503	503	567	1960	820	914	781	436	6643	6679	4133
Anthomyiidae	1	83	97	45	67	12	2	4	0	2	1	33	86	433	472	?
Fannidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Scatophagidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	386	13
HYMENOPTERA																
Hymenoptera larvae	0	0	0	0	0	0	0	1	0	0	0	0	1	2	0	0
Ichneumonidae	0	0	0	0	1	12	10	34	44	17	36	67	62	283	692	570
Braconidae	0	0	0	0	0	4	5	1	14	2	33	5	12	76	50	17
Chalcidoidea	0	0	0	0	0	0	0	0	0	0	1	0	1	2	70	7
Cynipoidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Bombus sp.	0	0	0	1	1	2	0	1	1	0	1	0	0	7	12	1
ACARINA	1	74	206	273	422	473	505	580	988	768	664	435	268	5657	19166	4554
ARANEA																
Linyphiidae	27	122	150	125	116	93	70	49	87	27	35	52	56	1109	1859	991
Lycosidae	0	8	54	89	94	242	229	238	269	341	63	103	135	1865	3550	1877
Lycosidae egg sac	0	0	0	0	0	2	6	5	25	53	15	6	27	139	122	34
Thomisidae	0	1	4	3	4	9	4	7	6	9	3	0	4	54	156	73
Dictynidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0
Total	44	378	906	1292	2265	2899	3843	2912	5316	3061	5761	2657	1480	32816	52617	18037

probably leading to a reduction in the number of especially micro-arthropods recovered from the traps. Finally, a total of eight pitfalls (22 July, 19 and 26 August) were flooded due to heavy rain. Most likely, this lead to a significant loss of arthropods from the traps especially from Station 2 situated in a fen area.

The total number of arthropods caught each week during the field season are presented in Table 4.4. Total catches from the 1996 and 1997 seasons are given for comparison. Note that 1996-data should be doubled to allow comparison, as only half the number of yellow pitfalls was operated this year. The phenology of various taxa at the pitfall trap stations is given in Figs 4.7-12.

In 1998, the taxa diversity was relatively low as compared to the previous years. Furthermore, when comparing the 1998 catches with the 1996 and 1997 catches (Table 4.4) the most striking difference is the overall low number of arthropods recovered from the pitfall traps in 1998. But it should be noted that some taxa actually increased in number (*e.g.* Mycetophilidae and Aphidoidea), others showed a significant decrease in number (*e.g. Chironomidae* and *Ichneumonidae*), while other taxa were more or less unchanged (*e.g. Muscidae* and *Anthomyiidae* flies). It should also be stressed that interpretation of the differences must be made with much caution because the sorting level (mostly to family level only) may cover differences in species composition.

The most pronounced difference between 1997 and 1998 in the phenologies shown in Figs. 4.7-12 is the doubling of the number of *Mycetophilidae* (fungus gnats) recovered from the pitfalls and the pro-

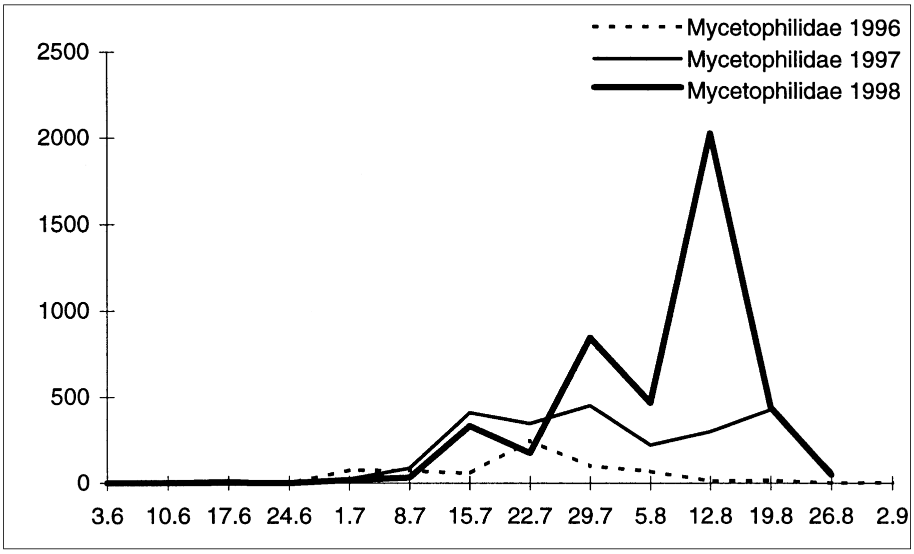


Fig. 4.7. Phenology of Mycetophilidae *(fungus gnats) 1996-98 plotted against date. Data pooled from all pitfall trap stations. Data from 1996 have, due to lower trap number, been doubled to allow comparison.*

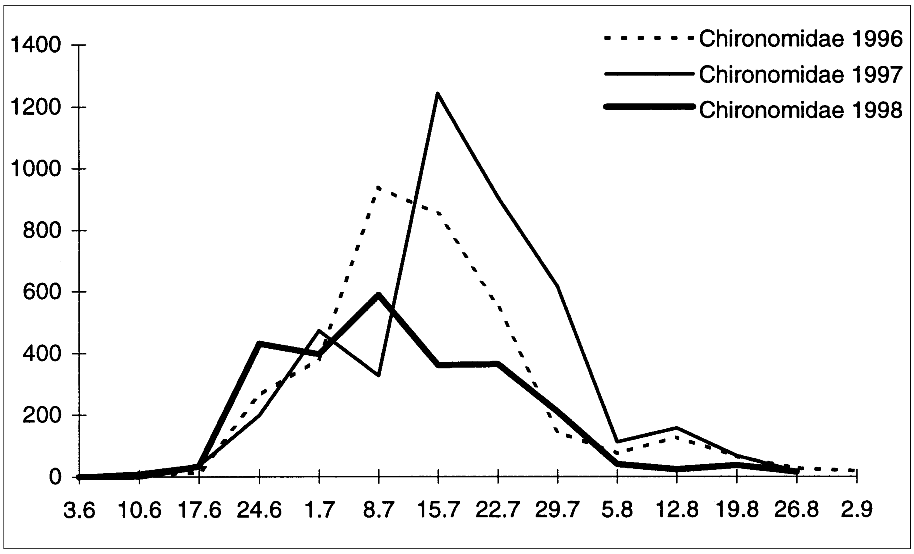


Fig. 4.8. Phenology of Chironomidae *(midges) 1996-98 plotted against date. Data pooled from all pitfall trap stations. Data from 1996 have, due to lower trap number, been doubled to allow comparison.*

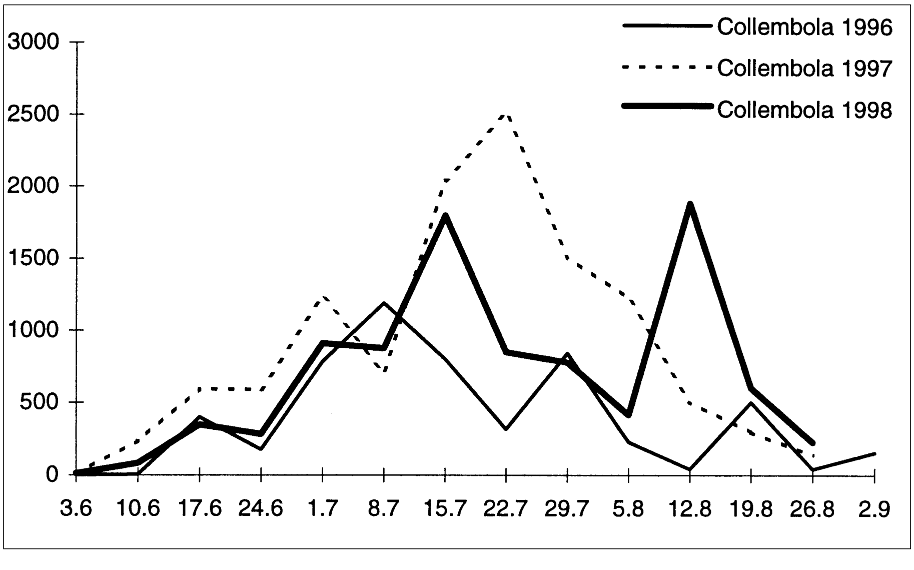


Fig. 4.9. Phenology of Collembola *(mites) 1996-98 plotted against date. Data pooled from all pitfall trap stations. Data from 1996 have, due to lower trap number, been doubled to allow comparison.*

Fig. 4.10. Phenology of Clossiana sp. *(polar and Arctic fritillary butterflies) 1996-98 plotted against date. Data pooled from all pitfall trap stations. Data from 1996 have, due to lower trap number, been doubled to allow comparison.*

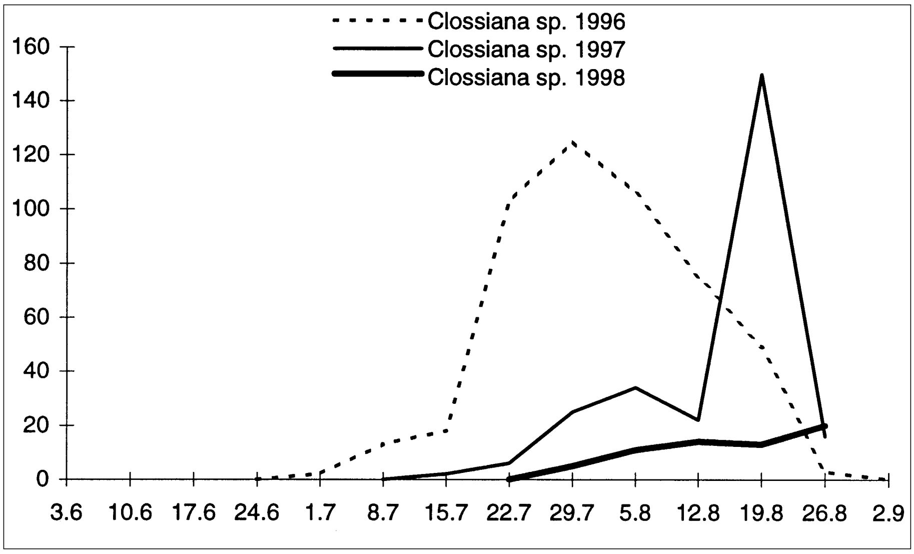
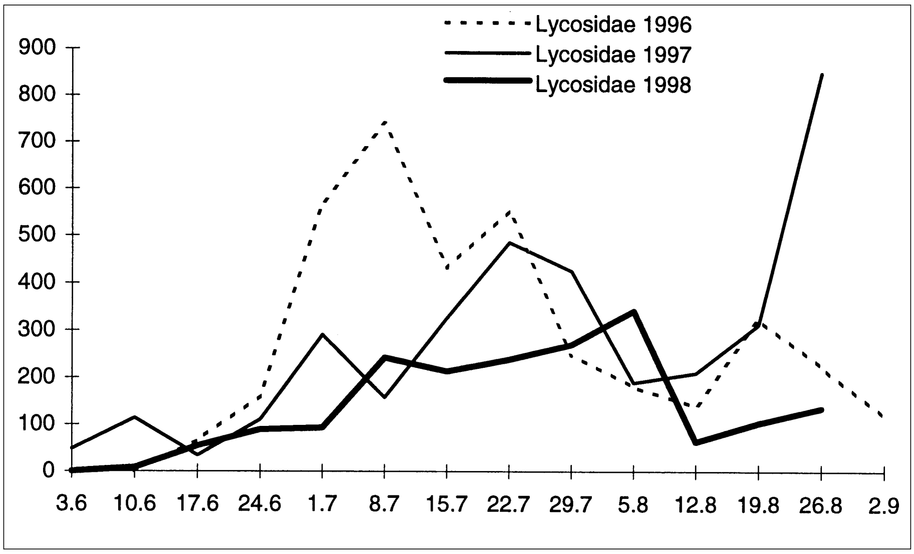


Fig. 4.11. Phenology of Lycosidae *(wolf spiders) 1996-98 plotted against date. Data pooled from all pitfall trap stations. Data from 1996 have, due to lower trap number, been doubled to allow comparison. Note that data presented here include both* Lycosidae *adults and juveniles because these were not separated in 1996 and 1998.*



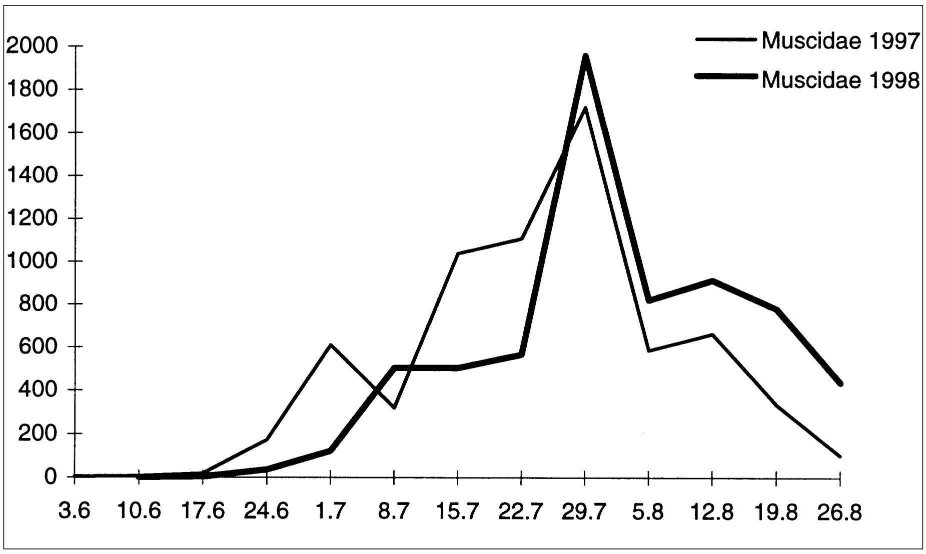


Fig. 4.12. Phenology of Muscidae *(flies) in 1997 and 1998 plotted against date. Data pooled from all pitfall trap stations. Data from 1996 are not included because* Muscidae *were not separated from* Anthomyiidae *in 1996.*

nounced peak in the second week of August (Fig. 4.7). The *Chironomidae* (midges) on the other hand showed a large reduction in number and peaked in the beginning of July, which is a little earlier than in 1997 but at the same time as in 1996 (Fig. 4.8).

In the *Collembola* (springtails), the phenology in the beginning of the season diverged only little from 1996 and 1997 with a peak in early July, but at the end of the season a large second peak arose (Fig. 4.9). The *Clossiana* species (polar and Arctic fritillary butterflies) were caught in even lower numbers than in 1997. Their phenology showed a slow build up in number, but unlike the previous years no peak was seen within the sampling period (Fig. 4.10). The *Lycosidae* (wolf spiders) too had a slow build up in numbers, reaching only half the 1996 and 1997 totals (after correction of the 1996-figures). The peak was delayed a couple of weeks when compared to the previous years and the peak was not very well defined in 1998 (Fig. 4.11). Note that *Lycosidae* adults and juveniles were not separated in 1996 and 1998, and the 1997 number of *Lycosidae* is therefore the sum of adults and juveniles (see Meltofte and Rasch 1998). The *Muscidae* flies only showed minor changes when compared to 1997 (Fig. 4.12). Both in 1997 and 1998 the peak arose in late July and the total number collected was the same in both years.

4.2.2 Window traps

The window traps were established on 1 June and remained active until 26 august. This season, no traps were destroyed by musk oxen and there was no loss of arthropods from the window traps during the whole season. Catches from 1998 are presented in Table 4.5 together with the total catches from 1996 and 1997.

Like in the pitfall traps, the numbers of arthropods collected from the window traps were lower in 1998 than during the previous years. Moreover, the same lower taxa diversity as in the pitfall traps was seen in the window traps, and no new taxa were found in the window traps in 1998.

Most arthropods collected from the window traps were Chironomidae (midges). Compared to 1997, only half the number of Chironomidae were collected in 1998 and the peak in early July was about one week later than both 1996 and 1997. But this was still one week earlier than in the pitfall traps (Fig. 4.8). Muscidae flies too showed a reduction in numbers in 1998 as compared to 1997 but the Muscidae peaked at the same time as in 1997 (late July to early August).

On 12 August, a large amount of Acarina (mites) was collected from the window traps. These were probably blown into the traps by the heavy winds during the preceeding days.

Table 4.5. Total number of arthropods caught at the window trap station in 1998. The station holds two window traps placed perpendicular to each other. Each window measures 20 x 20 cm. Values from each date represent catches from the previous week. Totals from 1996 and 1997 are given for comparison.

Date	03.6	10.6	17.6	24.6	01.7	08.7	15.7	22.7	29.7	05.8	12.8	19.8	26.8	T1998	T1997	T1996
No. of trap days	6	14	14	14	14	14	14	14	14	14	14	14	14	174	184	182
COLLEMBOLA	0	0	0	0	0	0	0	0	0	1	1	3	0	5	15	65
HETEROPTERA																
Nysius groenlandicus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Coccoidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
THYSANOPTERA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
LEPIDOPTERA																
Coilias hecla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Clossiana sp.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	6
Noctuidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Geometridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
DIPTERA																
Trichoceridae	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0
Culicidae	0	0	0		1	6	10	28	10	59	21	1	2	138	142	98
Chironomidae	13	10	22	736	1371	1019	183	251	8	61	48	11	10	3743	7725	6510
Cecidiomyiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Mycetophilidae	0	0	3	2	44	12	193	4	127	161	67	12	0	625	240	64
Empididae	0	0	0	0	0	0	1	0	6	1	1	0	0	9	1	77
Agromyzidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Syrphidae	0	0	0	0	0	0	0	0	2	4	2	0	0	8	16	4
Calliphoridae	3	0	0	0	0	1	0	1	2	1	86	0	0	94	6	2
Muscidae	4	2	0	3	13	117	0	81	253	158	0	13	16	660	809	1355
Anthomyiidae	0	0	12	1	2	0	0	1	0	0	0	5	5	26	11	?
Scatophagidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	11
HYMENOPTERA																
Ichneumonidae	0	0	0	0	0	0	7	0	3	0	0	2	2	14	44	43
Braconidae	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0
Chalcidoidea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Bombus sp.	0	0	0	0	0	0	0	0	1	0	1	0	0	2	6	5
ACARINA	0	0	0	0	0	0	0	14	8	50	750	4	0	826	189	342
ARANEA																
Linyphiidae	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	8
Lycosidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Total	20	12	37	742	1431	1155	394	381	420	496	977	52	37	6156	9248	8623

4.2.3 Predation on *Dryas* flowers by larvae of *Sympistis zetterstedtii*

A total of three larvae of *Sympistis zetterstedtii* was encountered during the weekly visits to the Dryas study plots, all on 10 July. Compared to the previous years, the peak predation rate on the reproductive organs of *Dryas* was generally lower, showed less variance and appeared generally later in 1998 than in the previous years (Table 4.6).

Table 4.6. Peak ratio (%) of Dryas flowers predated by larvae of Sympistis zetterstedtii *in selected study plots in 1996-1998.*

Plot	Date 1996	Pred.	Date 1997	Pred.	Date 1998	Pred.
Dryas 1	17.7	2	24.6	6	15.7	3
Dryas 2		0	05.8	5		0
Dryas 3	01.7	11	24.6	18	08.7	3
Dryas 4	24.6	17	15.7	1	15.7	7
Dryas 5	08.7	2	08.7	8	15.7	2
Dryas 6		0		0		0
Dryas 7		-		-		0
Dryas 8		-		-		0

4.2.4 Predation on *Salix arctica*

No woolly-bear *Gynaephora groenlandica* caterpillars were found during the weekly counts in the *Salix arctica* study plots, but several woolly-bear caterpillars were encountered in Zackenbergdalen. The first woolly-bear caterpillar was seen on 31 May and during the whole season caterpillars were encountered almost daily with a total of 39 individuals.

The predation on *S. arctica* by an unknown *Lepidoptera* larvae seen in 1996 were, like in 1997, not observed in any of the study plots during the 1998 season.

4.2.5 General phenological observations

Only minor changes in the dates of first observations on selected arthropods were seen (Table 4.7) although all species observations except for the *Bombus* species dates were later than in the two previous years.

4.2.6 Line transect

During the line transects through Store Sødal and from Daneborg to Zackenberg (see sections 4.3.6 and 4.4.4) also bumble bees were recorded. They were far less abundant in 1998 than in 1997, when twelve were recorded in Store Sødal as compared to four in 1998. The same difference was found on the Daneborg – Zackenberg transect, where none were seen in 1998 as compared to five in 1997.

Table 4.7. Dates of first observations of selected arthropods in 1996-1998.

Species	Date 1996	Date 1997	Date 1998
Colias hecla	26.6	02.7	09.7
Clossiana sp.	10.6	16.6	19.6
Tipula arctica	12.6	23.6	25.6
Culicidae	20.6	24.6	25.6
Bombus sp.	06.6	01.6	31.5

4.3 Birds

Hans Meltofte

Bird observations were recorded by myself during 26 May – 25 July and by Thomas B. Berg during the rest of the field season. During June, the main effort was to census the breeding birds in the 19 km^2 census area in Zackenbergdalen (section 4.3.1), while in July emphasis was on breeding phenology, *i.e.* finding nests and young and rechecking these (sections 4.3.2 and 4.3.4). 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 (section 4.3.3).

On 10 June, I joined an ATV (all terrain vehicle) trip to upper Store Sødal. During 10-23 July, Frank Riget and co-workers recorded bird observations in upper Store Sødal and Store Sø (see section 5.4.3). Line transects through Store Sødal were walked by Thomas B. Berg and Niels Martin Schmidt during 16-18 July and between Daneborg and Zackenberg on 25 July (section 4.3.6). Also in late July, Sandøen in outer Young Sund was visited (section 4.3.7). Valuable observations were provided by several other researchers and staff during the entire season.

Table 4.8. Number of trips and hours (trips-hours) allocated to bird censing and breeding phenology sampling west and east of Zackenbergelven during June and July, respectively. A few trips in late May are included in the June figures.

Month	West of river	East of river	Total
June	6-25	18-66	24-91
July	8-35	13-59	21-94
Total	14-60	31-125	45-185

Table 4.9. Estimated number of pairs/territories in three sectors of the 18.8 km^2 census area in Zackenbergdalen, 1998.

Species	West of the river (3.39 km^2)	East of river <100 m (9.15 km^2)	East of river >100 m (6.26 km^2)
Red-throated diver	0	3	0
Pink-footed goose	0-1	0	0
King eider	0	1	0
Long-tailed duck	0-1	6-7	0
Rock ptarmigan	0	3-5	1
Great ringed plover	9-11	9-13	20-21
Red knot	3	15-16	9-13
Sanderling	12-13	33-39	17-18
Dunlin	20-25	54-68	1
Ruddy turnstone	6-9	41-45	8
Red-necked phalarope	0	1-2	0
Red phalarope	0	0-1	0
Long-tailed skua	4	15	3-4
Northern wheatear	1	0	0
Snow bunting	16-18	17-20	8

This year, I tried to use egg dimensions and weight to calculate start of incubation and thereby first egg dates following the method described by Hoyt (1979). Even though precision instruments (a Vernier gauge to 0.01 mm and a balance to 0.01 g) were used, the method did not produce more accurate results than the egg floating method (Paassen *et al.* 1984). When the balance furthermore showed to be unstable under low temperature conditions, the method was abandoned.

For scientific names in this chapter, see section 4.3.8.

Table 4.10. Census results from the 18.8 km² census area in Zackenbergdalen, 1996-98.

Species	1996	1997	1998
Red-throated diver	1-2	2	3
Pink-footed goose	0	1	0-1
King eider	2-3	2	1
Long-tailed duck	5-8	4-6	6-8
Rock ptarmigan	3	11-15	4-6
Great ringed plover	54-56	40-48	38-45
Red knot	33-43	35-44	27-32
Sanderling	51-63	55-70	62-70
Dunlin	69-82	75-91	75-94
Ruddy turnstone	42-52	49-58	55-62
Red-necked phalarope	0-1	0-2	1-2
Red phalarope	0	0	0-1
Long-tailed skua	25-29	22-25	22-23
Northern wheatear	0	0	1
Snow bunting	45-55	45-56	41-46

4.3.1 Breeding populations

The 18.8 km² census are in Zackenbergdalen was covered on almost daily trips between mid June and late July (Table 4.8). The main census effort in the extensively covered area east of Zackenbergelven was between 12 and 22 June, while the intensive study area west of the river was covered regularly during late June and most of July, following an initial complete census on 19 June. The reduced effort in the latter area in June, as compared to 1997, was due to difficulties crossing the river during the peak of snow melt. In total, the hours used for the initial complete coverage of the entire area between 12 and 22 June amounted to 43 hours, as compared to 44 hours in 1997 and 36 hours in 1996. In late May and early June a number of reconnaissance trips were made in both areas.

The census results are presented in Table 4.9, and in Table 4.10 they are compared with revised figures for 1996 and 1997. The most pronounced difference is that red knots were found in lower numbers in 1998 than in the two previous years. Also great ringed plovers and snow buntings were found in slightly lower numbers, while dunlins and ruddy turnstones show increasing trends.

Rock ptarmigans decreased after the peak in 1997. Between 5 and 10 broods were encountered inside the census area, but none of them appeared

Table 4.11. Median first egg dates for waders at Zackenberg in 1998 as estimated from incomplete clutches, egg dimensions and weight, egg floating, hatching dates and weights of pulli.

Species	Median date	Range	N
Great ringed plover	16 June	5 June - 9 July	4
Red knot	20 June	9-23 June	4
Sanderling	18 June	13-26 June	13
Dunlin	16 June	10 June - 5 July	23
Ruddy turnstone	12.5 June	7-29 June	23
Red-necked phalarope	23 June	-	1

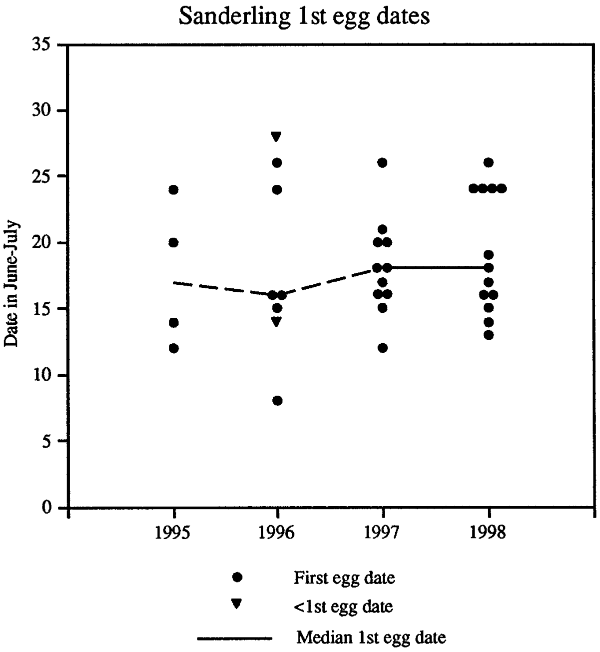


Fig. 4.13. Estimated first egg dates for sanderling 1995-98. Dates are number of days after 31 May. Medians based on samples of less than 10 nests/broods are dashed.

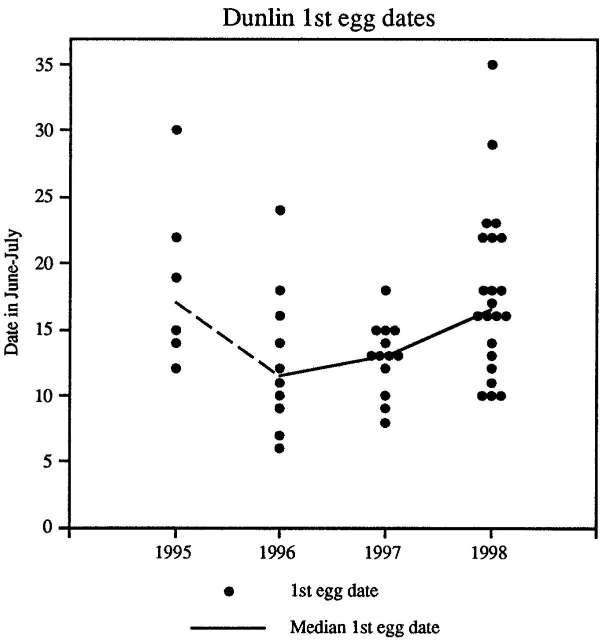


Fig. 4.14. Estimated first egg dates for dunlin 1995-98. Dates are number of days after 31 May. Medians based on samples of less than 10 nests/broods are dashed.

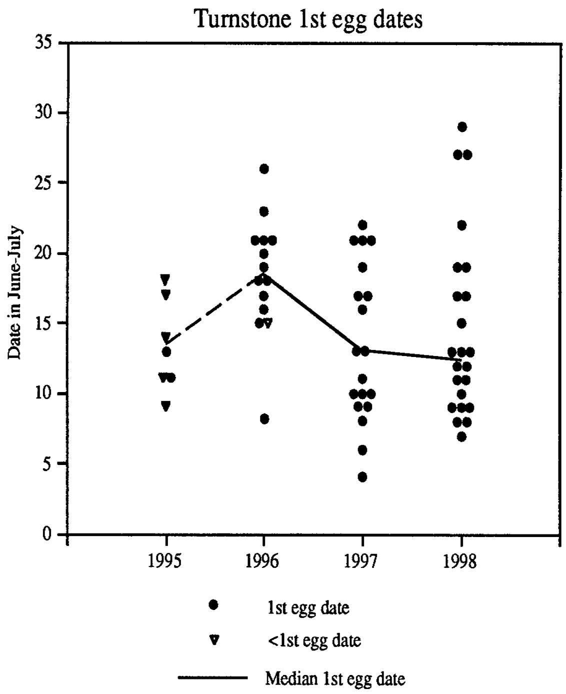


Fig. 4.15. Estimated first egg dates for ruddy turnstone 1995-98. Dates are number days after 31 May. Medians based on samples of less than 10 nests/broods are dashed.

until late July and August, so several of them probably originated from outside the census area (see section 4.3.8).

Red-necked phalarope and northern weathear proved to breed inside the census area for the first time since the start of our monitoring in 1995 (see section 4.3.8).

4.3.2 Reproductive phenology in waders (shorebirds)

First egg dates are presented in Table 4.11, and for the three best covered species, data for 1995-1998 are presented in Figs. 4.13-15. It appears that median first egg dates for sanderling and ruddy turnstone were similar to 1997, whereas dunlins bred a few days later. This is likely to be related to the somewhat later initial phase of the snow melt in 1998 (see sections 4.1.1 and 4.1.3). Sanderlings and ruddy turnstones often nest on exposed sites that have little or no snow-cover early in the season, while most dunlins nest in fens that are snow covered until mid or late June and thereby more sensitive to annual variations in snow melt.

The very late clutches of great ringed plover, dunlin and ruddy turnstone may have been relayed clutches.

4.3.3 Breeding success in waders

As in the previous three years, the overall breeding success of waders at Zackenberg seems to have been good. Out of 38 wader nests found with eggs, 21 hatched successfully, while 12 apparently were predated. Most predated nests were of ruddy turnstone (8 of 17 found). In one further turnstone nest, three out of four eggs apparently were predated, and in one otherwise successful dunlin nest, a starred egg was left behind. One red knot nest failed a day before hatching because of flooding during a spell of rain and snow. The faith of the two remaining nests is uncertain.

As nests were not visited during the period from finding until estimated hatching, it is not relevant to calculate daily survival rates. Furthermore, it is likely that even our few visits at nests increase predation by guiding foxes etc. to the nests. One fox den in the census area east of the river was occupied by a fox family, and stray foxes were seen at several occasions on both sides of the river together with three ermine families (see section 4.4).

The counts of juvenile waders in the old and the present deltas of Zackenbergelven produced accumulated numbers in the same order of magnitude as in previous years, except in great ringed plover (Table 4.12). The lower numbers of this species together with the somewhat lower numbers of juvenile dunlins may have been the result of large amounts of sediments that covered the present delta after the extreme rush of river water on 16 August (see section 3.3). Hence, 84 % of the juvenile dunlins stayed in the old delta in the second half of August 1998.

Table 4.12. 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, 1995-98. In case of missing counts etc., data have been interpolated.

Species	1995	1996	1997	1998
Great ringed plover	96	126	249	42
Red knot	5	22	0	6
Sanderling	304	726	149	333
Dunlin	325	360	323	232
Ruddy turnstone	80	108	82	109
Total	810	1342	803	722

4.3.4 Reproductive phenology and success in long-tailed skuas

In accordance with the abundance of lemmings (see section 4.4) the entire population of long-tailed skuas apparently nested. A total of 23 nests were found, but two of these were probably re-nestings after failure of initial clutches that had already been recorded. Hence, a total of 21 pairs were documented to have laid eggs out of a population of 22-23 pairs in the census area (see Table 4.9).

Compared to 1997, when most of the population also nested, egg-laying took place somewhat later in 1998. 16 clutches were initiated between 7 and 16 June, and seven of these on 11-12 June as compared to peak laying on 6-7 June in 1997 (range 4-23 June). Further six clutches, that were initiated between 23 June and 2 July, were probably relaid clutches. The somewhat later egg-laying in 1998 may have been related to the more extensive initial snow-cover this year (see sections 4.1.1 and 4.1.3).

19 clutches, including four relaid, held two eggs, one relaid clutch held one, while one initial and one relaid clutch that only held one egg, may not have been complete.

Eight or nine nests produced pulli. The rest were predated by foxes or some of them probably by glaucous gulls. West of the river, where the fox den was not occupied this year, all four nests produced pulli, and three of them probably even a juvenile. East of the river, where one of the fox dens held a fox family with five pups, 14-15 out of 19 nests were predated. One or two nest were predated just after hatching of the first young, and only 3 pairs are likely to have produced juveniles. As with waders, our visits at skua nests may have contributed to the predation by guiding foxes etc. to the nests. In total, six juvenile long-tailed skuas apparently fledged from the census area this year as compared to at least 4-5 in 1997, none in 1996 and one in 1995.

4.3.5 Breeding barnacle geese

A pair with four a few days old goslings was encountered on the coast west of the trapping station on 26 June, and two days later a pair with two similarly a few days old goslings appeared along Zackenbergelven north of the research station. During early July, several pairs gathered at Lomsø, and on 7 July a total of seven pairs with 21 goslings was present here and in the old delta of Zackenbergelven. On 15 July, a total of 12-13 pairs with 28 goslings was counted at Lomsø. On 21 July, the record was 14 pairs with 31 goslings at Lomsø and 3 pairs with 7 goslings together with the moulting barnacle geese at the coast east of Grænseelv (see section 4.3.8). Including the pair with two goslings that remained in the area along the river north of the research station until mid August, the average brood size was 2.88 on 7 July (N = 8), 2.14-2.31 on 15 July (N = 13-14), and 2.22 on 21 July (N = 18).

Hence, a total of at least 18 pairs of barnacle geese brought their goslings to Zackenbergdalen in 1998, besides a few pairs of apparently failed breeders that remained together with the successful breeders. Opposite to these, the non-breeding immatures most often stayed by themselves (see section 4.3.8).

For comparison, 19-21 successful families appeared in 1997, 6-7 in 1996 and 7 in 1995. Average brood size in late July was 2.63 in 1997, 3.0 in 1996 and 2.0 in (early August) 1995.

Furthermore, during the line transect survey through Store Sødal on 16-18 July three goslings were recorded together with 75 adults at the lake in the southwestern part of Lindemansdalen ("Lindemanssø" just north of Zackenbergelven), 10 goslings were encountered together with 92 adults at Store Sø, and four goslings were recorded together with 31 adults in upper Store Sødal. This is the first time during our work at Zackenberg that we have recorded broods of barnacle geese in Store Sødal. During an aerial survey in 1988, six pairs with goslings were recorded in upper Store Sødal (Bay and Boertmann 1988).

Table 4.13. Birds recorded (adults/young) during line transect surveys through Store Sødal and from Daneborg to Zackenberg (see map in Meltofte and Thing 1997).

Species	Store Sødal 16-18 July	Daneborg 25 July	Total
Red-throated diver	2		2
Pink-footed goose	123		123
Barnacle goose	244/17	6/6	250/23
Common eider		119/5	119/5
Rock ptarmigan		1	1
Great ringed plover	61	9	70
Sanderling	7	3	10
Dunlin	56	6/1	62/1
Ruddy turnstone	4	4	8
Long-tailed skua	7	2	9
Glaucous gull	8/2	3	11/2
Arctic tern	7	2	9
Common raven	2	7	9
Snow bunting	62/5	2	64/2

4.3.6 Line transect

After an evaluation of the results obtained during 1996 and 1997, the line transect surveys through Store Sødal and from Daneborg to Zackenberg have been reduced only to take place in July (see also section 4.4.4).

Again, the results from the July survey in 1998 (Table 4.13) are surprisingly similar to the results obtained during the previous years. The most striking difference is the lower number of snow buntings in Store Sødal: 62 adults as compared to 103 in 1997 and 111 in 1996 (a somewhat different route in 1996). Also the numbers of pink-footed geese were lower: 123 as compared to 263 in 1997 and 253 in 1996. This reduction both applies to Store Sødal and the coast east of Zackenberg, where only five pink-footed geese moulted this year (see also section 4.3.8).

4.3.7 Sandøen

On 25 July, when a thorough survey of the islet was performed, about 100 common eiders were recorded around Sandøen together with totals of 50-100 Sabine's gulls and 400-500 Arctic terns on the islet. Quite clearly, 1998 was not a good breeding season for these species on Sandøen. Only seven Arctic tern nests with a total of 11 eggs (4 nests with 2 egg and 3 with 1) besides six live and two dead pulli were found on the central plateau of the islet. Seven Sabine's gull nests with a total of 10 eggs (3 with 2 eggs, and 4 with 1) besides two live and three dead pulli were also found on the central plateau. Finally, five eider nests with a total of 21 eggs was found in the same area, and no young were seen on the water around the islet. An estimated total of 400 Arctic terns but no Sabine's gulls were present on 25 August.

This poor breeding performance must be related to the late break up of the fjord ice around the islet, as described in section 3.5.

4.3.8 Other observations

This section presents bird records in the study area other than those presented in sections 4.3.1-4.3.7. When nothing else is stated, observations refer to the census area in Zackenbergdalen.

Red-throated diver *Gavia Stellata*

During 3-6 June, 1-2 red-throated divers daily circled over Zackenbergdalen, and on 5 June one individual landed on a small pond for a short while. From 9 June, one or two pairs were present on the ponds around the station almost daily, and from 12 June they also appeared in the deltas of Zackenbergelven.

On 19 June, the first bird was incubating on an islet in the largest pond just south of the station. Two pulli had hatched on 17 July, and they successfully left the pond between 28 and 30 August. The breeding schedule at this place was six days later than in the previous year, in accordance with the later ice melt in 1998.

A bird was incubating on the shore of Lomsø on 2 July. Two pulli had hatched by 29 July, and they were still present when checked for the last time on 31 August.

On 14 July, a bird was incubating on an islet in a pond in the eastern part of Rylekærene ("Ryledammen"). Incubation must have been initiated somewhat earlier, as one out of two pulli on 10 August was estimated to be about one week old (the bird was still sitting on the nest on 2 August). They were still present on the pond when last checked on 24 August.

Finally, a red-throated diver was incubating on the shore of Hestehale Sø in the southwestern part of Morænebakkerne (see Fig. 5.3.1 in Meltofte and Rasch 1998) on 13, 20 and 24 July. Two large pulli were recorded here on 22 August, so they probably hatched in late July or early August.

A pair of divers were recorded on the lake in the southwestern part of Lindemansdalen ("Lindemanssø") on 15 July, but no sign of breeding was observed.

Hence, a total of five pairs of red-throated divers were present in Zackenbergdalen/Lindemansdalen this year, of which at least four pairs hatched eight pulli. This is by far the best breeding season so far, since our monitoring began in 1995.

Up to eight feeding red-throated divers were recorded off the deltas of Zackenbergelven at a number of occasions in August.

Great northern diver *Gavia immer*

On 14-16 July, a pair of great northern divers was recorded on the smaller lake northeast of the large lake in the westernmost part of Store Sødal (west of the watershed). No sign of breeding was found.

This is the first record of the species in A.P. Olsen Land/Wollaston Forland.

Pink-footed goose *Anser brachyrhynchus*

Besides 17 newly arrived pink-footed geese on 27 May, 1-7 were recorded almost daily in the census area until 16 June, when the first flock of 16 individuals on moult migration appeared. One pair stayed in the area during the whole period and may have attempted to breed. None were seen on a trip to upper Store Sødal on 10 June.

Besides the 16 apparently newly arrived individuals on 16 June, moult migration of immature Icelandic pink-feet was recorded during 19-30 June, when a total of about 250 passed northbound, and flocks of up to 30 were staging in the area. A few were seen during early July, and to our great surprise, only five individuals were moulting at the coast in the southeastern part of the valley when checked on 21 July. In this area, about 250-300 individuals moulted in the three previous seasons. The reason for this poor number may be found in the late appearance of open water off the river outlets in that area (see section 3.5), but it can not be excluded that five helicopter flights during the most sensitive period 10-13 July, of which one passed straight over the moulting area at low altitude, may have contributed to the desertion of the area.

In upper Store Sødal, 123 moulting pink-feet were recorded during the line transect survey (see section 4.3.6), while c. 150 were recorded by the research team working in the same area during 18-20 July.

During August, pink-footed geese were only recorded around the time of southward migration, when 42 were seen on 22 August, about 200 flew south during 28-31 August, and 200 were staging at Ulvehøj on the latter date.

Barnacle goose *Branta leucopsis*

A maximum of 78 barnacle geese was recorded on snowfree land around the research station already on 27 May. Immigration from the south apparently took place until 6 June. During June, flocks mainly consisting of immatures were recorded in the same area, with a maximum of 58-81 individuals counted in the entire census area on 15 June. None were seen on a trip to upper Store Sødal on 10 June.

During the moult in July, 21 stayed at Lomsø, 55 at the coast east of Grænseelv and 65 at 'Lindemanssø' just north of Zackenbergelven. Besides the c. 250 moulting non-breeders recorded in Store Sødal (which includes the 65 birds at 'Lindemanssø') during the line transect survey (see section 4.3.6), a total of 126 individuals were encountered at lakes west of the watershed on 13 July. This adds up to a total of at least 310 moulting non-breeders in the study area (see also section 4.3.5.).

The first (poorly) flying adult was encountered on 10 August, and during the rest of the month, flocks of up to 260 were recorded in Zackenbergdalen.

Northern pintail *Anas acuta*

A male pintail was seen in the census area on 14 and 27 June. This is the northernmost record in Greenland so far (cf. Boertmann 1994).

Common eider *Somateria mollissima*

On 12 June, the first two pairs of common eiders were encountered in the delta of Zackenbergelven. A few more observations were made until 18 females with one duckling were recorded off the old delta on 17 July. Numbers increased during the rest of July and August, so that maximum numbers of 88 adult females and 17 pulli besides two adult males were recorded in August.

King eider *Somateria spectabilis*

The first and only pair of king eiders appeared on the ponds at the research station on 15 June. They were recorded together for the last time on 3 July, when even 2-3 other males were present.

Long-tailed duck *Clangula hyemalis*

On 2 June, the first pair of long-tailed ducks appeared on a shallow pond just south of the research station. Numbers increased from 7 June until a total of 6-7 pairs were recorded on 17 June. In late June the pairs started to break up, and on 30 July, a female with a brood of four pulli appeared on a pond north of the research station. Later, they stayed on the ponds south of the station, until they were recorded for the last time on Lomsø on 20 August.

On 10 July, a female with a brood of ducklings was encountered on a lake in the central part of upper Store Sødal.

A maximum of 16 individuals were found in the delta of Zackenbergelven on 3 July, and on 18 July, 19 moulting males had gathered at the coast west of the trapping station. Here, up to 38 were recorded a number of times during late July, and in August, a maximum of 48 was found along the coast off Zackenbergdalen.

Gyr falcon *Falco rusticolus*

On the very day of our arrival (26 May), a male gyr falcon caught a great ringed plover in the fen at the research station. Single individuals were recorded in the valley one more time in May, one time in June, six times in July and two times in August.

On 27 July and 7 August, a pair with one juvenile was seen on a nest on the coast three kilometres west of the delta of Zackenbergelven.

Rock ptarmigan *Lagopus mutus*

Several pairs of rock ptarmigans were recorded inside the census area and on the slopes of Zackenberg until 12 June, whereupon only males were seen. A nest with 11 eggs was found in Morænebakkerne on 24 June, and on 15 July, a female with 9 “one week old” pulli was encountered here.

Between 3 and 7 broods of up to 8 pulli were encountered inside the census area during 26 July to 14 August, and a further 2-3 broods of 5-7 juveniles were recorded on 18 August. As only 4-6 pairs were estimated to have established territories inside the census area during June (see section 4.3.1), some of them may have originated from outside the area. This is supported by the fact that they appeared so late in the season. One further brood of eight pulli was encountered in the valley west of Zackenbergfjeldet on 23 July, and on 10 August, 10 pulli were recorded north of Morænebakkerne.

Hence, it appears that in spite of a lower number of pairs this year as compared to the peak season of 1997, 1998 was a good breeding season for ptarmigans at Zackenberg.

Several spots with scattered winter plumage feathers of ptarmigans in Zackenbergdalen indicated that many ptarmigans had been predated during the previous winter.

Great ringed plover *Charadrius hiaticula*

Great ringed plovers were present in good numbers already when we arrived on 26 May, and song display was recorded from 31 May. The last pre-breeding flock of five was seen on 12 June. Juveniles were seen in the deltas of Zackenbergelven from 1 August, and a maximum of 15 adults was recorded here on 4 August.

European golden plover *Pluvialis apricaria*

Single golden plovers were recorded on 30 May, 19 June (two separate individuals) and 2 July, respectively.

Red knot *Calidris canutus*

Knots were singing in the census area from our arrival on 26 May until 18 July. Four juvenile knots together with four juvenile ruddy turnstones were encountered at 250 m a.s.l. on Aucellabjerg on 24 August, and up to five juveniles were recorded in the deltas of Zackenbergelven later in August.

Sanderling *Calidris alba*

The first sanderling was recorded on 30 May, and not until mid June appreciable numbers were seen. Song display was recorded from 5 June, and pairs were active together until 12 July. Groups of apparent post-breeders were seen from 1 July, and on 23 July a maximum of 23 adults was counted in the deltas of Zackenbergelven. Juveniles were present in the deltas from 29 July, and on 28 August a peak record of 119 juveniles was achieved.

Pectoral sandpiper *Calidris melanotos*

A female pectoral sandpiper was seen feeding in the census area on 17 June and 2 July. This is the fifth record in Northeast Greenland (Boertmann 1994).

Dunlin *Calidris alpina*

Dunlins were heard singing from 27 May, and immigration was recorded until 8 June. Song was heard until 16 July, and the next day a flock of five post-breeders was seen. Peak records of 86 and 84 adult dunlins were made in the deltas on 1 and 4 August, respectively. On 29 July, the first juveniles were seen in the deltas, and a maximum of 112 juveniles was recorded here on 28 August.

Ruddy turnstone *Arenaria interpres*

Turnstones were present already when we arrived on 26 May, and on 28 May a flock of 40 was recorded. Territorial behaviour was noted from 30 May. On 1 July, a post-breeding flock of five was seen, and on 23 July three newly fledged broods were recorded. Many juveniles were encountered in the terrain during August, and a maximum of 29 was recorded in the deltas of Zackenbergelven on 17 August.

Red-necked phalarope *Phalaropus lobatus*

A female red-necked phalarope was recorded on the ponds around the research station from 5 June, and on 9 and 11 June two females were found. A pair was present from 21 or 23 June, and on 4 July an anxious females was encountered in the eastern part of the census area (just south of fox den no. 2). On 17 July, a male with four, a few days old pulli was found in the fen and pond area just south of the research station. This constitutes the first proof of breeding in the area and the northernmost breeding record in East Greenland so far (Boertmann 1994). However, three pairs were recorded in our area already in June 1964 (Rosenberg *et al.* 1970), and two juveniles were seen in August 1996 (Meltofte and Thing 1997).

Red phalarope *Phalaropus fulicarius*

A pair of red phalaropes appeared on the ponds just north of the runway on 12 June, and one individual passed by the day after. A single female was recorded at different places in the census area on 16 and 17 June, and on 27 June, a male was present. These birds were the first seen since we began our work at Zackenberg.

Arctic skua *Stercorarius parasiticus*

One or two individuals were recorded five times during 17 July – 7 August.

Long-tailed skua *Stercorarius longicaudus*

The first long-tailed skuas – a ‘flock’ of 11 – appeared in the census area on 28 May, and on the next day, a ‘flock’ of 13 was recorded. The first flying juvenile appeared in late July, and pairs with fledged young were present in the area until late August (see further section 4.3.4).

Great skua *Stercorarius skua*

A pair of great skuas was recorded over the snow covered tundra on 9 June, and again on 17 August, two birds were seen in the deltas of Zackenbergelven.

Glaucous gull *Larus hyperboreus*

In June, up to five glaucous gulls were hunting lemming on the tundra of Zackenbergdalen. Immatures were recorded on 3 and 19 June. Up to four individuals were seen along the river almost daily during the entire summer.

Two pairs were apparently breeding on large stones in the river bed of Zackenbergelven in lower Store Sødal, where they were present already on 10 June, when everything was covered in snow and ice. One further pair was recorded at the western end of Store Sø during the line transect survey in mid July. In the uppermost part of Store Sødal, up to three individuals were recorded at lakes by the research team working there, also in mid July. At Hestehale Sø in Morænebakkerne, where a pair bred successfully in 1997, only a lonely individual defended a territory during June and July.

In the deltas of Zackenbergelven, a maximum of 18 adults and four juveniles was recorded on 25 August, and two immatures were found on 22 August.

Ivory gull *Pagophila eburnea*

An ivory gull was recorded over outer Young Sund on 31 July.

Arctic tern *Sterna paradisaea*

A pair of Arctic terns was recorded over the newly forming melt water in the delta in westernmost Store Sø on 10 June, and five were recorded here during the line transect survey in mid July. Furthermore, up to two individuals were recorded at lakes in upper Store Sødal in mid July. One individual was seen over a lake in Morænebakkerne on 19 June, and on 24 June, a pair stayed in the old delta of Zackenbergelven.

Black guillemot *Cepphus grylle*

A black guillemot was recorded in outer Young Sund on 31 July.

Snowy owl *Nyctea scandiaca*

A snowy owl was seen at the research station on 10 August. In spite of the abundance of lemmings, this was the only observation this year.

Meadow pipit *Anthus pretensis*

A meadow pipit was encountered close to the research station on 31 May and 4 June. Flight display was noted on the first date. This is the northernmost observation of the species in East Greenland so far (Boertmann 1994).

Northern weathear *Oenanthe oenanthe*

A pair of wheathers was seen feeding young in a nest in the northernmost part of the census area west of the river during 3-7 July. On 13 August, three juveniles were recorded in the westernmost part of the area, and on 18 August, an adult was encountered at Ulvehøj.

Common raven *Corvus corax*

1-3 adult ravens were recorded regularly in the census area during late May and June. Two juveniles appeared in the northern part of the valley on 25 June, and apparently one further brood of 2-3 juveniles appeared at the old trapping station on 28 June. A single juvenile raven often stayed at the research station during 30 June – 14 July. Groups of up to five were recorded in July and August.

Arctic redpoll *Carduelis hornemanni*

Up to four individuals were recorded regularly during late May and all of June. In late May and early June they were often singing, and fierce fights among four birds were seen on the slopes of Zackenberg on 1 June.

An adult with one juvenile appeared in the census area on 18 July, and one further juvenile was recorded on 24 July.

Snow bunting *Plectrophenax nivalis*

A maximum of 50 snow bunting was seen in a flock on 27 May, but after 4 June, only dispersed individuals and pairs were recorded.

The first juveniles were recorded on 12 July, and on 30 August, a flock of 150 was encountered.

4.4 Mammals

Thomas B. Berg

Records of mammals were made by Niels Martin Schmidt (27 May – 14 August), by Thomas B. Berg (4 July – 2 September) and by Hans Meltofte (27 May – 25 July). Additional random observations were supplied by most other personnel during the entire field season.

The 2.5 km^2 census area for collared lemming *Dicrostonyx groenlandicus* was censused for winter nests and active summer burrows. The total number of muskoxen *Ovibos moschatus* was censused once a week within the 39.1 km^2 study area in Zackenbergdalen and counted daily from a fixed, elevated point at the station. All fresh carcasses of mammals were recorded whenever found throughout the season. The registration of old muskox carcasses was continued. The two line transects Zackenberg – Store Sødal and Daneborg – Zackenberg were walked by Thomas B. Berg and Niels M. Schmidt in mid July. Methods of the mammal monitoring were the same as in 1996 and 1997 (see Meltofte and Thing 1997 and Meltofte and Rasch 1998).

On 25 July an automatic digital camera was placed at the southeast end of Sandøen, where walruses haul out. The camera was programmed to take four pictures each day between 25 July and 25 August. All observations of mammals other than lemmings, foxes and muskoxen are presented in section 4.4.5.

*Table 4.14. The annual number of recorded winter nests within the 2.5 km^2 census area in Zackenbergdalen. Category I denotes nests from the previous winter, Category II from earlier winters. * includes nests from the winters of 1993-95.*

Year	Category I	Category II
1995	279*	830
1996	161	263
1997	342	109
1998	711	109

4.4.1 Collared lemming population

Already during snowmelt in June it was clear from the numbers of lemmings seen on the snow and the snowfree patches that 1998 was a lemming peak year. 161 individuals were recorded during the entire season; most of them during snow melt in June

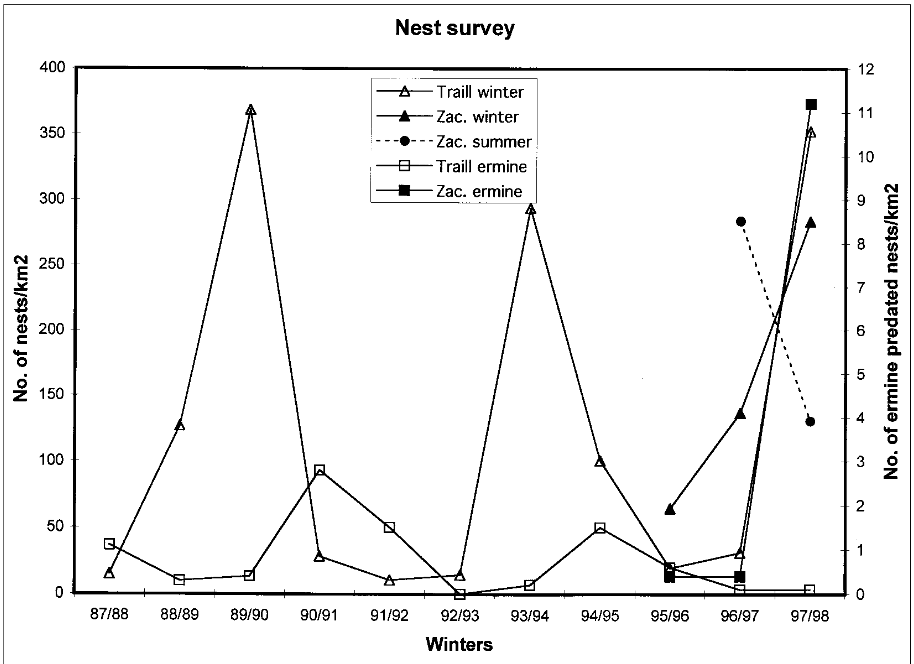


Fig. 4.16. Lemming winter nest index (left axis) and ermine index (right axis) shown as nest/km^2 and nest predation/km^2 in Karupelv valley, Traill Ø (open signs) and at Zackenberg (solid signs). Data covers the amount of nests built from October to May. Data from Traill Ø were kindly provided by Benoît Sittler (partly published in Sittler 1995).

(see section 4.4.5). This is 11 times the number seen in 1997 and 29 times the number recorded in 1996. The number of fresh winter nests increased by 208 % as compared to 1997 (Table 4.14). In total, 820 nests were examined. Of these, 711 were from the previous winter while 109 were of older age. The last category equalled the number found in 1997.

In contrast to the situation in 1997, the number of active summer burrows declined from 710 in 1997 to 346 in 1998 (Fig. 4.16). The dramatic drop in the amount of active summer burrows in 1998 may indicate an early summer crash of the lemming population.

As experienced on Traill Ø during 1988-1998, the build up of a lemming peak can take place either during two years (1988-90) or in only one year (1993-1994 and 1997-1998, Fig. 4.16). The lemming population at Zackenberg, which in 1997, for various reasons, seemed to be out of phase with the Traill Ø population, turned out to peak synchronously with this site 250 km to the south. 1997 was just in a state of building up for the 1998 peak.

The density of lemming winter nests predated by ermines at Zackenberg reached 11.2 per km^2 in 1998, or four times the maximum figure at Traill Ø (Fig. 4.12). Normally, a peak in the ermine predation appears one year after the lemming peak due to the delayed implementation of the foetus in ermines. At Zackenberg, the conditions in 1997 were favourable enough for the ermine to breed leading to a high ermine population along with the lemming peak in 1998.

Long-tailed skuas, who depend on sufficient amounts of lemmings to produce a clutch, bred extensively in Zackenbergdalen in 1998, as they did in 1997 (see section 4.3.4). Opposite to 1997, Zackenbergdalen hosted no breeding snowy owls in 1998 despite the lemming peak (see section 4.3.8), while Traill Ø held 21 pairs (Sittler pers. comm.) within an area similar to the size of Zackenbergdalen (50 km^2).

Table 4.15. Records of lemming winter nests and active summer burrows during the transects Zackenberg – Store Sødal (75 km) and Daneborg (DNB) – Zackenberg (25 km). Records are made within 3 m on each side of the track by each of the two persons walking the transect, giving total lengths of 150 km and 50 km, respectively.

Section	Winter nests		Summer burrows	
	Number of records	No./km	Number of records	No./km
Lower St. Sødal				
1996	1	0.011	1	0.011
1997	8	0.089	9	0.100
1998	8	0.089	0	0
Upper St. Sødal				
1996	3	0.050	1	0.017
1997	3	0.050	0	0
1998	13	0.217	6	0.100
DNB - Zackenberg				
1997	22	0.440	21	0.420
1998	17	0.340	1	0.020

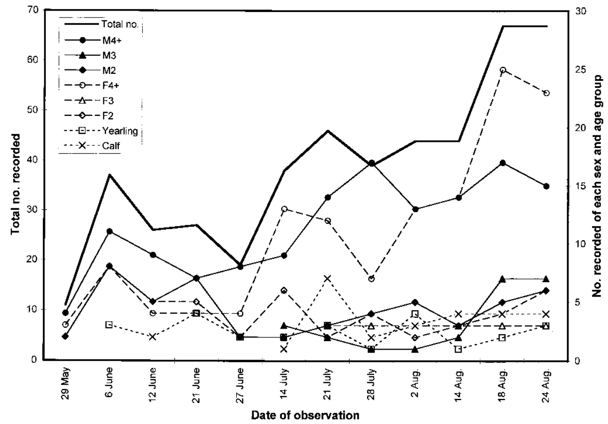


Fig. 4.17. Sex distribution within age groups of the local muskox population inside the census area in Zackenbergdalen recorded on the weekly census. Total = sum of the eight underlying graphs (left axis), M/F 4+ = males/females 4 years old or more, M/F 3 and 2 = three and two year old males/females, Yearl. = one year old males/females, Calf = calves born in 1998.

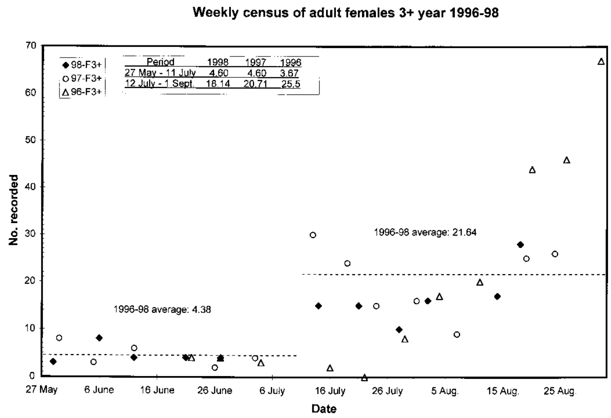


Fig. 4.18. Total numbers of females three years old or more (3+) recorded within the 39.1 km^2 census area from 1996 to 1998. The 3+ category is chosen to illustrate the reproductive pool of females. The three year average of number of 3+ females within the two seasons (27 May – 11 July and 12 July – 1 September) are shown with a punctured line. See also Table 4.17-19.

The lemming peak was also visible in upper Store Sødal, while the recorded number of nests and burrows in lower Store Sødal and on the Daneborg – Zackenberg transect did not show an increase as compared to 1997 (see Table 4.15). Despite the decrease of winter nests recorded between Daneborg and Zackenberg, the number was still higher here than in the inland areas.

Within the 2.5 km^2 lemming census area a total of 29 fixed sites were checked for casts from long-tailed skua and snowy owl and scats from Arctic fox and ermine. Due to the absence of snowy owls in the area in 1998, the nine casts found in 1998 must belong to the period from mid August 1997 and until the snowy owls left the area for their winter quarter. The figures for long-tailed skua, fox and ermine all show a clear increase in numbers as compared to 1997 (Table 4.16).

Table 4.16. Numbers of casts and scats collected from 29 fixed sites within the 2.5 km² lemming census area. The samples represent the period from mid August 1997 to mid August 1998.

Year	Skua casts	Owl casts	Fox scats	Ermine scats
1997	44	0	10	1
1998	69	9	46	3

4.4.2 Muskox population biology

An extensive description of the monitoring elements and underlying parameters concerning distribution, phenology and structure of the local muskox population at Zackenberg is given in section 4.4.2 in Meltofte and Thing (1997).

Muskox population dynamics and structure

Distribution, size, sex and age composition of herds (four categories from calf up to 4+ year) within the 39.1 km² census area were recorded weekly throughout the field season June – August. Fig. 4.17 shows that the number of yearlings remained constant during the three month of observation, which means that the increase of adult females (F4+) between 27 June and 14 July was due to immigration of cows with new-born calves and cows without yearlings or new-born calves. This scenario seems to cover a large annual variation as seen in Fig. 4.18 and Table 4.17. If muskox cows normally breed every second year, it is remarkable that the ratio of cows potentially in heat has remained the same over the three years 1996-1998 (Table 4.17) despite different average number of females, *i.e.* 26, 21 and 18, respectively.

In addition, distribution and size of herds were recorded daily from an elevated point at the station between 19.30 and 22.00 hrs covering about 100 km². These daily observations were divided into herds occurring inside the census area (ISCAR, Fig. 4.19) and those occurring outside the census area (OSCAR, Fig. 4.20). Comparing Figs 4.19 and 4.20 it appears that the central part of Zackenbergdalen (the 39.1 km² census area) is used more intensively towards the culmination of the rutting season in the first part of September. It also appears that fewer muskoxen used Zackenbergdalen (ISCAR) in 1998 than in the previous two years.

Table 4.17. Average number per age group of muskoxen recorded at the weekly censuses inside the census area in Zackenbergdalen. The two periods are defined subjectively from Fig. 4.18. Data for adult females were generated from the assumption that the first year of reproduction is in an age of four (mating at an age of three), that a cow normally only gives birth to one calf, and that a cow normally only breeds every second year.

Age and period	1996	1997	1998
Calves			
27 May - 11 July	2.33	1.00	0.40
12 July - 1 Sept.	14.25	8.00	3.57
Yearlings			
27 May - 11 July	3.33	3.80	2.20
12 July - 1 Sept.	17.50	6.71	2.29
Adult females 3+ year without calves			
27 May - 11 July	1.33	4.00	4.20
12 July - 1 Sept.	13.14	12.71	14.57

Table 4.18. Muskox densities (individuals/km²) in Store Sødal (91.8 km²), the census area in Zackenbergdalen (39.1 km²) and in the coastal region between Daneborg and Zackenberg (37.4 km²) in mid July 1996, 1997 and 1998, respectively. Faeces index was calculated as number of winter and summer piles of pellets recorded per km walked, i.e. Store Sødal: number/(2 × 75 km) and Daneborg – Zackenberg: number/(2 × 25 km).

Year	Store Sødal	Zackenbergdalen	DNB - Zackenberg
1996	0.37	0.35	-
1997	0.39	1.61	0.13
1998	0.62	1.18	0.86
Winter piles 97/98	1.59 / 1.55	-	4.90 / 1.14
Summer piles 97/98	0.49 / 0.39	-	0.82 / 0.68

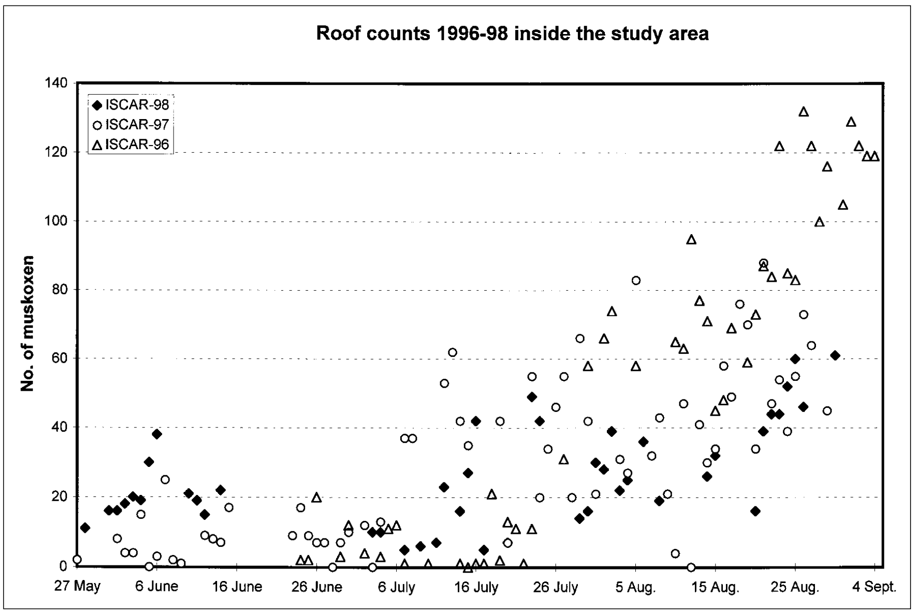
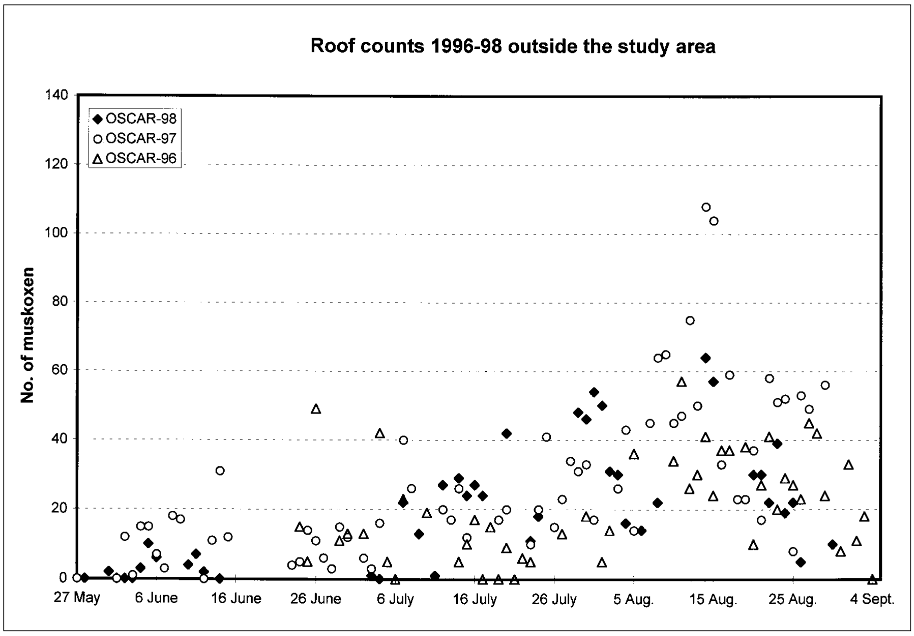


Fig. 4.19. Daily counts from the station of muskoxen inside the census area during the three month field seasons of 1996, 1997 and 1998, respectively. ISCAR = Inside Census Area.

Fig. 4.20. Daily counts from the station of muskoxen outside the census area during the three month field seasons of 1996, 1997 and 1998, respectively. OSCAR = Outside Census Area.



Distribution and social environment of muskoxen

The two transects (through the adjacent valley Store Sødal and along the coastal area from Daneborg to Zackenberg) were walked in July only. The 1998 transects showed a more even distribution of muskoxen in July among the three areas, than was the case in the previous two years (Table 4.18). While the pellet indexes in Store Sødal were close to those found in 1997, a dramatic drop in the winter index was seen from 1997 to 1998 on the Daneborg – Zackenberg transect. An explanation could be that the winter of 1997/98 was more rich in snow than 1996/97 and that accumulation of snow was more pronounced in the coastal area than in the inland and hence made the coastal area less favourable for muskox as winter feeding ground.

Based on the weekly census from June to August the demography of the population is calculated (Table 4.19). It appears that the ratio of new-born calves was lower than in 1997 and only half the ratio in 1996. The flux of animals between Zackenbergdalen and other areas on Wollaston Forland explains how a cohort can increase in number from one year to the next as seen in Table 4.19. Although there is an unknown flux of muskoxen in and out of the census area the figures in Table 4.19 indicate that the winter survival of calves born in 1997 was low. This may, as with the low ratio of new-born calves, be related to the larger amounts of snow in the 1997/98 winter and may be even to presence of ice horizons in the snow as indicated by the occurrence of above zero temperatures during the 1997-1998 winter (see section 3.1).

The habitat use in relation to altitude shows pronounced annual variations especially in June (Fig. 4.21), which may reflect variations in snow patterns and plant phenology. As in 1997, no significant sexual differences were found in the altitude distribution. Altitudes from 0 to 100 m a.s.l. and between 200 and 300 m a.s.l. seem to be the most important habitats holding 65-85 % of the muskoxen recorded within the entire altitude range between 0 and 700 m a.s.l. used by muskoxen.

Fresh muskox carcasses

Only one fresh carcass was found inside the census area, an old male (ID#: 98-6) with an estimated age of 12-15 year. The second and last recorded fresh carcass in 1998 was of an old bull found on the snow at the west end of upper Store Sødal on 10 June.

Table 4.19. Sex and age distribution (%) of the muskox population in Zackenbergdalen as it appeared from all weekly censuses in the period 1996-98. Sex of calves could not be assessed in the field but is assumed to be 1:1. In 1997, no separation was made between age class 3 year and 4+ year, so figures have been interpolated from the average proportion of the 3 year age class compared with the 4+ year age class for both 1996 and 1998.

	F-calf	M-calf	F1	M1	F2	M2	F3	M3	F4+	M4+
1996	9	9	12	12	2	8	5	1	27	15
1997	6.5	6.5	6	8	9	9	6.3	2,9	28.7	17.1
1998	4.3	4.3	2.5	2.5	8.4	9.2	5.3	6.1	30.3	27

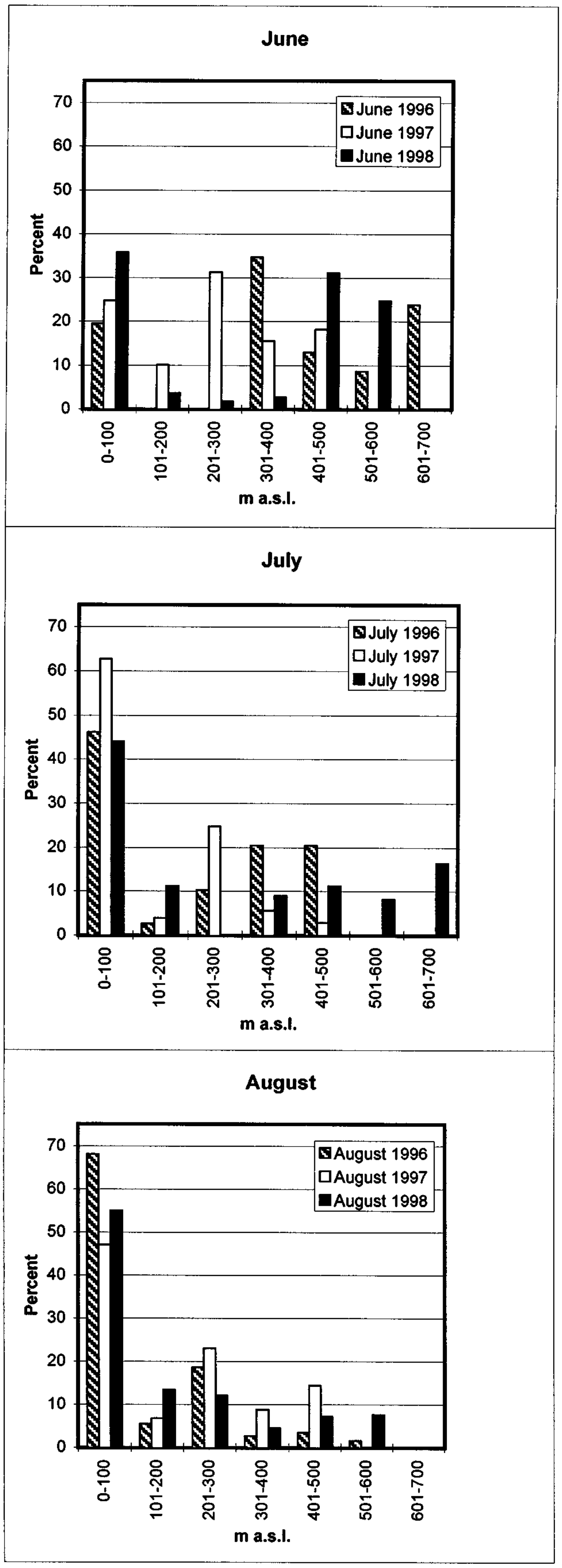


Fig. 4.21. Altitudinal distribution of two years old and older muskoxen within the 39.1 km² census area recorded on the weekly censuses during June – August 1996, 1997 and 1998, respectively. The age group ≥2 years is chosen to illustrate number of animals that may be individually distributed. Yearlings and calves follow the cow.

4.4.3 Arctic fox dens

Only one den (no. 3) was used for breeding in 1998, housing one adult female with 5 pups, all white phase. The first pup was seen on 5 July. On 6 July all five pups were seen together with the female and another adult white fox about 500 m away, which the female gave alarm calls against. Last time all five pups were seen together was on 20 July. Eight days later only three pups were seen together with the adult female. On 30 July, two pups were seen. Only one pup was seen 31 July and 2 August. On 10 August the den was empty.

Den no. 4 is situated only 50 meter from no. 3 and was used as playground by the pups in den no. 3. Den no. 1 only showed some signs of activity in the beginning of June, and so did den no. 5 in mid July.

No signs of foxes were found at den no. 2, but fresh wolf tracks were recorded at the den on 27 May. In early July, the den housed at least one adult ermine with six juveniles. The first observation of ermines was made on 5 July, when one adult with two juveniles were seen, and all seven ermines were seen on 7 July. The hunting efficiency of the adult ermine was clearly demonstrated during almost one hour of continuous observation giving four succesful hunts. Short hunting trips lasting less than 15 minutes resulted each time in catches of a lemming that was brought back to the den and left there for the young. Immediately afterwards, the adult disappeared for another hunt. One hunt lasted only 4 minutes including departure from the nest, location of the lemming 500 meters from the nest, killing and returning with the prey.

4.4.4 Line transect

The transect through Store Sødal was walked 16-18 July and the one from Daneborg to Zackenberg on 25 July (Table 4.20) (see also section 4.3.6 for bird observations). In total, 57 muskoxen were recorded in Store Sødal compared to 36 in 1997 and 40 in 1996. Four calves were recorded giving a calf ratio of 7 %. The number of muskox winter and summer faeces piles has been discussed in section 4.4.2. Besides muskox, ermine was the only other mammal species recorded. On the south side of upper Store Sødal one adult and four juveniles were seen.

As in 1997, fresh tracks of wolf and fox were recorded in Store Sødal.

4.4.5 Other observations

Collared lemming *Dicrostonyx groenlandicus*

Lemmings were recorded taken by fox, ermine, glaucous gull and long-tailed skua. In total, 161 lemmings were recorded during the entire season. Of these, 129 (80.6 %) were seen during snow melt in June. At least three families of lemmings were

Table 4.20. Results from the 75 km line transect through Store Sødal, 16-18 July, and the 25 km line transect from Daneborg (DNB) to Zackenberg on 25 July, respectively. Faecal piles of muskoxen are recorded by two persons, giving a transect length of 50 km per transect segment (lower Store Sødal (north and south side) and upper Store Sødal, respectively). Each pile of faeces within 1 metre to each side of the track was recorded. M = male, F = female, 4+ = 4 years or more. Lemming winter nests and summer burrows are censussed three metres to each side of the transect.

Observations		Lower St. Sødal North side	Lower St. Sødal South side	Upper St. Sødal	DNB - Zack
Muskox	M4+	6		1	3
	M3	0		4	1
	M2	2		1	2
	F4+	5		9	18
	F3	0		2	3
	F2	2		1	2
	M1	1		1	1
	F1	1		1	1
	Unsp. yearling			4	1
	Calves	2		2	
	Unsp. muskoxen			12	
	Winter piles	86	47	100	57
	Summer piles	14	24	20	34
Arctic wolf			track	track	
Arctic fox		tracks			
Ermine				5	
Lemming	Winter nests	7	1	13	17
	Summer burrows			6	1

seen at the station area, one of them having four juveniles born in mid July.

Polar bear *Ursus maritimus*

On 6 July, a 3-4 years old polar bear passed the lowland of Zackenbergdalen. It had been seen on the fjord ice off Daneborg a few hours earlier, and it passed the station at a distance of 500 m on its way back to the fjord, where it disappeared over the ice in the direction of Clavering Ø and Tyrolerfjord.

Arctic wolf *Canis lupus*

A pack of four wolves was seen by a SIRIUS sledge team at Revet near inner Tyrolerfjord on 26 May. They visited Zackenbergdalen including four of the fox dens during the 'night' of 3-4 June without being seen. On 17 June, a single wolf was seen in Morænebakkerne, and on 25 June, a pack of three wolves was seen in Oksebakkerne on the opposite side of Zackenbergelven.

Arctic fox *Alopex lagopus*

Tracks in the snow were often seen in June. In total, 38 records of foxes were made in Zackenbergdalen and five in Upper Store Sødal during the entire season. The minimum number of individuals recorded were two adults (one blue, one white) and one blue juvenile in Upper Store Sødal, one white adult west of Zackenbergelven, besides three adults (one blue, two white) and six juveniles (one blue and five white) east of Zackenbergelven. The two blue foxes (an adult and a juvenile) were seen independently of each other on 7 June and 29 July, respectively, near the station. The blue juvenile may likely have come from an unknown den east of Grænseelv. During the water bird censuses in August, a white adult was seen several times foraging in the two deltas at low tide.

Arctic hare *Lepus arcticus*

Arctic hares are most active during night and spend most of their daytime resting close to rocks or big stones. Due to several night trips to the top of Aucellabjerg, Arctic hares were recorded in higher numbers in 1998 than during the previous years. In total, 22 records were made on Aucellabjerg (min. 15 individuals), 7 records on Zackenberg (min. 2 individuals) and 3 records in upper Store Sødal (min. 3 individuals).

Ermine *Mustela erminea*

As mentioned earlier, ermines were abundant due to good breeding conditions in 1997 (see section 4.4.1). A minimum of three ermine dens with juveniles was encountered in Zackenbergdalen, one west of Zackenbergelven (min. 3 juv.), one near Østerport (min. 2 juv.) and one in fox den no. 2 (min. 6 juv., see section 4.4.3.). Furthermore, a den with a minimum of 5 juveniles was found in Upper Store Sødal. In total, a minimum of 13-14 adults and 17 juveniles were recorded.

Walrus *Odobenus rosmarus*

Two visits were made to Sandøen on 25 July and 25 August, respectively, to mount and take down a digital camera overlooking the beach, where the walruses haul out. The camera was situated in a weatherproof fibre glass box on a 170 cm high tripod placed 1 m above sea level. On 25 July, 28 individuals were present, of which four were in the water along the shore, the others hauled out in one group on the beach. None were seen on 25 August. Four photos were taken daily on fixed intervals giving a total of 126 pictures. The pictures are now being analysed by Erik W. Born and Thomas B. Berg.

Seals

During the daily muskox counts from the station from 28 May until the fjord ice broke up in the inner part of Young Sund in mid July, the occurrence of seals on the fjord ice was recorded. A total of 141 seals was recorded on 19 days of observation, giving an average of 7.4 (range: 0-18). This is 0.8 less than recorded in 1996 and 1997. In both 1996 and 1997, the maximum number of seals on the ice was 21. In addition, five bearded seals, two ringed seals and three unspecified seals were recorded in Young Sund on boat trips or from the shore.

5 Research projects

5.1 Carbon cycling and trace gas exchange in Zackenbergdalen

Torben Røjle Christensen, Anna Joabsson, Lotte Illeris, Daniel Johansson, Anders Michelsen and Svend Jonasson

In 1998 we established a new set of experiments most of them connected to a project called Biospheric Controls on Trace Gas Fluxes in Northern Wetlands (CONGAS) funded by the European Community for the period 1998-2000. Partly building on experiences and results from our previous Zackenberg studies (Christensen *et al.* 1998, submitted; Friborg *et al.* submitted; Nordstrøm *et al.* submitted; Søgaard *et al.* submitted; Meltofte and Thing 1997; Meltofte and Rasch 1998) we carried out measurements and experimental manipulations in the following habitats: *Cassiope* heath near the meteorological station, at the drained fen site (Tørvekæret) and on a dry heath near the station.

The overall subject of study is the environmental and climatic controls on the patterns of plant production and ecosystem respiration in tundra habitats. New experiments established in 1998 emphasize linkages between the exchanges of CO_2 and CH_4 in heath and fen ecosystems. In the CONGAS framework, Zackenberg is part of a transect of experimental sites ranging from central Siberia over N Finland, N Sweden, Iceland and through to NE Greenland. At Zackenberg we are currently operating with two PhD projects. Anna Joabsson (Lund University) is concentrating on the effects of vascular plant production on CH_4 formation and transport processes in wet tundra ecosystems. The main experiment involves shading the vegetation in order to reduce the net carbon flow while investigating the subsequent effects on processes leading to net CH_4 emission. Lotte Illeris (University of Copenhagen) is working on the controls on photosynthesis and respiration in mesic and dry tundra habitats. Lotte's investigations are focussing on experimental manipulations of the soil water balance.

As mentioned above, most of the study components on which we worked in 1998 were initiated this year and are expected to run for at least three field seasons. Except for some results from old sites reporting of the 1998 activities is therefore limited to an outline of the experiments initiated.

5.1.1 The fen experiments

Anna Joabsson and Torben Røjle Christensen

With the shading experiments in the fen area (Fig. 5.1) we are investigating the linkage between vascular plant production and net CH_4 emission. We hypothesize that a major fraction of the substrate utilized by CH_4 producing bacteria emanates from carbon that has been recently fixed by vascular plants. Easily degradable carbon becomes available for CH_4 production by plant derived "rhizodeposition", where root turnover and exudation of *e.g.* organic acids make up a pool of substrates. Based on the idea of a quantitative or qualitative dependence of substrate carbon sequestration from the plants upon primary production, the shading treatment in "Rylekæret" aims at lowering the vascular plant photosynthetic rate in order to investigate effects on net CH_4 emission. The shading "tents" were put up in two different habitat types, defined as being mesic and wet. Along with measurements of CH_4 and CO_2 flux, other environmental parameters, *e.g.* photosynthetic active radiation (PAR) and temperature at different depths, were being logged throughout the season.

In response to a 50-60 % reduction of PAR in the shaded plots (Fig. 5.2), net ecosystem production (NEP) decreased and was maintained at a lower level throughout the growing season in both the mesic and the wet habitats (Fig. 5.3). No treatment effects on vascular plant species composition or shoot density could be seen after this first season of the experiment. Shading can therefore be considered an efficient tool to manipulate NEP while keeping other environmental factors as constant as possible. The field experiments will be maintained for two additional seasons, 1999 and 2000.

5.1.2 The heath experiments

Lotte Illeris, Anders Michelsen, Torben Røjle Christensen

Large areas in the Arctic contain dry tundra which makes a different contribution to the carbon fluxes than wet areas, where it has been shown that CO_2 efflux is likely to increase if the moisture level de-

Fig. 5.1. Shading experiment in »Rylekæret« (mesic habitat). Photo: Daniel Johansson.

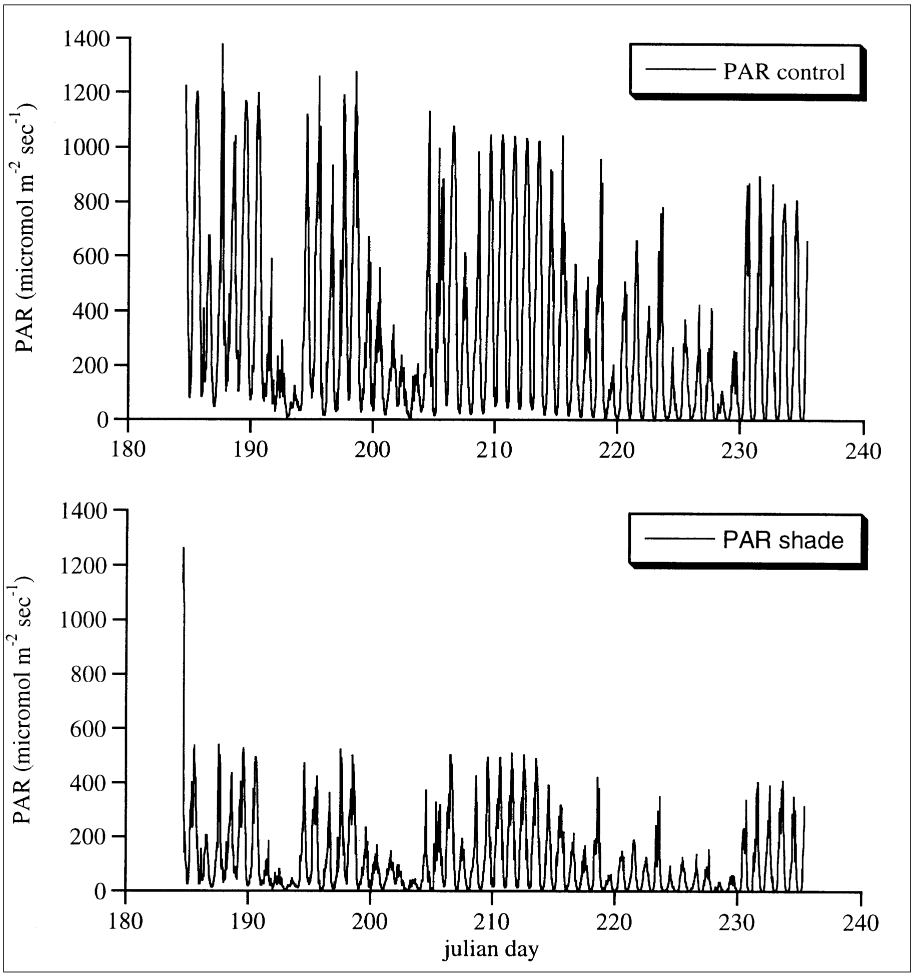


Fig. 5.2. Photosynthetic active radiation (PAR) as measured under the shading »tents« (top) and in the control plots (bottom).

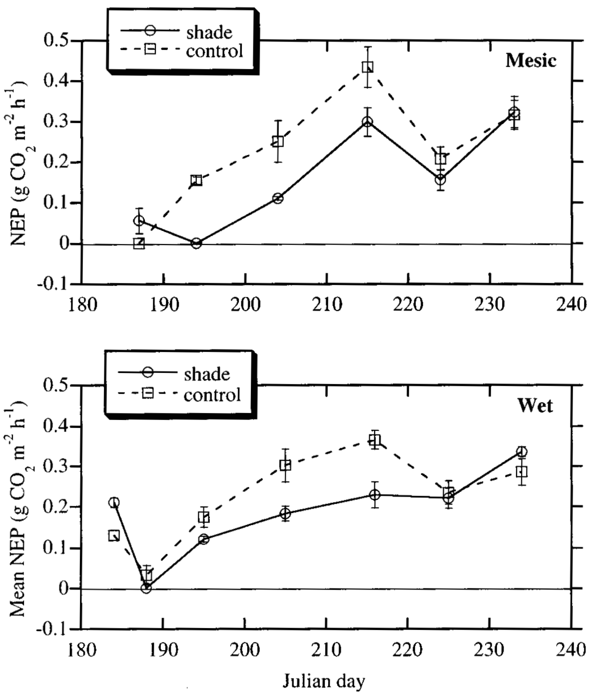


Fig. 5.3. Net ecosystem production (NEP) in shaded plots and control plots in the mesic (top) and wet (bottom) habitats.

clines under future changed climate scenarios. However, soil moisture levels below 200 % dry weight have previously been shown to limit soil microbial activity in Arctic soils. Therefore, a future soil drying may limit decomposition in dry Arctic soils, while future wetter conditions, as predicted by some climate models, may enhance decomposition of dry organic soils.

The purpose of this experimental study, which was started in the summer of 1998 and will continue in 1999 at a *Cassiope* heath, is to estimate the importance of soil moisture for the ecosystem carbon balance in High Arctic dry heath. A watering experiment with three different levels of weekly watering have been set up at the heath, and weekly measurements of ecosystem CO_2 fluxes has been conducted by a well established infra-red gas analysis system (PP-Systems). The 1998 season data are currently being processed in order to assess treatments and samples to be planned for the 1999 season.

5.1.3 The drained fen experiments

Lotte Illeris, Torben Røjle Christensen, Anders Michelsen and Svend Jonasson

A factorial experiment was undertaken in 1996 and 1997 adding nutrients and sucrose in a naturally drained fen area (Christensen *et al.* 1998; Meltofte and Thing 1997, Meltofte and Rasch 1998) with the purpose of identifying limiting factors for soil microbial activity as well as for plant performance. In 1998 no additional applications were carried out.

In order to assess reactions in the moss cover to the nutrient and sugar amendments the previous years, measurements of relative vegetation index (RVI) was carried out in each of the plots during the early part of July 1998. The RVI of the phosphorous (P) and the phosphorous plus nitrogen (NP) treated plots was higher than in the other plots (Fig. 5.4). That is, the growth of mosses was most pronounced in plots treated with P, and hence moss growth appeared to be strongly P limited in Tørvekæret. At the same time, the moss growth was reduced in the plots treated with sugar (lower RVI) compared to the control plots, indicating that other factors were limiting the moss growth in these plots.

Taking into consideration that the microbial activity (measured as CO_2 efflux from the soil) did not respond to the nutrient amendments (Christensen *et al.* 1998) but increased strongly after the sugar additions (Meltofte and Thing 1997), the soil microbes seemed to immobilise soil inorganic nutrients in the plots treated with sugar and hence, limit the possibilities of further growth of the moss layer. This suggested competition for nutrients between plants and microbes in the Arctic is in line with previous experimental results from sub-Arctic ecosystems (Jonasson *et al.* 1996; Schmidt *et al.* 1997) as well as patterns in ^{15}N abundance observed in plants of various life forms in sub-Arctic and Arctic areas including Zackenberg (Michelsen *et al.* 1998).

Analyses of soil extracts from 1996, 1997 and 1998 of inorganic nitrogen and phosphorus, dissolved organic nitrogen and carbon, microbial carbon, nitrogen and phosphorus and of the nitrogen and chlorophyll content of the mosses are currently undertaken in order to investigate this hypothesis further, and to determine whether the activity (CO_2 release) and biomass of the soil microbes is limited by carbon or nutrient lability. These analyses are almost completed.

5.1.4 Dry *Kobresia-Dryas-Salix arctica* heath experiments

Anders Michelsen and Lotte Illeris

The complete factorial experiment with nitrogen, phosphorus and water additions to a dry *Kobresia-Dryas-Salix arctica* heath initiated in 1996 and continued in 1997 (section 5.1.5 in Meltofte and Rasch 1998) was maintained in 1998. During the summer of 1998 weekly water additions were performed whereas no nutrients were added to the plots. No sampling was performed in 1998 as this is planned for the 1999 summer season in order to obtain longer term data on nutrient partitioning between plants and soil microbes in a dry arctic heath system.

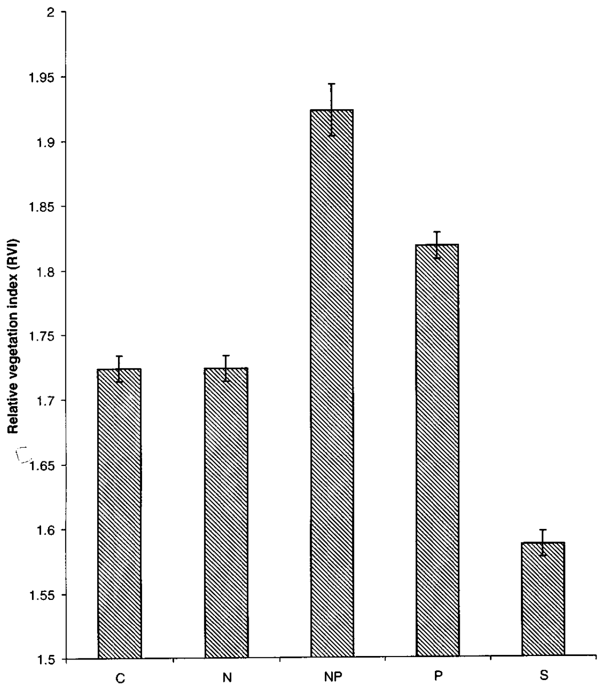


Fig. 5.4. The relative vegetation index (RVI), i.e. the greenness, of the surface in the drained fen experimental treatments (control, nitrogen, nitrogen + phosphorous, phosphorous and sucrose). The error bars represents standard error of the means.

5.2 Micro meteorological measurements of carbon dioxide

Åsa Rennermalm

The prediction saying that global warming will alter the carbon balance in the sensitive High Arctic ecosystems has led to increased interest in the carbon dioxide balance of these areas. Both measurements and modelling are needed to gain a better understanding. Models are useful to improve our knowledge about the carbon dioxide exchange processes. Measurements are used to quantify the actual fluxes and to verify the models.

In this study, carbon dioxide fluxes have been measured using the eddy correlation technique. Water vapour and other standard meteorological parameters, such as air temperature and radiation have been measured in order to be related to the carbon dioxide flux. The applied eddy correlation system consists of a 3D sonic anemometer (Gill Solent, UK) for wind speed recording and an infrared gas analyser (Li-6262, LICOR, USA) for measurement of water vapour and carbon dioxide concentration. This instrumentation to determine fluxes has become a standard among scientist working with fluxes. The resulting data represent fluxes at ecosystem level.

In the Zackenberg area, the eddy correlation system was installed in the fen Rylekærene. This area represents one of the most productive (in terms of biomass) areas in Zackenbergdalen. Previous stud-

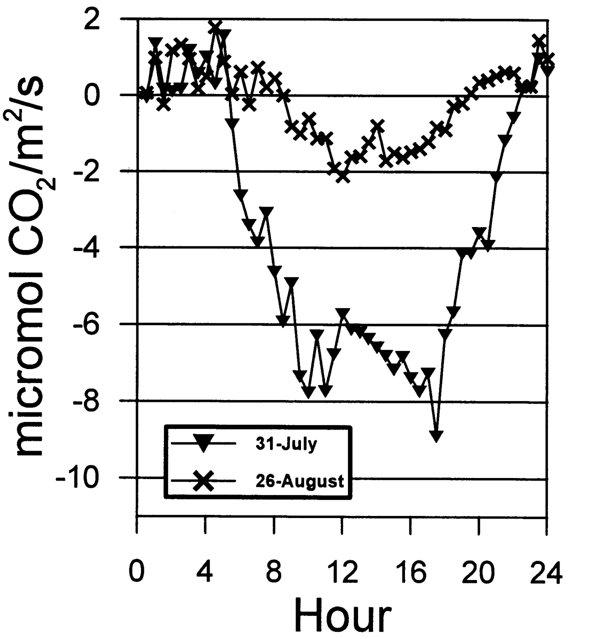


Fig. 5.5. Carbon dioxide flux from Rylekærene on the 31 July and the 26 August. Negative values represent uptake of carbon dioxide while positive values represent release.

ies in Rylekærene show that during the entire growth season the sink strength, *i.e* the uptake of carbon dioxide, were -96.3 g C/m^2 in 1996 and -48.9 g C/m^2 in 1997 (negative sign means uptake of carbon dioxide by the plants). These values are large compared with values from other Arctic and Boreal wetlands, and they indicate a great variability from year to year. The data illustrate the importance of quantifying fluxes and the governing variables, so that normal variations in climate can be separated from unusual perturbations of the climate that could be attributed to 'Climate Change'.

The daily variation of the carbon dioxide flux from Rylekærene on two different occasions in the growing season are presented in Fig. 5.5. On both occasions the fen acted as a sink of carbon dioxide. At the peak of the growing season (31 July) the uptake of carbon dioxide at midday was three to six times higher than at the end of the growing season (26 August). In the period between 31 July and 26 August, photosynthetic active radiation and leaf area index decreased and thereby affected the uptake in a negative way. This is further illustrated when the net ecosystem exchanges from the two days are compared (Fig. 5.6). From the 31 July to the 26 August, the sink strength of the fen decreases, from -309 to -18 mmol $CO_2/m^2/d$. This is mainly due to lower daytime net assimilation, but also to a rise in nighttime respiration from 15 to 28 mmol $CO_2/m^2/d$. This trend will probably continue and cause a shift in the balance between respiration and assimilation which eventually will turn Rylekærene in to a source area of carbon dioxide in the late part of the growing season and in the winter. The overall net assimilation of carbon dioxide in the summertime will therefore be more or less balanced by the net respiration during the rest of the year.

5.3 Atmospheric fluxes of CO_2 and CH_4 from lakes in Zackenbergdalen

Nanna Høegh

The overall objective of this project is to estimate the effects of local and global influences on the microbial carbon dynamics in selected terrestrial and coastal ecosystems in Greenland. Emphasis is placed on the methane and carbon dioxide dynamics in these ecosystems. The changes caused by the antropogenous greenhouse effect are expected to be greater and occur relatively faster at higher latitudes. This in combination with the fragility and slow recovery of Arctic ecosystems indicates that global change will have a particularly strong impact in the Arctic. Since the Arctic is already contributing to the global carbon balance by sequestering atmospheric carbon in its soils, any response to climate change could result in feedbacks of global significance. The estimates in literature of the carbon balance in the Arctic are for terrestrial ecosystems only, but additional carbon loss from the aquatic environment might be important.

The objective of this study is to investigate the carbon loss from aquatic ecosystems in the Zackenberg area to the atmosphere. Chamber measurements of the fluxes of CO_2 and CH_4 was carried out from seven different lakes in Morænebakkerne and from the new and the old Zackenbergelven deltas. The measurements were conducted over a five week period and the first measurements were made while the lakes were still partly covered by ice. The data is now being processed and preliminary results indicate that a substantial amount of carbon is lost to the atmosphere from especially three lakes (Table

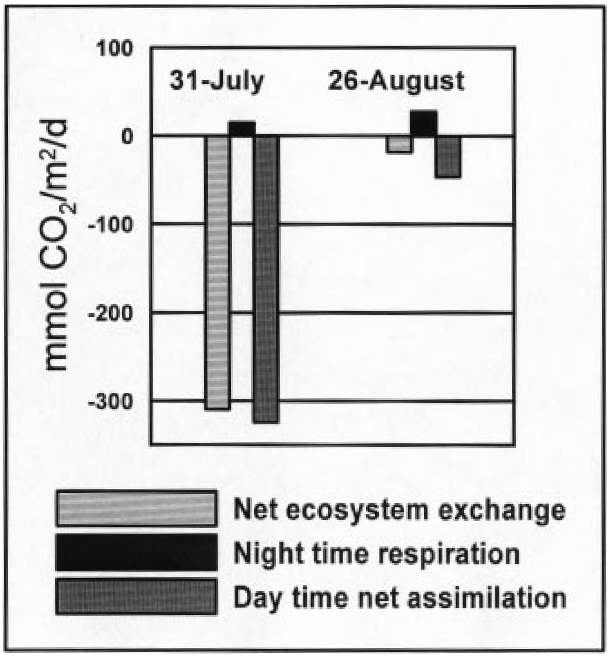


Fig. 5.6. Carbon balance for Rylekærene on the 31 July and the 26 August. The net ecosystem exchange is made up by day time net sink of carbon dioxide and night-time source.

5.1). Seasonal trends include a buildup of CH_4 under the ice during winter and an increased CH_4 flux in the beginning of August.

A special emphasis was placed on investigating the complex interactions between methane producing and methane oxidizing microorganisms in the sediments and water column. The role of methane oxidation as a biological filter in the sediments was investigated using the inhibitor DME (Dimethyl Ether). Radiolabled methane ($^{14}CH_4$) was used to characterize *in situ* methane oxidation rates in the water column. The methane production in the sediments ranged from 0 mg CH_4/m^2/day in Hjerte Sø to 34.4 ± 19.0 mg CH_4/m^2/day in Træsko Sø. In Hjerte Sø up to 100 % of methane produced in the sediments was oxidized. The methane production in the sediments in Vesterport Sø was associated with bubbling events (Fig. 5.7). *In situ* oxidation rates in the water column are being processed and the results will be available in 1999. Further measurements next field season will enable establishment of a carbon budget for the whole growing season. It will also be investigated how the microorganisms involved in the methane cycle respond to simulations of climate changes, and experimental manipulations will be carried out using sediment and water samples collected at the different sites.

The carbon fluxes from the deltas were somewhat different from those measured in the lakes. In the new Zackenbergelven delta no measurable fluxes were observed. In the old Zackenbergelven delta the methane fluxes from the water surface decreased from 0.7 mg CH_4/m^2/day in the beginning of July to 0.3 mg CH_4/m^2/day in August. The methane fluxes from the sediments increased from 0.6 ± 0.3 to 12.6 ± 12.5 mg CH_4/m^2/day over the same period with a noticeable decrease during low tides when the sediment is in direct contact with the atmosphere. These results indicate that a substantial amount of methane is being oxidized in the water column.

Table 5.1. Methane fluxes in lakes in Morænebakkerne. The value for Langemand Sø on 13 July was taken above a hole in the ice.

Lake	Date	Depth m	Temp. °C	CH_4 flux mg/m²/d
Thors Hammer	27/7	3.4	9.5	0
	1/8		13	0
Hjerte	12/7	6.7	1.3	0.5
	26/7		8.4	0
	1/8		12.5	0.2
Langemand	13/7	6.1	0	1.2
	2/8		9.3	0.3
Sommerfugle	8/7	1.8	5.9	0
	25/7		10.3	6.1
Træsko	18/7	2.7	3.8	34.8
	26/7		9.1	6.2
	1/8		12.5	70.4
Trap	18/7	1.5	1.1	0.9
	25/7		6.3	127.3
Vesterport	8/7	0.7	4.3	3.6
	25/7		11.3	270.2
	2/8		12	685.4

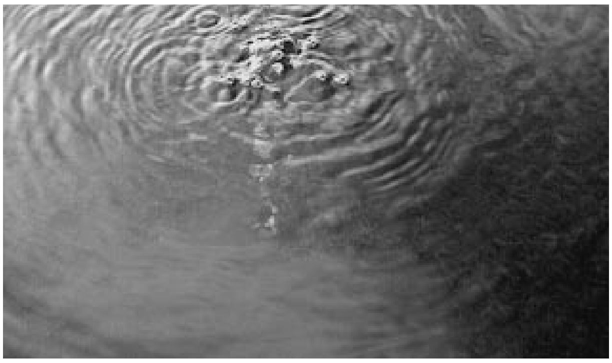


Fig. 5.7. Ebullition of methane produced in the sediments in Vesterport Sø (2 August 1998). Photo: Nanna Høegh.

5.4 Lake Investigations at Zackenberg

Erik Jeppesen, Kirsten Christoffersen, Frank Landkildehus, Nanette Hammeken Arboe, Frank Riget and Martin Søndergaard

The purpose of the Zackenberg lake investigations in 1998 was threefold:

1. To develop a monitoring programme to be incorporated into the BioBasis programme.
2. To increase our understanding of the biological interactions in lakes in northeastern Greenland.
3. To describe the climate conditioned changes in the lakes on the basis of analyses of biological remains in the lake sediment

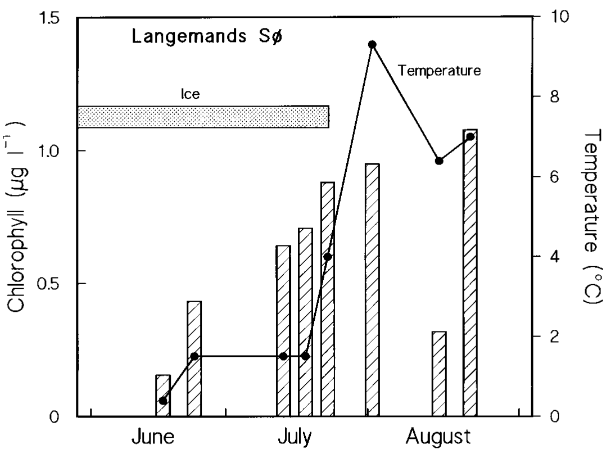


Fig. 5.8. Seasonal variation in chlorophyll a (columns) and temperature (•) in Lake Langemands Sø in 1998. The duration of the ice cover period is also shown.

5.4.1 Monitoring programme for lakes in Morænebakkerne

For the purpose of establishing a monitoring programme, measurements of a number of physico-chemical and biological variables were undertaken from mid-June to the end of August in six lakes in Morænebakkerne (of which three were without fish). In June, the lakes were totally covered with ice, and sampling thus required boring of holes through the ice. In July, when the lakes were only partly ice-covered, samples were initially taken from the ice edge and later from a boat. The results showed considerable seasonal variations in most variables, variations that closely followed the changes in temperature (illustrated by Fig. 5.8 showing changes in chlorophyll *a*). Within the last few years significant differences have occurred in temperature and the duration of the ice coverage period both on a seasonal and on a year-to-year basis, and for monitoring purposes more frequent measurements during summer therefore seem necessary if a reliable picture of the state of the lake ecosystem is to be obtained. Therefore, we recommend that samples are taken fortnightly from mid July to mid August. The 1997 investigations showed great differences in the biological community of lakes with Arctic char compared with lakes without fish (Jeppesen *et al.*, 1997). We therefore recommend that sampling as a minimum is conducted in one lake with and one lake without fish (*e.g.* Sommerfuglesø and Langemands Sø). We suggest that a number of physico- chemical variables are measured every year, that phytoplankton and zooplankton are also determined every year, but at variable frequencies, that fish investigations are undertaken once every 6 year and that palaeoecological investigations of surface sediment are carried out once every twelfth year.

5.4.2 Investigations in lakes in Store Sødal

In 1998, investigations comprising determination of fish stock size, zooplankton, phytoplankton, micro-organisms and a number of physico-chemical variables were made in 15 lakes in Store Sødal (Fig. 5.9). In addition, samples for determination of stable isotopes ($\delta\ ^{15}N$ and $\delta\ ^{13}C$) were taken that may provide information on the food choice of each individual organism. The $\delta\ ^{13}C$ relationship may reveal where the food derives from and the $\delta\ ^{15}N$ relationship may reveal the food chain level of the organism. Finally, samples of the upper 1 cm of the sediment were taken for palaeoecological investigations. The samples are currently being analysed. We also conducted experiments to elucidate the role of the tadpole shrimp, *Lepidurus arcticus*, and below some preliminary results of the fish and *Lepidurus* investigations are described by Riget *et al.* and Christoffersen *et al.*, respectively.

5.4.3 Arctic char in lakes at Zackenberg

Frank Riget, Erik Jeppesen, F. Landkildehus, Peter Gertz-Hansen and Kirsten Christoffersen

Arctic char (*Salvelinus alpinus*) has a circumpolar distribution. In Greenland, Arctic char occurs in an anadrome form and a landlocked form in rivers and lakes all around Greenland, often as the only freshwater species. Each year in spring the anadrome char migrate to fjords or coastal waters in search of food. In autumn, they go back into lakes and rivers to spawn and spend the winter. The landlocked Arctic char live their whole life in lakes or rivers, often in places where migrating behaviour is impossible because of physical barriers. The landlocked Arctic char frequently occur in two or three co-existing forms, which may differ in size, habitat use, diet, reproductive strategy, growth and endoparasitic fauna. In recent years, there has been widespread discussion about the so-called 'char problem', which is related to whether different forms of landlocked char represent separate subspecies, or whether they are different ecological forms of the same species (Nyman *et al.* 1981; Nordeng 1983).

In 1997, the Arctic char populations in lakes in Morænebakkerne were studied (Jeppesen *et al.* 1998), and in 1998 we followed up with studying lakes in Store Sødal (Fig.5.9). Survey gill nets with different mesh sizes were used. They were placed along the coast line, at the soft bottom in the deeper parts of the lakes and in the pelagic. Fish length and weight were measured, and they were classified as mature, if they would spawn the same year. From subsamples of the catch, otoliths were taken for age determination and analysis of stomach content.

Shallow lakes

If shallow lakes are defined as lakes with a maximum depth of 10 m, char populations have been investigated in a total of 27 shallow lakes. Char was present in all except one lake with a maximum depth above 3 m and absent when maximum depth was below 3 m. The absence of char in the most shallow lakes may be related to the ice thickness during winter, which is 2-2.5 m in Northeast Greenland lakes.

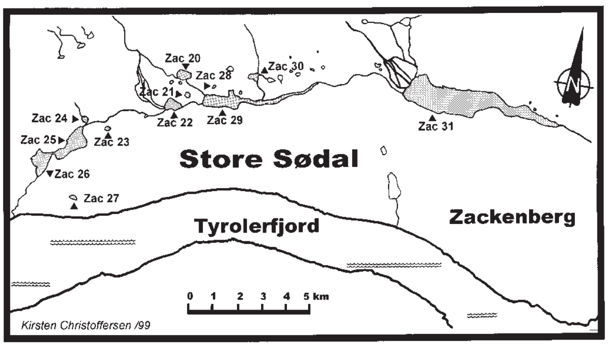


Fig. 5.9. Map of Store Sødal showing the sampling sites of the lake investigations in 1998. Based on air photos and field observations in 1998.

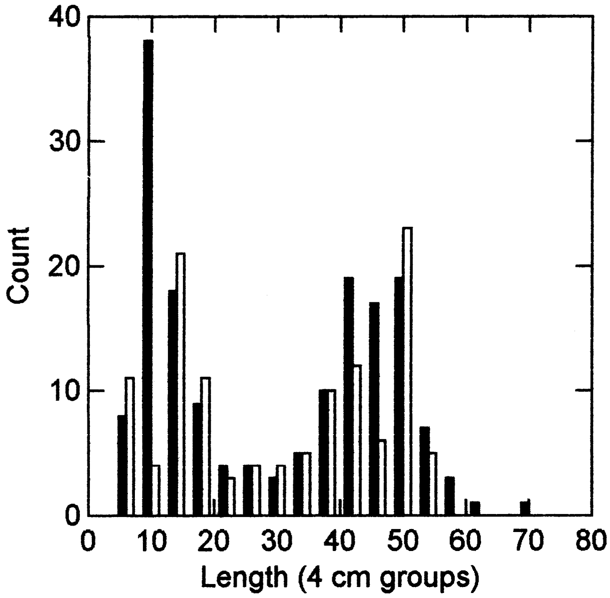


Fig. 5.10. Length distribution of the chars caught in Lake 25 and 26 (empty bars) and Lake 22 and 29 (black bars).

The Arctic char found in the shallow lakes belong to the so-called dwarf form, which has a number of feature charateristics. First the small size at maturity. Fish length ranged from 7.0 to 13.5 cm and 90 % of the caught fish had mature eggs or gonads. Second, the dwarf form is dark, it has a brown belly and still parr-marks on the back. The dwarf char is relatively old; a 13.5 cm char caught in Lake 30 was 14 years old. The main food items were chironomid larvae, pupae and newly emerged chironomid pupae. Char density measured as catch per unit effort was low in these shallow lakes compared to deeper lakes.

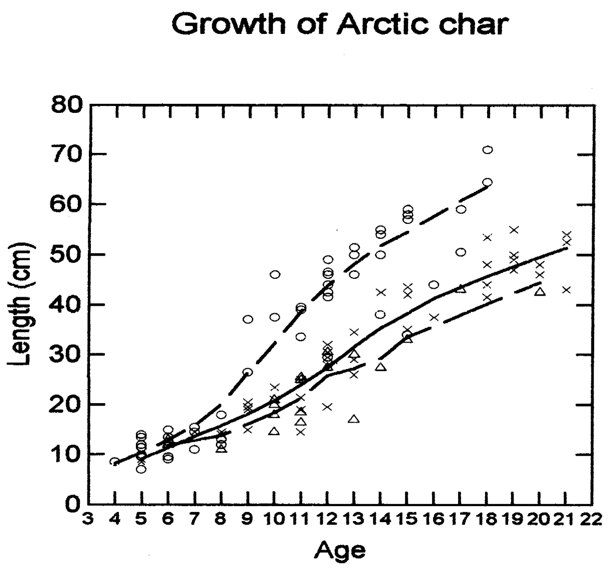


Fig. 5.11. Growth curves. Lines are drawn by LOWESS smoother. Circles and broken line: Anadrome chars from Lake 22, 29 and 31. Crosses and solid line: Landlocked chars from Lake 25 and 26. Triangles and broken line: Resident chars from Lake 22, 29 and 31.

Deeper lakes

Site 25 and 26 in Store Sødal are lakes with a maximum depth of about 20 and 14 m, respectively. The lakes are connected by a small river and accordingly fish are able to move between the lakes. The lakes hosted both the dwarf form and a bigger 'normal' form. Thus, Arctic char from about 38 to 56 cm are quite numerous in these lakes, the maximum char length observed being 57 cm (Fig. 5.10). The main food items were chironomid pupae and newly emerged pupae, and for bigger chars also smaller fish. The bimodal length distribution in these lakes follow the pattern observed in undisturbed Arctic lakes, which may be related to the occurrence of different forms of Arctic char.

Zackenbergelven

In lakes in the Zackenberg system, an anadrome population of Arctic char occurs together with char not migrating to Young Sund during summer. Anadrome char were caught in high numbers in Lake 22 and 29 (Fig. 5.10), which are important spawning and wintering lakes.

When both migrating and non-migrating char co-exist, it may be difficult to determine to which type the different fish specimens belong. However, as for bigger chars the anadrome type is lighter in colours especially on the belly, has empty stomachs, no or very little infection by *Diphyllobotrium spp.* and has relatively high growth rate. Based on these criteria, nearly all char above 30 cm belong to the anadrome population and only few were supposed to stay all the year round in the river. As for smaller char, it is impossible to determine whether they belong to the anadrome form or the resident form. However, the dwarf form was distinguished from the parr fish of anadrome char by its darker color, especially for adults.

The growth rate of anadrome populations increased markedly from age 8 or 9 compared to the resident forms and the landlocked populations (Fig. 5.11). Compared to anadrome populations in southwest and central West Greenland, the anadrome behaviour in Zackenberg begins at a considerably higher age.

5.4.4 Studies of *Lepidurus arcticus*

Kirsten Christoffersen, Nanette Hammeken Arboe, Frank Landkildehus, Erik Jeppesen and Martin Søndergaard

Observations and experimental studies during the summer of 1998 gave new insight into the wax and vane of the tadpole shrimp *Lepidurus arcticus*. This circumpolar crustacean is found in northern Greenland lakes and is common in ponds and shallow lakes with a soft bottom. They hatch from resting eggs in the bottom as soon as the ice melts and grow quickly through a number of developmental stages. During their first few weeks the larvae are frequently seen swimming in the water, but as they

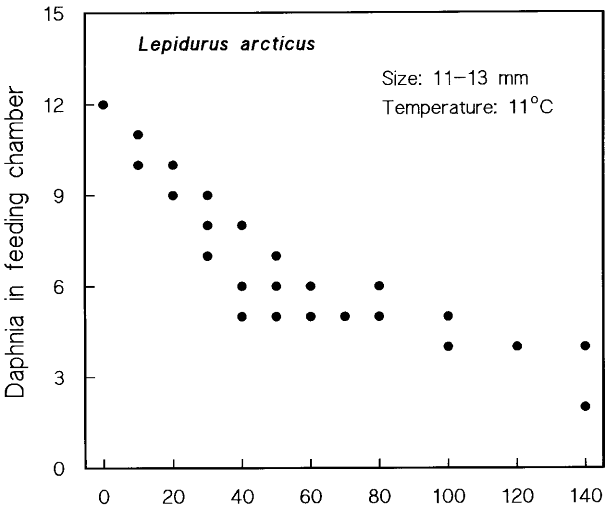


Fig. 5.12. Removal of Daphnia pulex *by* Lepidurus arcticus *over time when placed in 0.5 litre chambers. The data set represent three feeding trials with individual* Lepidurus.

grow larger they spend more time in and on the sediment. Newly hatched individuals are a few millimetres long and fully grown specimens become several centimetres long by the end of the summer.

Our survey of the biological structure in lakes around Zackenberg in 1997 revealed that *Lepidurus* is absent from or very low in number in lakes with Arctic char. *Lepidurus* is described in literature as a scavenger eating sedimented material and presumably also small organisms living in the sediment, but its quantitative role for the decomposition has not been studied yet. Several observations of the behaviour of *Lepidurus* in Gadekæret and ponds in Sydkærene in 1997 indicated that they are able to catch the crustacean *Daphnia pulex* when swimming in the water. It was therefore hypothesised that *Lepidurus* has several feeding strategies and a high food intake (judged from their high growth rate) which potentially could affect benthic and planktonic microorganisms. Two types of experiments were conducted to test this hypothesis.

A major experiment was performed in Sydkærene using enclosures to study the effects of *Lepidurus* on planktonic and benthic organisms. Nine enclosures were established in the beginning of July. Each enclosure consisted of transparent polyethylene cylinders (diameter 1.25 m, height 1 m) connected to a steel skirt anchored in the sediment. The total volume of water in each enclosure was 0.41 m^3. The density (individuals m^3) of *Lepidurus arcticus* inside the enclosures was manually adjusted at the beginning of the experiment. Replicate enclosures received 0, 10 and 30 individuals, respectively, which seems to be within the range of natural densities in the surrounding lakes and ponds. Analysis of the plankton and benthic samples collected intensively during a 6-week period will reveal whether *Lepidurus* are capable of controlling the population growth of other organisms.

Another set of experiments focused on the predation rate of *Lepidurus* on *Daphnia pulex*. Both organisms were sampled in ponds around Zackenberg and placed in small containers (0.5 litre) at ambient temperature. A number of repeated feeding experiments demonstrated that *Lepidurus* is able to catch and consume *Daphnia pulex*. They easily consume up to 6 *Daphnia pulex* per hour (Fig. 5.12). Although this estimate is clearly biased due to the manipulated conditions (increased encounter rate) it indicates that *Lepidurus* is an active and effective predator on relatively larger prey items.

5.4.5 Predator-prey interactions in the pelagic zone of shallow lakes

Nanette Hammeken Arboe

In fishless lakes *Daphnia* is the top predator. *Daphnia* predates on both phytoplankton and components from the microbial community, *i.e.* picoalgae (PA), bacteria, heterotrophic nanoflagellates (HNF) and ciliates. When planktivorous fish or the tadpole shrimp *Lepidurus arcticus* are present the predation on *Daphnia* will be high, and the lower trophic level will therefore consist of copepodes, which are more selective in their food preferences than *Daphnia*. Copepodes are mainly predating on phytoplankton and ciliates. The biological structure of the lower trophic levels will therefore depend on the presence of either *Daphnia* or copepodes. The microbial community and the phytoplankton is regulated by predation (top-down control) or the availability of nutrients (bottom-up control). In oligotrophic environments the standing stock of bacteria, PA and phytoplankton will be limited by the availability of nutrients as well as predation.

The purpose of the study was to investigate predator-prey interactions and food selection by *Daphnia pulex* and copepodes, and to investigate the role of bottom-up versus top-down control. All experiments were performed in July 1998 as short time incubations (1-2 days) using polyethylene bottles (1-2 liter) in lake nr. 19, which is situated in Sydkærene.

To investigate how three different predators influence the biological structure of the underlying trophic levels, water from lake nr. 19 was prescreened to remove large organisms and added only one type of predator before being incubated in the lake. The potential predation on phytoplankton and the microbial community were examined with either *Daphnia pulex*, copepods or *Lepidurus arcticus* as the top predator. In addition to this, experiments were carried out to study food selection by the predators. The hypothesis was that *Daphnia pulex* has a strong impact on all the components of the microbial community, that copepodes mainly have an influence on the phytoplankton community and that *Lepidurus arcticus* do not predate on either the phytoplankton or the microbial community. Preliminary results indicate that *Daphnia pulex* had a strong negative impact on the abundance of HNF whereas the copepodes had a positive impact. The presence of *Lepidurus arcticus* as the top predator did not influence the number of HNF. Sporadically counting of the bacteria samples indicates that when the number of HNF increases the number of bacteria decreases and *vice versa*. This indicates that the abundance of bacteria is regulated by the abundance of HNF which again is regulated by the presence of either *Daphnia* or copepodes. Further analyses of the samples will show if this is also true for other parts of the microbial community.

To determine the maximum ingestion rate for *Daphnia pulex* and to examine if *Daphnia* has the ability to switch to new food items, when it is enduring food limitation because of intraspecific competition, an experiment testing the effect of increasing density (0-54 individuals per liter) of *Daphnia pulex* in the same volume of lake water was set up. Analyses of the collected samples have not yet been carried out.

Another set of experiments was carried out to study the potential growth rates of phytoplankton, ciliates, HNF, bacteria and PA in the absence of predators and with and without addition of nutrients (N and P). The hypothesis was that PA and bacteria will respond faster to the addition of nutrients (because of their higher surface to volume ratio) than phytoplankton, and that the number of HNF and ciliates will show positive correlation with the number of PA and bacteria. Finally, it was expected that the abundance of phytoplankton should be positively influenced by the absence of predators. Analyses of the collected samples have not yet been carried out.

This part of the project “Lake Investigation at Zackenberg” was sponsored by the Greenland Homerule and the Danish Ministry of Research and Information Technology as a Zackenberg Scholarship.

5.5 Global change effects on unicellulars and plants: experimental physical – ecological and paleoecological approach of tendencies in diversity and community structure

Louis Beyens, Ivan Nijs, Koen Trappeniers, Andy van Kerckvoorde, Mark Heuer, Fred Kockelbergh and Ivan Impens

How will communities of organisms deal with the expected warming in the Arctic? This is the main theme around which this research programme pivots. Several questions are asked: What is the present ecological situation (recent ecology)? What can we learn from the past communities (palaeo-ecology)? How will a warmer microclimate in the future affect ecosystems (radiation-experiment)?

Fig. 5.13. Microprocessor-controlled infrared heating system to simulate climate-warming in the field. Photo: Louis Beyens.

In the 1998 field season an investigation of the present ecology of testate amoebae and diatoms was carried out at Zackenberg. Samples were taken from 30 moss sites, 45 waterbodies and 26 soil sites, and physical-chemical measurements were conducted on these habitats. Together this resulted in more than 800 samples. At present we have determined 91 different testate amoebae taxa in the water samples. The recent data on community ecology in the waterbodies will be used to interpret the fossil data obtained from the peat sections which form the second point of interest. Peat columns from two different sites will be radiocarbon dated and analysed for the fossil testate amoebae and diatoms to detect the possible palaeo-signals from past environmental events like the Little Ice Age.

The third pillar of the research is to simulate a future warmer climate by heating small plots of tundra with infrared radiation, using a system called Free Air Temperature Increase (Nijs *et al.* 1996). This technique allows us to increase the surface temperature of the vegetation as well as the soil 2.5 °C, by modulating the output of heaters with an electronic control circuit (Fig. 5.13). The system is driven by a 16 kW generator and consumes about 50 liters of fuel per day. During the last third of the 1998 summer, soil samples from the upper 11 cm of the active layer were analysed to follow the reaction of testate amoebae and diatoms with respect to their generation time and community structure in this warmer soil environment. We also examined the influence of climate-warming on different fluxes of carbon (canopy photosynthesis, above ground respiration and the sum of the autotrophic and heterotrophic component of belowground respiration) in patches of vegetation dominated by *Arctagrostis latifolia* and *Salix arctica*. These data will be linked with canopy, air and soil temperatures, soil humidity, permafrost depth, vegetation cover, growth of individual plants and soil carbon and nitrogen content, in order to reconstruct the end-of-season carbon budget, explain observed temporal variability

Fig. 5.14. The snow fence and some of the installations seen from the SW. Photo: Hanne Hvidtfeldt Christiansen.

in CO_2 fluxes, and assess the influence of climate-warming. New plots will be heated during a complete growing season in 1999 to estimate changes in source/sink behaviour on an annual basis and to assess shifts in species diversity.

In a separate experiment we exposed small patches of *Vaccinium/Salix* vegetation to different ultraviolet-B levels, using polyethylene-covered mini open tops that transmit different intensities of UV-B. Damage to the photosynthetic apparatus and production of protective pigments (flavonoids) were investigated.

5.6 Dynamics of High Arctic soils: Physical and chemical processes in the active layer – permafrost system

Bjarne Holm Jakobsen, Hanne Hvidtfeldt Christiansen, Bo Elberling, Birgit Hagedorn and Ron Sletten

The project focus is on the role of the terrestrial, active layer physical and chemical feed-back mechanisms for the carbon cycle. Field studies will be integrated with freezer experiments studying the following topics:

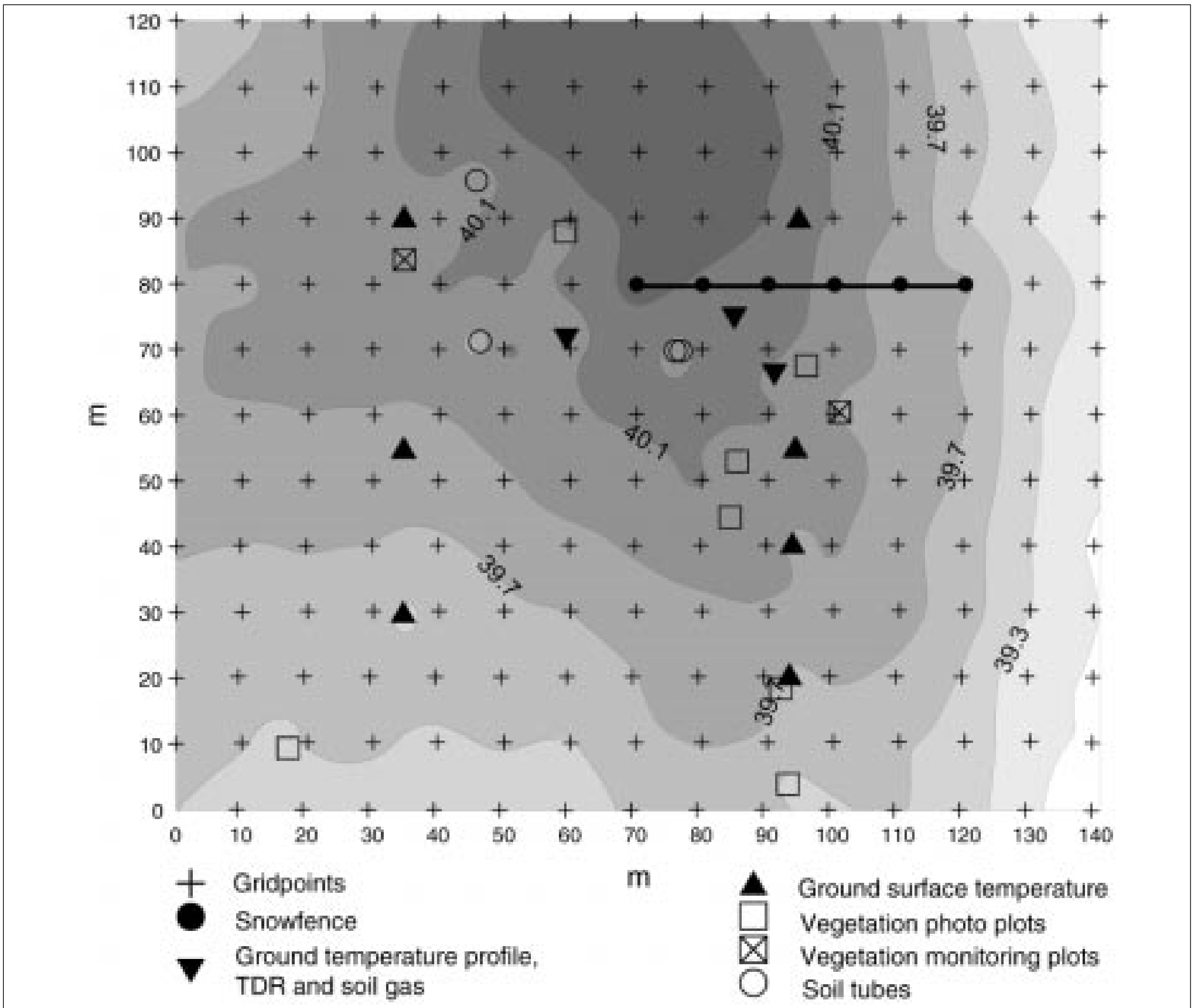


Fig. 5.15. The topography of the snow fence monitoring grid, and location of the different installations. North is towards the top.

1. Thermodynamic conditions of the active layer and phase transformation of water and ice.
2. Transport mechanisms (diffusivity and permeability) of gas and water in both snow and partly frozen soil.
3. Chemical fluxes.
4. The effect of climatic changes on active layer processes (snow fence experiment).

5.6.1 Snow manipulation, site installations, system characterization and monitoring

A snow fence was established in late July east of Zackenbergelven, in the central part of Zackenbergdalen on slightly sloping fluvial deposits, in order to study the effect of a prolonged snow cover on active layer processes. Special emphasis is on the regime of soil water, soil gasses (particularly CO_2), soil temperature and soil water chemistry. In addition the effect on the vegetation will be followed. The fence will from snowfall in the autumn 1998 cause a drift to build up downwind from the fence, and thereby simulate the effects of a change in climate causing a deeper and longer lasting snow cover.

The snowfence east of Zackenbergelven is located about 1 km north of the meteorological station (UTM Zone 27; 8,265,300 m N; 513,700 m E). The fence is oriented 70°N, which is perpendicular to the dominating winter wind direction from NNW. It is c. 1.7 m high and 50 m long. For every 2.5 m, iron poles are standing in the permafrost. On the poles a wire netting (mesh size of 4 cm) covered by a plastic coating makes the fence. It is secured in all directions by wires that are anchored in the permafrost (Fig. 5.14).

A grid 140 m x 120 m, with a 10 x 10 m grid size, has been established. It covers the snow fence affected area and a control area, not affected by the snow fence. The topography of this grid and all installations around the fence are shown on Fig. 5.15. At three sites, *i.e.* two affected by increased snow cover and one reference site, soil temperature is measured and logged at eight depths from the upper part of the permafrost (50-70 cm) to the terrain surface. For snow cover documentation, ground surface temperature is registered at additional seven locations, and air temperature is measured in two heights above one of the temperature profiles in the grid. At all three active layer study sites, Time Domain Reflectometry (TDR) probes have been installed at all depths where the soil temperature is being logged, and 1 litre bottles for collection of soil air have been installed at four depths (5, 15, 35 and 45 cm) covering the active layer down to the permafrost table, about 50-60 cm below the soil surface. In 42 of the grid cells the percentage of the 9 dominating vegetation types was determined by visual estimation using a standard ITEX frame. An intensive measuring programme will be carried out covering an entire thaw-freeze cycle in 1999, to document and evaluate the physical, chemical and geomorphological effects of the prolonged snow cover.

To know the active layer thaw progression in the snow fence area prior to the start of the manipulation, a weekly registering in all 195 grid points was carried out from the establishment of the fence to the end of the summer 1998. The average depth of the thawed layer in the grid was 51 cm in early August, and 56 cm in late August. Similar thaw progression data have been collected since the early summer of 1996 in the ZEROCALM1 grid (see description in section 5.1.12. in Meltofte and Thing 1997), and will be used as a proxy for the active layer thaw progression in earlier years, as this grid is topographically almost identical to the snow fence grid.

Preliminary results on soil air CO_2 concentrations in the active layer show values of 500-1000 ppm close to the soil surface and ranging from 2000-4000 ppm at greater depth. Due to a extraordinary wet summer of 1998 at Zackenberg, with especially much rain in August, soils at the snow fence experimental site were almost completely water saturated at the end of the field season in late August.

West of Zackenbergelven, in an area dominated by *in situ* weathered gneissic bedrock, a study of the control of seasonal thawing and freezing and soil respiration on silicate weathering rates has been initiated. Along a c. 200 m long transect at the eastern slope of Zackenberg (UTM Zone 27; 8,266,826 m N; 511,111 m E) five sites were selected for weathering studies. Three soil profiles are covered by different vegetation communities and two soil profiles are solifluction lobes where vegetation is scarce or absent. Suction lysimeters, triple Time Domain Reflectometry probes, Pt 100 temperature probes, CO_2 probes, wells and piezometers were installed in all soil profiles. The goal of this study is to model silicate weathering rates based on collected data from an entire freeze-thaw cycle in 1999.

In the ZEROCALM2 grid (see description in section 5.1.12 in Meltofte and Thing 1997) an extended registration of soil temperatures in various parts of the snow patch area has been initiated. Three temperature profiles were installed in the centre of the snow patch area. An automatic camera was set up to take daily photos during the 1998-1999 winter for documentation of the growth of the snowpatch, which will be used for calibration with the temperature data information.

5.7 Snowcover distribution in Zackenbergdalen

Steen Birkelund Pedersen

The purpose of this investigation is to describe and analyse the inter- and intra-annual snow distribution in Zackenbergdalen.

Snow is with the exception of a few month in the summer, the dominant surface type in Zacken-

Fig. 5.16. Picture taken with the digital camera on 17 July 1998. In the bottom of the valley most of the snow has disappeared. On south facing slopes snow drifts are still a dominant feature in the landscape.

bergdalen. The spatial and temporal variation of the snow-cover is therefore a very important factor in the ecosystem. Because of the high albedo of snow compared to other surface types, the presence of snow in an area has a major impact on the interaction between surface and atmosphere which again influences the energy balance.

Snow also have a direct influence on plant and animal life. Muskoxen and lemmings are among the animals that are greatly influenced by the thickness of the snow-cover during winter. In the summer, the distribution of snow drifts determines the plants composition in different areas.

When temperature is below 0 ˚C, snow is very easily transported by the wind, and snow drifts establish on slopes facing away from the main wind direction. This means that changes in snow amount, wind direction and average wind speed could affect the plant composition and animal life in the area.

During the 1998 field season point measurements of snow depth, snow density and albedo were conducted on four different locations in the valley. To extrapolate the point measurement to the entire valley, three different types of images that covers the valley will be used, *i.e.* satellite images, images from a digital camera at fixed position (UTM Zone 27; 8,265,603 m N; 509,982 m E) and digitalized slides taken with a normal hand held camera from mainly two different locations (UTM Zone 27; 8,265,603 m N; 509,982 m E and UTM Zone 27; 8,264,536 m N; 512,683 m E). The point measurement are applied as ground truth data for these images.

The main focus will be on images from the digital camera because this relatively new technique, provides cheap images with a lot of possibilities. As described in section 3.4.1 in Meltofte and Rasch (1998), the digital camera is controlled by an electronic timer. Fig. 5.16 shows a picture taken 24 August 1998 by the digital camera. During the winter two pictures are taken each week. During the summer four pictures are taken each week. In contrast to satellite images, which measures the reflectance of radiation in different parts of the electromagnetic spectrum (both the visible and invisible parts), images from both the digital camera and the images from the hand held camera only measures reflected radiation from the visible part of the spectrum. The digital camera does probably not change the physical values of the reflection when sampling and storing information, and calculation of *e.g.* the albedo is therefore possible. Unfortunately this may not be the case for digitalized slides. There is one major problem in interpreting images taken by a digital camera or digitalized slides: The pictures are taken with an inclined angel and different pixels in the image does therefore not represent areas of equal size. For this purpose a computer programme for geometrical correction has been developed as a part of this project by Kim Have from the Danish Technical University. Fig. 5.17 shows a picture from 30 June 1997 before and after geometrical correction.

The satellite images previously used by Mikkel P. Tamstorf to describe the snow distribution in the Zackenberg valley, (see Meltofte and Thing 1997) will also be used in this study because these images

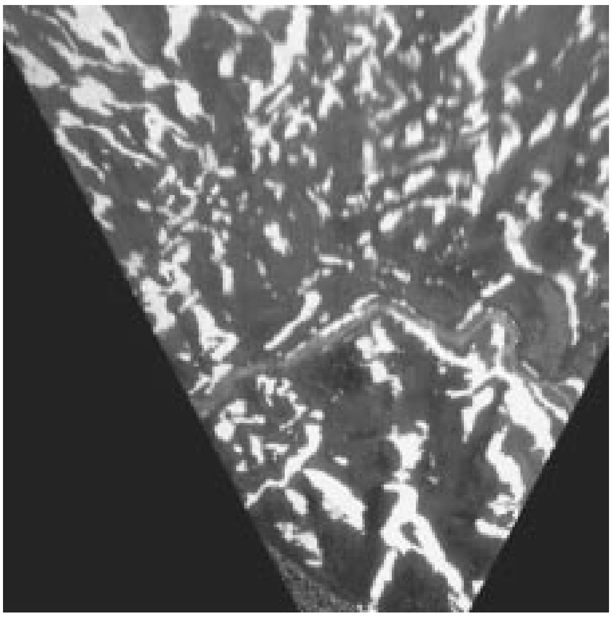


Fig. 5.17. Picture of the lower part of Zackenbergdalen on 30 June 1998 before and after geometrical correction.

represent the only snow documentation from the valley before 1995.

Hopefully, the use of the three different kinds of images will allow a description of the inter- and intra-annual snow cover variation during melt off in the past ten years.

5.8 Collared Lemming Project – Zackenberg

Thomas Bjørneboe Berg

The project continued data sampling on collared lemming *Dicrostonyx groenlandicus* initiated in 1995 on habitat selection, feeding biology, population dynamics and morphology.

As mentioned in secton 4.4.1., the remarkable increase in number of winter nests clearly indicate that 1998 was a lemming peak year and that 1997 only showed an increasing population in contrast to the assumption from 1997 (sections 4.4.1. and 5.7. in Meltofte and Rasch 1998). The exact location of all 1997-98 winter nests (710) and active summer burrows (326) within the 2.5 km^2 census area was determined using an electronic theodolite giving each nest and burrow an UTM coordinate. As seen from Fig. 5.18-21 the summer habitat is more restricted as compared to the winter habitat. Parameters recorded during the examination of nests and burrows were the same as in 1996 (Berg 1997) but with additional parameters on the position of the winter nest, digged into the ground or placed loosely on the ground (*i.e.* placed within the snow and then during snow melt ending up on the ground). The ratio of "in the surface" to "on the surface" was 46:54 in 1997 and 50:50 in 1998. Only the number of nests used for breeding and nests with white moulted fur differed from the situation found in 1997 and 1996. Half of this increase is caused by the high number of ermine predated nest which all left white fur lining in the nest. If the 28 ermine-predated nests are subtracted the proportion of nests containing white fur still shows an increase from 0.003 % in 1997 to 0.042 % in 1998 (14 times the amount found in 1997). The proportion of nests with grey moulted fur stayed the same during 1996-1998. The ratio between the four categories of pellet index remained the same from 1997 to 1998.

As the pellet index may reflect activity around the nests, nest aggregation may do the same. Compared to 1996, both 1997 and 1998 showed a higher degree of nest aggregation looking at aggregations containing more than three nests. The difference between years are not significant. Size of winter nests is expressed by five categories with 5 cm intervals from less than 10 cm to more than 25 cm. Although there is a tendency of a greater proportion of nests >15 cm in 1998 than in 1996 and 1997, there are no significant differences between years. The greatest difference in the composition of the various nest sizes was found between 1996 and 1998: (Chi Square-test: d.f. = 4; χ^2 = 9.388; p = 0.0521).

Nest material has shown the same pattern in 1996-1998. Graminoids (95-97 %) leaves of *Salix* (73-90 %), and mosses (38-62 %) were the most frequent material used in all three years.

5.9 Home range and habitat choice of the collared lemming, *Dicrostonyx groenlandicus*

Niels Martin Schmidt and Thomas Secher Jensen

At Zackenberg collared lemmings have been monitored since 1995 by means of winter nest and summer burrow countings (see Meltofte and Thing 1997, Meltofte and Rasch 1998). In order to provide further biological information about the species, a field investigation including home range analysis and habitat analysis of the collared lemming was conducted in spring-summer 1998.

The home range of the collared lemmings was investigated using radio telemetry. Small radio collars were mounted on a total of 27 individuals and these animals were tracked several times each day (and night) during the whole summer season (from 1 June to 1 September). All caught animals were sexed and weighed, and their reproductive status checked at every capture. Furthermore, all caught animals were marked individually using microchips implanted under the skin.

Four individuals caught and radio collared before snow melt yielded information about the winter

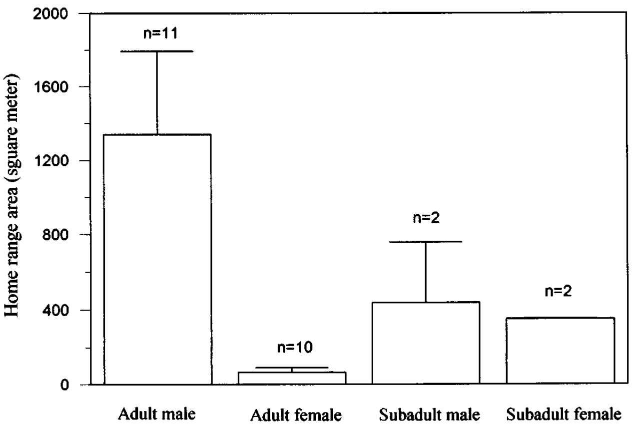


Fig. 5.22. Area of summer home range (95 % minimum convex polygon) of the collared lemming in the Zackenberg valley. Areas are given as mean + SE. Sample size is indicated above each bar.

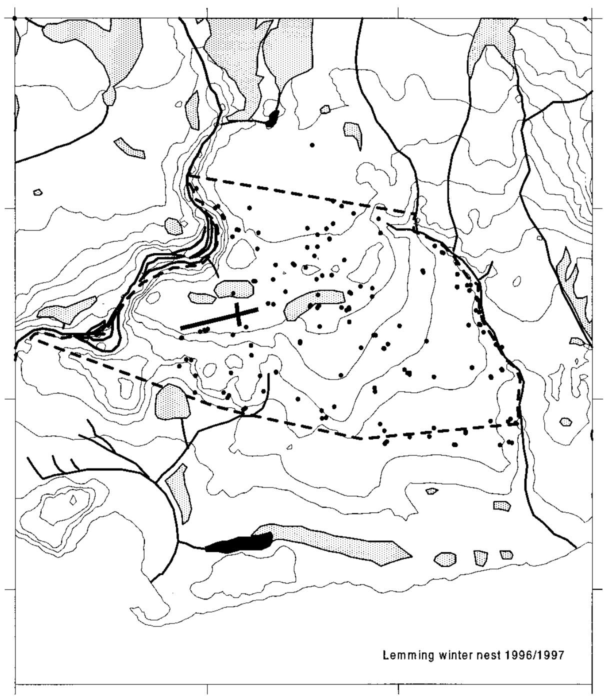


Fig. 5.18. 342 lemming winter nests built in the winter 1996/1997 within the 2.5 km² study area. Each nest is represented by a dot. Because many nests were placed few metres apart the scale of the map does not allow separation between these nests. Winter nests are occurring outside the south east boarder of the area, this is due to a small enlargement of the area created in 1997, which has not been adjusted to the figure.

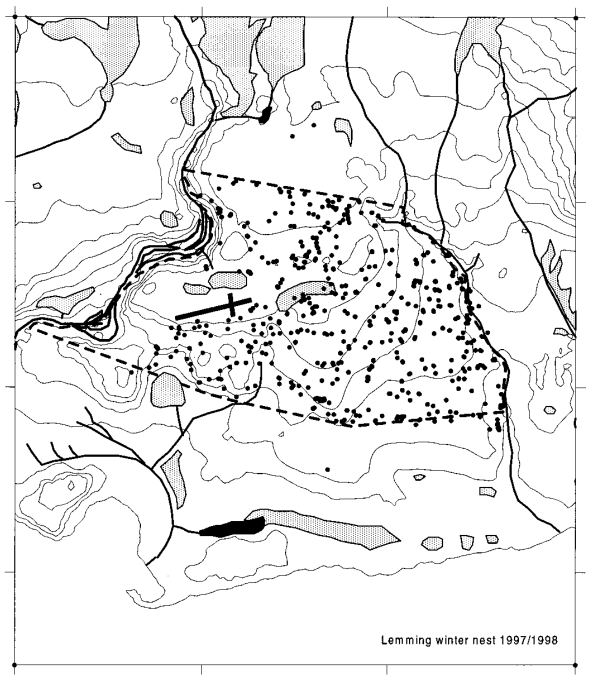


Fig. 5.19. 710 lemming winter nests built in the winter 1997/1998 within the 2.5 km² study area. Each nest is represented by a dot. Because many nests were placed few metres apart the scale of the map does not allow separation between these nests. Winter nests are occurring outside the south east boarder of the area, this is due to a small enlargement of the area created in 1997, which has not been adjusted to the figure.

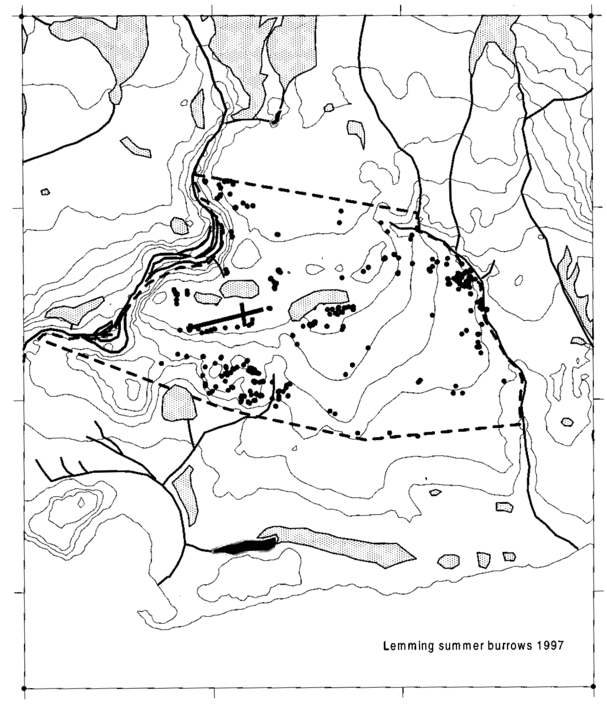


Fig. 5.20. 710 lemming summer burrow entrances used in the summer 1997 within the 2.5 km² study area. Each burrow entrance is represented by a dot. Because many burrow entrances were placed within less than one metre or only a few metres apart the scale of the map does not allow separation between these entrances.

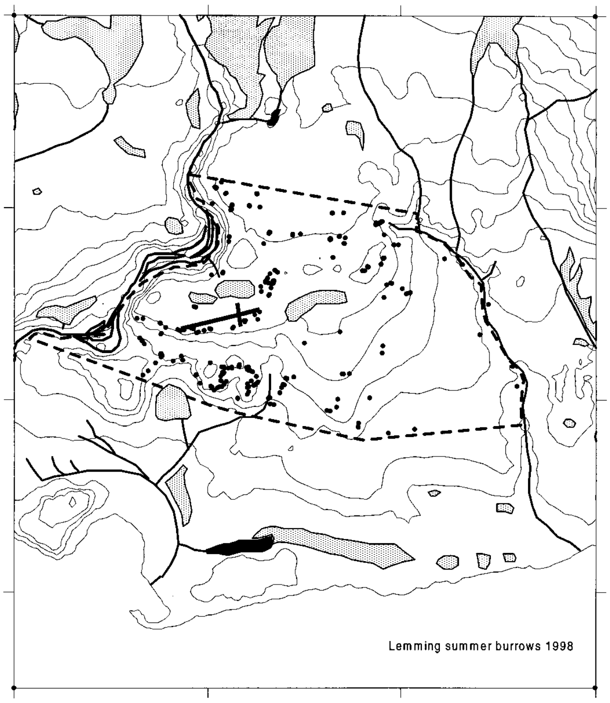


Fig. 5.21. 326 lemming summer burrow entrances used in the summer 1998 within the 2.5 km² study area. Each burrow entrance is represented by a dot. Because many burrow entrances were placed within less than one metre or only a few metres apart the scale of the map does not allow separation between these entrances.

habitat and home range. These animals were also followed during snow melt when they moved to summer burrows located in small dry ridges close to their winter home range. The rest of the radio collared animals were caught at their summer burrows.

Despite large individual variation adult male home ranges were significantly larger than adult female ($p < 0.01$, Kolmogorov-Smirnov). No other significant difference in home range area was seen among age or sex groups ($p > 0.05$, Kolmogorov-Smirnov) (Fig. 5.22). Home range overlaps between adult females were almost absent while there was a considerable overlap between adult males and between adult males and females, suggesting that females are territorial and males not, and the mating system is therefore probably polygynous.

Summer weight of reproductive active males was positively correlated to home range area which again was positively correlated to the number of females inside the home range, and larger males therefore had access to more females. But despite having access to reproductive avtive males only 17 % of the females caught were pregnant, which is very low compared to other studies (*e.g.* Negus and Berger 1998).

Generally, body weight was slightly decreasing over summer indicating that available food and/or more likely foraging time was limited compared to the winter season. During summer lemmings also suffered heavy mortality due to predators and only one radio collared lemming lived through summer. However, the predator was only identified in a few cases: In two cases the collared individual was killed by skuas and in three cases by foxes. In most other cases the collar was found lying on the ground (often bloody), or radio contact was just lost and not recovered even after intensive search within a radius of c. 1000 meters from last known position.

The winter season with its protective snow cover may therefore be regarded as the most favourable season for the collared lemmings in the Zackenberg valley. This hypothesis is furthermore supported by the catching of juvenile lemmings during show melt showing that breeding took place at least as early as April when the snow is still covering the valley.

In 1998 as well as in the previous years (see Meltofte and Thing 1997 and Meltofte and Rasch 1998) data on several habitat variables have been collected. These include the species composition of plants around the winter nests and summer burrows as well as on the micro-topographic variation of the terrain, soil structure etc. These habitat data will be compared statistically with data on the same parameters collected on 117 randomly chosen plots within the lemming monitoring area. This will hopefully allow the identification of the important components (*e.g.* the amount of *Salix arctica*, *Dryas* or micro-topographic variation around the nests) of the collared lemming habitat.

5.10 Characteristics of the mountain vegetation of Zackenberg

Fritz Hans Schwarzenbach

This study of the altitude distribution and ecology of vascular plants in mountainous regions is a continuation of studies at Zackenberg in 1956 and in the rest of East and North Greenland between 70° and 83° N in 1948, 1952, 1954, 1956, 1991, 1994 and 1995.

Fredskild and Mogensen (1997) and Bay (1998) have already stated that the flora at Zackenberg is very rich in species and that many vegetation types are present due to the high diversity of habitats. Compared with the plant-life in more continental parts of East and North Greenland the vegetation types of wetlands are very well represented in the Zackenberg area. Mosses, fungi and lichens are much more abundant than elsewhere. A remarkable feature is the large areas with dense and homogenous vegetation in the lower parts of Zackenbergdalen. A difference in the flora and vegetation on respectively the western and the eastern side of the valley is due to different soils caused by different bedrock geology on each side of the geological flexure and thrust zone running through Zackenbergdalen.

Zackenberg belongs to a transitional zone between the outer coast with oceanic conditions and the inner fjord belt with dry and warm summers. The intermediate position along the marked climatic gradient from east to west is shown by the presence of species typical for the outer coast as well as species preferring a more continental climate. It is surprising that even continental species like *Calamagrostis purpurascens*, *Rumex acetosella*, *Armeria scabra* or *Arctostaphylos alpina* are present. These species are tolerant to high concentrations of salt in the soil, and they grow – mostly as small patches – on the marine terraces south of the station.

The intermediate position of Zackenberg is also indicated by the altitude limits of plants. The upper limit of vascular plant is nearly reached at the summit of Zackenberg (1372 m a.s.l.). The altitude limits of 16 common species observed along the east-facing slope of Zackenberg are c. 300 m below the same limits on the nunataks between Waltershausengletscher and Wordie Gletscher (north of 74° N) and c. 500 m lower than in Andrée Land (73° N). It is therefore estimated that the average temperature during the growth-period at Zackenberg is c. 1.5 °C lower than in the nunatak zone and c. 2.5 °C lower than in Andrée Land.

Inversions of temperature during low clouds or fog are frequent at Zackenberg during the summer, as it was observed in 1998. These inversions have a striking influence on the altitude distribution and the phenology of vascular plants. Low clouds or fog reduces the surface temperature and postpones the development of plants. Therefore, *Vaccinium uliginosum* had ripe berries and leaves with autumn colours at levels above 400 m already in the first half of August 1998, 2-3 weeks earlier than in the lowland.

A few observations might stimulate further studies on micro-evolutionary processes of vascular plants. The first example concerns the dwarf-shrub *Rhododendron lapponicum* as a co-dominant species of the dry heath at the eastern slope of Zackenberg with the highest site at 770 m a.s.l. The species grows on gneiss, whereas it is usually found on calcareous soils. It was not observed on the eastern side of the valley. A second species of interest is *Tofieldia coccinea* known as a minor component of the *Cassiope* heath and also found on dry slopes. The species was surprisingly common in the *Empetrum* heath west of Zackenbergelven but was not found in the eastern side of the valley. A third example is *Ranunculus glacialis* which is extremely common in the study area. *Ranunculus glacialis* grows on wet soils and is one of the most frequent species of middle and high altitudes reaching 1320 m a.s.l. south of the Zackenberg summit and at least 790 m a.s.l. on Aucellabjerg. The last example concerns a group of species with *Saxifraga hirculus, Saxifraga platysepala, Polemonium boreale, Ranunculus glacialis* and *Cochlearia groenlandica* which are rather common at higher altitudes on Aucellabjerg. This combination of species has not been observed in other regions visited by the author.

The extended areas of a well developed and dense vegetation in the flat lower parts of Zackenbergdalen are exceptional compared with the loose and fragmented vegetation found in most other mountainous regions in East and North Greenland. Therefore, results gained by experiments in the highly productive vegetation types around the Zackenberg station may not be representative for other regions.

5.11 Changes in Arctic Marine Production

Søren Rysgaard, Jens W. Hansen, Mikael K. Sejr, Jens Borum, Jens S. Laursen, Göran Ehlmé and Magnus Elander

This year our project, "Nutrient dynamics in Northeast Greenland waters and sediments" was completed, but the work within Young Sund continues in our new project, " Changes in arctic marine production" also financially supported by the Danish Research Councils.

The overall hypothesis of this project is that global warming is expected to affect the rate of ice-melting and thereby light availability in polar regions. Investigations concerning the responses of production, consumption, and degradation in Arctic coastal marine ecosystems to future changes in temperature and sea ice-cover will be carried out. The aim is to study the regulation of primary production, and the effects of alterations in primary production on secondary production and bacterial recycling of nutrients. This will be accomplished through detailed laboratory and field studies of primary and secondary producers and mineralization processes in Young Sund. The project is a collaboration between several scientific institutions and is expected to supply new knowledge of the mechanisms regulating production and consumption in Arctic marine areas, and to provide an extensive data-set for use as reference in the future. Further information about the new project can be found on the internet at location: http:/dmu.dk/LakeandEstuarineEcology/CAMP.

Since the beginning of January we have spent much time developing and testing laboratory and field equipment to be used during next year's campaigns. In additon, several man months have been used for purchase and subsequent packing. This year we had two field campaigns, one during May-June and one in August.

5.11.1 Investigations below the sea ice

The purpose of the May-June campaign was to test the equipment developed for use within and below the sea ice during the 1999 field campaigns. During winter and spring we spent some time figuring out how to make a suitable hole in the sea ice, large enough for divers and equipment, which would enable us to measure various components below and within the sea ice of Young Sund. The best way of penetrating the sea ice turned out to be a combination of several techniques. On our mid-May visit to one of our standard stations in Young Sund (water depth 36 m), the 1.3 m sea ice was covered by 1 m of snow. First the snow was removed in a circle with a diameter of 2.5 m. Then a test hole was made using a powered ice-drill to observe how much of the sea ice it was possible to remove without welling up of sea water into the hole. A specially designed chain saw was used to remove the sea ice down to c. 40 cm

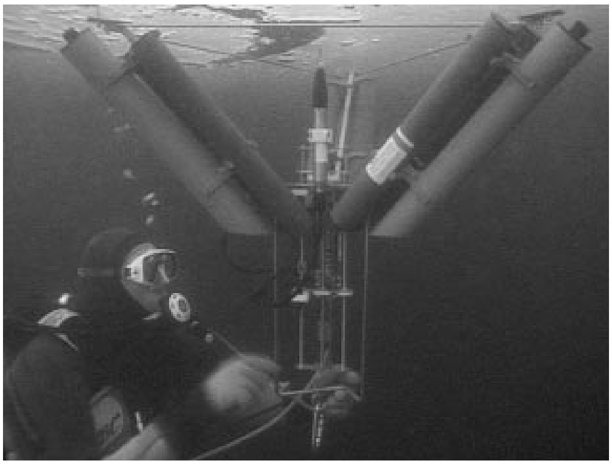


Figure 5.23. Measuring oxygen concentration profiles within the sea ice. Photo: Jens S. Laursen.

above the water column. The remaining sea ice was perforated several times with the powered ice-drill, and finally removed by a diver using a gas concrete saw.

Various diving equipment was tested at sub-zero temperatures and depths. Dive tanks with anti-freeze aqua lungs and security systems received special attention. Much experience was obtained and optimal diving equipment and rutines were selected to be used in the coming field campaigns.

Measurements of light, salinity, temperature, pH, O_2, flow and sea ice algae and phytoplankton production were made in order to study whether the man-made hole in the sea ice had any artificial effects on *in situ* conditions. The investigation covered a grid of data from the sea ice hole to a horisontal distance of 15 m and a vertical depth of 36 m. Results showed that extreme care should be taken when performing *in situ* incubations closer than 6 meter to the sea ice-hole, because the presence of the hole interferes with the natural light regime and therefore with measurements of sea ice algal and phytoplankton production. In order to estimate the exchange rate of various solutes, especially sea salts, between sea ice and water column a specially designed flux chamber was tested. Despite technical difficulties with stable long-term positioning of the equipment, data show that large variations in exchange rates occur. Further development of the equipment will proceed until next field campaign in 1999.

Samples of sea ice from below were collected by divers for identification of sea ice organisms and for quantification of chlorophyl *a* (Chl *a*). Several techniques for measuring primary production of the sea ice community were tested: (1) Intact sea ice samples of the lower 2-3 cm were incubated in the field with radio-carbon ^{14}C. (2) Measurements were performed of oxygen concentration profiles in the laboratory using a traditional setup (see section 5.2. in Meltofte and Thing 1997), and in the field by a specially designed remote profiling equipment (Fig. 5.23). (3) Finally, both Chl *a* and primary production measurements were performed in the field with a newly designed underwater PAM fluorometer.

In the beginning of June a survey was conducted covering the area from Lille Sødal to open water conditions at the entrance of Young Sund. Diving was performed in all available seal holes to obtain information of the geographic variability of sea ice structure and organisms. Measurements on ice-floes drifting within Young Sund in August showed that sea ice algal production was insignificant due to decay of the organisms and that sea ice algal primary production was replaced by phytoplankton production. However, preliminary data show that the concentration of sea ice algae and their primary production rate in the lower 2-3 cm of the sea ice were higher than found for phytoplankton during May-June. Therefore, we expect that sea ice algae may account for a considerable part of total annual primary production in Young Sund.

Figure 5.24. Feeding walruses on the bottom of Young Sund. Photo: Göran Ehlmé.

5.11.2 Underwater plants

Underwater plants (*Laminaria*) which were marked by thalli punching at 6-8 m depth in late August 1997 outside the coast of Daneborg were harvested by divers this August. Unfortunately, only few marked plants were recovered. This preliminary study showed that the annual growth of Laminaria is approximately one meter. However, visual inspection of a number of algae suggests that the growth rate can be even higher. Plants were 2-4 m long off the coast of Daneborg but longer and more vital near Sandøen at the mouth of Young Sund. To obtain a more precise and comprehensive data-set on growth rates numerous plants were marked this year. Leaf marking was performed along a depth transect (5 – 20 m) outside the coast of Daneborg and at 7 m depth between Sandøen and Kap Berghaus in the outer part of Young Sund. In addition to leaf marking, plant length was recorded. The plants will be harvested and growth recorded in May-June 1999. A new set of plants will be marked in May-June and harvested again in August 1999. This will be accomplished in order to differentiate between the winter and summer growth rates.

5.11.3 Sediments

A follow-up experiment was conducted to supplement previous field campaigns. Bacterial denitrification measurements were performed along a depth transect (20 – 163 m) from Daneborg towards Clavering Ø. Sediment cores from various depths were collected and incubated with ^{15}N-labelled nitrate at *in situ* conditions in the new laboratory facilities of the Daneborg station. This investigation was aimed to establish further information on the spatial distribution of bacterial denitrification in Young Sund and to verify recent model simulations.

In addition, sediment cores from various water depths (3 – 163 m) were collected for identification and enumeration of meiofauna. Results from earlier field campaigns have indicated that benthic animals increase transport of solutes and particles within the sediment of Young Sund, thus stimulating the biogeochemical processes. However, the effect of meiofauna on transport is still poorly investigated and through this preliminary study we hope to gain insight into the distribution of meiofauna.

5.11.4 Bivalves

Investigations from our previous project identified bivalves as being the dominant group of bottom infauna in Young Sund. Two species (*Hiatella arctica* and *Mya truncata*) were selected for further studies because of their relatively high abundance and the fact that they are the preferred diet of walruses in the sound. This makes them key secondary producers that link primary production to higher trophic levels.

In August, these two species were sampled in order to obtain estimates of their growth rate from the length of shells and number of growth rings. Six chambers with marked and measured individuals were placed at 15 meters depth off the coast of Daneborg enabling us to monitor *in situ* growth rates and to study the timing of growth in the relatively short summer period. Concrete blocks were also placed at the locality in order to monitor the recruitment of new mussels. Furthermore, the development of reproductive tissue from individuals sampled in different seasons will be compared. This will provide information on how growth and reproduction is adapted to the extreme seasonal fluctuations in the amount and quality of sedimenting food particles.

5.11.5 Walrus

Documenting the underwater activities of walruses on digital video and still pictures continued in August 1998. The photographic equipment was improved, based on the experiences from last year. The so called pole-cam system was developed further. A very small black-and-white video camera was mounted inside the glass dome of the underwater housing parallel to the Nikon F5 camera. The video signal was displayed on a monitor thus making it possible to take underwater stills in a completely controlled manner. The pole-cam was used with great success both in shallow water near Sandøen and in open sea from the rubber boat.

Video filming was done similarly to the previous campaigns using a Sony VX-1000 camera in an Amphibico underwater housing. Most of the filming was done by a free-swimming diver. Target walruses were approached repeatedly in a slow and very quiet fashion to give the animal a chance to get accustomed to the camera, the film team and the boat. Finally, the diver went into the water but initially only close to the boat and with one hand on the rail. On encouraging behaviour of the walrus, the diver moved away from the boat to finally submerge and follow the animal to the bivalve banks on the bottom. We found that this was accepted by only a few animals. However, diving sessions with two cooperative walruses produced unique footage of feeding behaviour on the ocean floor at a depth of 17-20 meters (Fig. 5.24).

One limitation to underwater photography in Young Sund is a somewhat unpredictable visibility. It varies during the summer due to algae blooming and also on a daily basis due to suspended matter, tide and current.

5.11.6 Acknowledgements

The Danish Research Councils (grant # 9700224) are acknowledged for financial support. Egon Frandsen and Thomas Rasmussen are thanked for excellent assistance in the field and laboratory. We also thank the SIRIUS military sledge patrol for their hospitality and help with unloading of equipment from “Kista Arctica”.

6 Disturbance

Hans Meltofte

6.1 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 (Table 6.1) was very much the same as in the previous year, except for June, when it was only half as high. Activities in the low impact study area (1b) remained very low, and so did activities in the protection zone for moulting and breeding geese (1c). Research zone 2 (Store Sødal) was visited a number of times including extensive activities during the lake ecology study in July (see section 5.4).

Moulting and breeding geese remained very sensitive to our activities. The almost total lack of moulting pink-footed geese around the peninsula to the southeast was most likely due to ice conditions, but helicopter flights may have contributed to the failure (see section 4.3.8).

Ten of the twelve ATV trips in June were on snow. Two of these trips went to Store Sø, and one to upper Store Sødal. Two went to Daneborg, and three more passed over the area south and southeast of the runway. Besides the three trips to Store Sødal, one more passed over the study area west of the river. The two trips on ground in June, most of the trips in July and all trips in August were along the route to Tørvekæret that was established in 1997, but several of these trips went short distances away from the marked route. Two trips in July went down in the area south of the station. The tracks on the marked route to Tørvekæret were clearly visible on the surface, and especially on soft, vegetated sites at the outlets from Tørvekæret, the vegetation was destroyed and the dark peat was exposed on the surface.

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, 26 May – 1 September 1998.

Research zone	May	June	July	August	Total
1	10	115	349	357	831
1b	1	4	18	10	33
1c (20.6-10.8)			3	2	5
2			62	6	68
ATV-trips		11	12	11	34

6.2 Aircraft activities in the study area

The number of fixed-wing aircraft take-off and landings in 1998 (Table 6.2) was less than half the number of flights in 1997 and even below the numbers in 1996. On the contrary, the number of helicopter flights, that must be considered much more disturbing to wildlife than fixed-wing operations, increased to more than the double of the 1997 total. In July, three helicopter flights went into upper Store Sødal, and in August, three more helicopter trips went into Store Sødal.

Table 6.2. Number of flights with fixed-winged aircraft and helicopters, respectively, over the study area in Zackenbergdalen 26 May – 1 September 1998 (two flights on the latter date are included under August). Each ground visit of an aircraft is considered two flights.

Type of aircraft	May	June	July	August	Total
Fixed-wing	2	8	14	26	50
Helicopter			12	20	32

6.3 Discharges

Waste was treated in the same way as in 1996 and 1997 (see Meltofte and Thing 1997). The total amount of untreated waste water let into Zackenbergelven from the kitchen, showers, sinks and laundry machines equalled 1215 ‘person-days’, a minor decrease from 1292 in 1997.

6.4 Manipulative research projects

On the first plateau south of the station (UTM Zone 27; 512,921 m E; 8,264,564 m N), three plots, each measuring 40 x 50 cm, were radiated with infrared heaters for 15 days in August (see section 5.5).

6.5 Take of organisms

In upper Store Sødal, Arctic char *Salvelinus alpinus* were collected in a number of lakes. Referring to the site numbers in section 5.4.3 the following numbers were taken (given in brackets): Site 20 (4), site 24 (1), site 25 (55), site 26 (64), site 30 (5), site 22 (115), site 29 (49) and site 30 (15).

7 Publications from ZERO

7.1 Scientific papers

Berg, P., Risgaard-Petersen, N. and Rysgaard, S. 1997: Interpretation of measured concentration profiles in sediment pore water. *Limnol. Oceanogr. 6*, 1500-1510.

Christensen, T.R., Jonasson, S., Michelsen, A., Callaghan, T.V. and Havstrøm, M. 1998: Environmental controls on soil respiration in the Eurasian and Greenlandic Arctic. *Journal of Geophysical Research 103 D22*, 29015-29021.

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7.2 Reports

Ba. C. 1998: *Vegetation mapping of Zackenberg valley Northeast Greenland*. Danish Polar Center and Botanical Museum, University of Copenhagen, 29 p.

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7.3 General information

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Christensen, P.B. 1998. Klimaændringer skal spores i Nordøstgrønland. *Midtjyllands Avis 14. november 1998.*

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8 Personnel and visitors

8.1 Research

8.1.1 Zackenberg

Nanette Hammeken Arboe, student, Freshwater Biological Laboratory, University of Copenhagen, (freshwater ecology, 7 July – 4 August)
Thomas Bjørnboe Berg, M.Sc., Danish Polar Center (BioBasis, lemming ecology, 15 July – 2 September)
Louis Beyens, Ph.D., Laboratory of Polar Biology, University of Antwerpen (testate amoebae ecology, 25 July – 14 August)
Hanne Hvidtfeldt Christiansen, Ph.D., Institute of Geography, University of Copenhagen (nivation, 4 August – 24 August)
Torben Røjle Christensen, Ph.D., Department of Plant Ecology, University of Lund (trace gas exchange, 28 June – 4 July)
Kirsten Christoffersen, Ph.D., Freshwater Biological Laboratory, University of Copenhagen, (fresh water ecology, 15 – 25 June and 7 – 25 July)
Birgit Hagedorn, Ph.D., Alfred Wegener Institute for Polar and Marine research (water chemistry, 25 July – 2 September)
Mark Heuer, M.Sc., Laboratory of Plant Ecology, University of Antwerpen (free air temperature increase, 4 August – 2 September)
Nanna Høegh, M.Sc., Aalborg University, Department of Civil Engineering, The Environmental Engineering Laboratory (trace gas exchange, 25 june – 6 August)
Lotte Illeris, M.Sc., Botanical Institute, University of Copenhagen (trace gas exchange, 28 June – 4 July)
Bjarne Holm Jakobsen, Ph.D., Institute of Geography, University of Copenhagen (pedology, soil water chemistry, 25 July – 14 August)
Erik Jeppesen, Dr.Sc., National Environmental Research Institute, (freshwater ecology, 7 – 25 July and 14 – 25 August)
Anna Joabsson, M.Sc., Department of Plant Ecology, University of Lund (trace gas exchange, 28 June – 15 July)
Daniel Johansson, M.Sc., Department of Plant Ecology, University of Lund (trace gas exchange, 4 July – 24 August)
Fred Kockelberg, Technician, Laboratory of Plant Ecology, University of Antwerpen (free air temperature increase, 4 – 19 August)
Frank Landkildehus, M.Sc., National Environmental Research Institute, (freshwater ecology, 15 – 25 June and 7 – 25 July)
Hans Meltofte, Dr.Sc., National Environmental Research Institute (BioBasis Manager, 26 May – 25 July)
Ivan Nijs, Ph.D., Laboratory of Plant Ecology, University of Antwerpen (free air temperature increase, 4 – 19 August)
Morten Hundahl Pedersen, M.Sc., Greenland Field Investigations (Climate Basis Manager, 4 – 15 July)
Jonathan Petersen, Technician, Greenland Field Investigations (Climate Basis, 4 – 15 July)
Steen Birkelund Pedersen, student, Institute of Geography, University of Copenhagen (GeoBasis, remote sensing, 15 June – 14 August)
Morten Rasch, Ph.D., Danish Polar Center (Station Manager, GeoBasis Manager, 26 May – 15 June and 14 August – 2 September)
Åsa Rennermalm, student, Institute of Geography, University of Copenhagen (trace gas exchange, 4 July – 2 September)
Frank Riget, Ph.D., National Environmental Research Institute (fresh water ecology, 7 – 25 July)
Thomas Secher, Ph.D., Institute of Biology, University of Aarhus (lemming ecology, 4 – 15 July)
Niels Martin Schmidt, student, University of Copenhagen (BioBasis, lemming ecology, 26 May – 14 August)
Fritz Hans Schwarzenbach, Gheggio, Switzerland (plant ecology, 4 – 14 August)
Martin Søndergaard, National Environmental Research Institute (fresh water ecology, 14 – 25 August)
Ronald Sletten, Ph.D., University of Washington (pedology, 25 July – 14 August)
Koen Trappeniers, M.Sc., Laboratory of Polar Biology, University of Antwerpen (testate amoebae ecology, 4 August – 2 September)

8.1.2 Daneborg

Jens Borum, Ph.D., Freshwater Biological Laboratory, University of Copenhagen, (marine ecology, 3 – 14 August)
Göran Ehlme, photographer, Water Proof Diving AB, Sweden (underwater photography, 3 – 25 August)
Magnus Elander, Ph.D. and photographer, Amarok AB, Sweden (underwater photography, 3 – 25 August)
Egon Frandsen, Technician, National Environmental Research Institute (marine ecology, 3 – August)
Jens W. Hansen, Ph.D., National Environmental Research Institute (marine ecology, 25 May – 16 June and 3 – 25 August)
Jens S. Laursen, M.Sc., Sønderjyllands Amt, (marine ecology, 25 May – 16 June)
Thomas Rasmussen, student, Institute of Geology, University of Copenhagen (marine ecology, 25 May – 16 June)
Søren Rysgaard, Ph.D., National Environmental

Research Institute (marine ecology, 25 May – 16 June and 3 – 25 August)
Mikael K. Sejr, M.Sc., Department of Genetics and Ecology, University of Aarhus (marine ecology, 3 – 25 August)

8.2 Logistics and construction

8.2.1 Zackenberg

Hauge Andersson, Logistic Officer, Danish Polar Center (logistics, 22 – 25 August)
Niels K. Jensen, logistician, Danish Polar Center, (logistics, 26 May – 15 June)
Joakim Larsen, cook, Danish Polar Center (cook, 15 June – 6 August)
Henrik P. Ø. Lassen, Logistic Manager, Danish Polar Center (logistics, 26 May – 10 August and 27 August – 2 september)
Aka Lynge, logistician, Danish Polar Center (logistics, 4 August – 2 September)
Kresten Mathiasen, logistician, Danish Polar Center (logistics, 15 June – 2 September)
Henrik Phillipsen, cook, Danish Polar center (cook, 6 August – 2 September)

8.2.2 Daneborg

Henrik P. Ø. Lassen, logistician, Danish Polar Center (logistics and renovation, 10 – 27 August)
Lasse Nielsen, carpenter, Venslev Hytter (renovation, 14 – 25 August)

8.3 Others, Zackenberg

Iris Madsen, secretary, Danish Polar Center (visit, 25 July – 1 August)
Rolf Müller, photographer, (photography, 11 – 14 August)
Bent Muus, Dr.Ph., Zoological Museum, University of Copenhagen (visit, 29 July – 4 August)
Poul-Erik Philbert, Information Officer, Danish Polar Center (public relation, 21 – 25 July)
Irene Seiten, desktop layouter, Danish Polar Center (public relation, 21 – 25 July)
Dorthe Vestergaard, consultant, Greenland Home Rule (visit, 25 -29 July)

8.4 Further contributors to the annual report

Peter K. Kristensen, student, National Environmental Research Institute, Denmark (BioBasis, invertebrate sorting)
Jacob Leonhard, student, National Environmental Research Institute, Denmark (BioBasis, invertebrate sorting)

9 Acknowledgements

The operation of Zackenberg Station and the Daneborg facility was funded by generous grants from the Commission for Scientific Research in Greenland and the Danish Polar Center Logistics Platform.

The Greenland Home Rule, Danish Ministry of Environment and Energy, Institute of Geography at University of Copenhagen and Danish Polar Center provided means for the monitoring programme Zackenberg Basic.

The SIRIUS military sledge patrol is thanked for its hospitality and help with unloading from the annual ship, Kista Arctica, of equipment and building materials for Zackenberg Station and the Daneborg branch. The National Environmental Research Institute is thanked for material support and man power for the renovation of the Daneborg facility, and members of Det Nordøstgrønlandske Kompagni, NANOK, is thanked for their help with repairing the roof on the Daneborg facility.

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