ZERO

ZACKENBERG ECOLOGICAL RESEARCH OPERATIONS

6th Annual Report 2000

Danish Polar Center
Ministry of Research & Information Technology
2001

Zackenberg Ecological Research Operations

6th Annual Report, 2000

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Front cover: Watercolour painting by the artist Jens Gregersen who visited Zackenberg in 2000.

The editors regret …
… that this issue of the ZERO Annual Report is published without
the usual contribution from the ClimateBasis programme.

We hope to be able to present the data together with the 2001 data in
the next annual report and regret the delay in printing of this annual report.

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Executive summary

Hans Meltofte and Morten Rasch

The 2000 field season at Zackenberg/Daneborg was not as busy as previous years in terms of bednights spent at the station. 60 persons visited the facilities and the total number of bednights was 1221.

In 2000, Zackenberg Station established cooperation with facilities both in Greenland and in the remaining part of the Arctic and in the Alpine area. The cooperation with facilities outside Greenland takes place under the context of two EU-funded networks ENVINET and SCANNET.

Unfortunately, it was not possible to have the climate data, normally reported in the ZERO annual reports, ready for this report. The most important climatic event in 2000 was the very limited snow thickness experienced. This resulted in large areas being snow free much earlier than in previous years, very early biological processes in the ecosystem, and an early development of an active layer.

Also the data on river water discharge are delayed this year. However, it can be stated that the total amount of water running through Zackenbergelven during the summer of 2000 was limited compared to previous years, probably due to very limited precipitation during the winter. This statement is based on the manual measurements of water level in Zackenbergelven carried out every morning.

The ice melt and the start of running water in rivers and rivulets in the study area were among the earliest recorded. The break up of the fjord ice in Young Sund was not particularly early. In fact, the fast ice off Northeast Greenland extended much further out at sea early in the season, than normally.

In accordance with the generally modest snow-cover, several vegetation plots were free from snow already at our arrival, and most others cleared earlier than recorded before. Flowering was early, but not particularly early as compared with the early seasons of 1996 and 1997. In most plots, numbers of flowers were within the range recorded in the others years, except for a number of plots that became snow-free very late in 1999, i.e. the previous season when flower buds are established. Greening indexes both in plots and in the whole study area reached higher values than the year before, and maximum was reached 1-4 weeks earlier than during the very late season of 1999.

Carbon dioxide uptake from the *Cassiope tetragona* heath north of the climate station was almost double as high in 2000 as in 1997, which may be related to the early snow melt and consequently early start of the growing season in 2000.

This year saw the highest number of terrestrial arthropods caught so far. Three groups of midges and flies, Chironomidae, Cecidomyiidae and Muscidae, all were caught in unprecedented high numbers in the window traps while three groups of flies, Phoridae, Calliphoridae and Muscidae, were all found in surprisingly high numbers in the pitfall traps. Again, this was presumably the result of the early snow melt and the fine weather during most of the summer.

Bird populations were largely within the range estimated for previous years. Red knots seem to have decreased and dunlins to have increased, while the rock ptarmigans reached an unprecedented low. In accordance with the limited snow-cover early in the season, first egg dates in waders were among the earliest recorded. Wader clutch sizes were normal and hatching success similarly within the range from previous years. However, a fierce snowstorm in mid July apparently killed substantial numbers of wader chicks. Still, 'normal' numbers of juveniles appeared at the coast in August, so breeding must have been more successful in other parts of the region.

The lemming population reached an absolute low, and only few long-tailed skuas bred. No young fledged. The average brood size for barnacle geese was the highest recorded so far, but fewer families brought their goslings to Zackenbergdalen, than during the last few years. More immature barnacle geese moulted in the study area than recorded before, which may be related to reduced competition from moulting pink-footed geese which our disturbance have expelled from the area.

In spite of the lemming winter nest low, the number of winter nests predated by stoats increased as compared to 1999, but still fell considerably below the peak in 1998, when the lemming population also peaked. Musk ox usage of Zackenbergdalen increased almost by 50% as compared to 1999, which may be related to the snow conditions in the two years, with 1999 as the most snow rich year recorded so far. Calfs made up about 10%, which is the highest proportion since the very good breeding year of 1995. The ratio of cows having a calf still alive in August in relation to cows without calves in 1999 was 0.70, which is the highest ratio recorded during 1996-2000. Three out of eight musk ox carcasses encountered in 2000 had eating marks from wolves. Three fox dens in Zackenbergdalen held a total of eight white phase pups, and relatively many foxes were seen in the valley. Seal numbers were back to 'normal' after the very large figures recorded in 1999.

Conditions in the two monitored lakes in Morænebakkerne were more favourable than in previous years due to an early ice melt and consequently earlier development and warmer water. In both lakes, total nitrogen was substantially higher than in 1999. Similarly, chlorophyll a concentrations were twofold higher than in 1999. The number of cyclopoid copepods in Langemandssø was high in 2000, and the number of advanced stages much higher than in previous years. Likewise, the number of Daphnia was high in Sommerfuglesø in 2000 compared to 1997 and 1999, but not as high as in 1998, when many small individuals occurred.

Ten individual research projects are described in this report. The largest research project is the *Changes in Arctic Marine Production* project in Daneborg with eighteen scientists involved, all working on the common goal to model the function of a high arctic marine ecosystem. At Zackenberg, a Swedish research group carried out studies of methane emission in relation to vascular plant production and a Belgian research group worked on global change effects on unicellulars and plants. An airborne hyperspectral scanning of the Zackenberg area was carried out from an aeroplane equipped with an HyMap scanner. In relation to the scanning, field investigations of spectral signatures of different habitats were carried out by the Institute of Geography at University of Copenhagen and the National Environmental Research Institute, Denmark. Other research projects comprised investigations on CO_2 concentrations in arctic soils, on the time budgets of waders, on the dynamics of the lemming population, on the hydrology of the Zackenbergelven drainage basin and a collection of the Greenlandic heteropteran, *Nysius groenlandicus*.

1 Introduction

Morten Rasch

In the 2000 field season 60 persons visited the Zackenberg/Daneborg facilities and the sum of bednights was 1221. Several large projects have expressed their interest in using Zackenberg in 2001 and/or 2002. One of them is a biodiversity project with participation from Danish and Swedish research institutions and c. 20 scientists involved. Furthermore, we hope that a reduced price on air tickets to Zackenberg/Daneborg which is planned for the coming years will encourage scientists to use the facilities. We are working on finding financial support to complete the original plans for the station which include a house accommodating 18 scientists and a combined power station, workshop and garage. With these two buildings it will be possible to remove the shelters, and it will be possible for scientists to stay at Zackenberg during winter.

Evaluation of the Danish Polar Center

Danish Polar Center was evaluated by an external evaluation panel in 2000, based on an investigation among the users of Danish Polar Center. The evaluation turned out positive, both for Danish Polar Center as a whole and for Zackenberg Station. Especially the foreign users of Zackenberg Station were positive about the station and the concept of ZERO (Zackenberg Ecological Research Operations).

The evaluation panel referred to the limited financial support for the Danish Polar Center Logistical Platform and the Zackenberg Station as a problem, and they recommended an increase of the governmental support with 2 million DKK per year. This recommendation was followed by the Danish Ministry of Information Technology and Research.

The increased support enables us to reduce the price on tickets (including starting fee at the station) from 26,000 DKK to 15,000 DKK, to increase the staff at the station during field season, to start maintenance work at Zackenberg, and to employ staff for the Daneborg facility. The cost of doing research in Northeast Greenland will now equal the expenses of working in West Greenland.

Cooperation with other sites

In year 2000, Zackenberg Station has established cooperation with a large number of research facilities in the Arctic, including Arctic Station (central West Greenland), Greenland Institute of Natural Resources (southern West Greenland), Kangerlussuaq International Science Support (southern West Greenland) and Ny Ålesund Large Scale Facility (Svalbard). The cooperation between the Greenlandic sites will include coordinated monitoring at the facilities and common marketing. The cooperation with Ny Ålesund includes common marketing as well as exchange of ideas and experiences relating to operating an arctic field facility.

Networks

Zackenberg Station is involved in two international networks, ENVINET and SCANNET. The ENVINET network consists of seventeen arctic and alpine research facilities and is funded by EU from 2000. The SCANNET network connects nine research facilities around the North Atlantic and received funding from EU in early 2001. Further details about the networks are found in the annual report for 1999 (Caning and Rasch 2000).

Plans for the year 2001 field season

We will start maintenance works at the station and improve the water supply system. If economically feasible we will also establish a VHF repeater on a mountain top close to the station in order to improve radio communication with scientists working in the field and with the Sirius military sledge patrol.

The Zackenberg Station and the study area

Details about the Zackenberg Station, the study area at Zackenberg and the administrative structure for Zackenberg have been given in previous annual reports (Meltofte and Thing 1996 and 1997; Meltofte and Rasch 1998; Rasch 1999; Caning and Rasch

2000), and information is also available on the website (www.zackenberg.dk).

The Zero Site Manual has all information about travelling to the Zackenberg Station. The site manual can be obtained together with the Zackenberg Application Form from the Zackenberg homepage (www.zackenberg.dk) or by writing, phoning or e-mailing to the Zackenberg Secretariat, Danish Polar Center, Strandgade 100H, DK-1401 Copenhagen K, Denmark, phone: +45 32880100, fax: +4532880101, e-mail: mr@geogr.ku.dk.

2 Logistics

Aka Lynge

In 2000, Zackenberg Station was open in 94 days, from 30 May to 1 September. In this period, 21 scientists and 3 logisticians worked at the station, and 8 guests paid a visit. The affiliation at Daneborg was used in the period 26 July-16 August by 13 scientists and 6 visitors. In connection with the 50th anniversary of the Sirius Sledge Patrol many people visited both Zackenberg and Daneborg.

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

Transportation

As we had problems with snow on the airstrip in 1999 we took no chances this year and decided to use a Twin Otter with skis for the first flight to the station. Unfortunately, there was no snow on the airstrip this year, and as the pilots did not want to spoil the skis, the pioneers were put down at Daneborg where they had to wait for a plane with wheels.

Because of the lack of snow we were also unable to drive to Store Sødal with equipment for water level observation as planned by Asiaq. Later on we carried the equipment in rucksacks.

The transport of heavy equipment took place with our All Terrain Vehicle and a trailer for restricted use in a traffic corridor.

The number of landings/take offs by plane counted 52 in 2000, 44 in connection with arrivals and departures of scientists and freight, and 8 in connection with transport of ship freight from Daneborg.

No helicopters visited Zackenberg in 2000.

Accomodation

In 2000 the accomodation of scientists took place in shelters. We hope to be able to build new accomodation soon so that both employees, scientists and visitors can be accomodated in proper houses.

Electrical power production

A new generator was put into operation last year. It has been working satisfactorily throughout the 2000 season and has delivered suffficient electrical power for all purposes. We are currently hoping to be able to make a new building for the generator, big enough for one more generator as well as a small workshop.

Water supply

As the soft water tanks have started to leak because of age, we have bought new tanks of stainless steel with plastic lining inside.These tanks should be easier to clean and should live longer than the bladders.

Waste

We have bought three new waste containers for overwintering waste waiting to be flown out. The containers are made of metal and they are so strong that bears cannot open or destroy them.

Tele communication

As in previous years, tele communication between Zackenberg and the world outside NE Greenland took place through a satellite phone, fax and e-mail. Tele communication is still expensive but reliable. Using the e-mail server at Institute of Geography, University of Copenhagen, for e-mail transmission has worked satisfactorily.

A foundation for a new HF-mast was prepared in 2000. The mast will be established in 2001.

3 Zackenberg Basic: The GeoBasis and ClimateBasis programmes

The GeoBasis and ClimateBasis programmes collect data describing the dynamics of the physical and geomorphological environment at Zackenberg.

GeoBasis is operated by the Institute of Geography, University of Copenhagen, in cooperation with the Danish Polar Center and takes care of geomorphological monitoring, monitoring of water quality in rivers and soils, and active layer monitoring.

ClimateBasis is operated by ASIAQ, Greenland Field Investigations, who runs the climate station and the hydrometric station. Unfortunately, the climate data and water discharge data which should have been processed by ASIAQ were not ready for publication before the deadline of this 6th annual report (although it was postponed for 7 months). We hope to publish the missing data from 2000 in the 7th annual report together with the climate data for 2001.

Locations and specifications of GeoBasis and ClimateBasis installations are described in previous annual reports (Meltofte and Thing 1996; Meltofte and Rasch 1998; Rasch 1999; Caning and Rasch 2000). Data collected by the two programmes may be ordered from Institute of Geography, University of Copenhagen (e-mail: mr@geogr.ku.dk).

3.1 The meteorological station

Morten Rasch

For the reasons given above there will be no reporting of climate data from 1999 and 2000 in this annual report. Hopefully, the climate data will be published in the 7th annual report in 2002.

3.2 TinyTalk/TinyTag dataloggers

Morten Rasch

In 2000, GeoBasis operated 30 TinyTag/-TinyTalk temperature dataloggers for measurements of air temperature at three sites, soil temperature profiles incl. air temperature at six sites, water temperature at two sites and snow and air temperature inside and outside a snow patch at four sites. Position, purpose of measurements, interval between measurements and period of operation are given in Table 3.2.1 in Meltofte and Rasch (1998). Statistics on time series from the period 1996-98 are given in Table 3.1.

In 1999 important failures were identified in time series from 13 out of 27 dataloggers due to fall out of the dataloggers (Caning and Rasch 2000). The technical problem was solved partly in the field season 1999 by changing defect loggers and partly in 2000 by reinserting of new temperature sensors at location where the sensor cables were leaky. However, the fall out influences the time series from 1999. Therefore, it has not been possible to calculate the annual statistics for 1999 for ten out of thirty loggers.

Type of measurements	Datalogger
Active layer temperature profile	P1, 0 cm
	P1, 10 cm
	P1, 50 cm
	P1, 118 cm
Active layer temperature profile	P2, 0 cm
	P2, 10 cm
	P2, 70 cm
	P2, 155 cm
Active layer temperature profile	P3, 0 cm
	P3, 10 cm
	P3, 66 cm
Active layer temperature profile	P4, 0 cm
	P4, 10 cm
	P4, 85 cm
Active layer temperature profile	P5, 0 cm
	P5, 75 cm
	P5, 135 cm
Active layer temperature profile	P6, 0 cm
	P6, 10 cm
	P6, 30 cm
	P6, 60 cm
Air temperature in Morænebakkerne	T1
Air temperature in Store Sødal	T2
Air temperature on Aucellabjerg	T3
Water temperature in Zackenbergelven	V1
Water temperature in Gadekæret	V2
Air/snow temperature in snow patch	S1, Plateau
	S1, Slope
	S1, Snow
	S1, Below

In 1999, the hydrometric station was equipped with a water temperature and conductivity sensor logging directly on the datalogger connected to the hydrometric station. For this reason, the measurement of water temperature in Zackenbergelven with a TinyTag datalogger (V1, Table 3.1) was suspended. Unfortunately, the new measurements of water temperature in Zackenbergelven are not reported in this report for the reasons given above.

3.3 The hydrometric station

Morten Rasch

Due to the lack of input of data relating to river water discharge it has not been possible to calculate the water discharge and the fluxes of suspended sediment, organic matter and solutes (Na, K, Ca, Mg, Fe, Al, Mn, Cl, NO_3, SO_4, HCO_3) in the river. During the year 2000 field season, samples were collected every day at 8:00 for determination of suspended sediment, organic matter and solute concentrations. These samples have all been processed at Institute of Geography, University of Copenhagen. At the same time pH, conductivity and temperature were measured in the river. It is however meaningless to report the time series on river water chemistry and sediment concentrations without a river water discharge curve. The data will hopefully be reported in the annual report for 2001.

In 2000 Zackenbergelven started to run at the hydrometric station on 8 June. Larger floods occurred in the periods 22-28 June, 2-12 July and 31 July-5 August. Due to the limited amount of snow in the Zackenberg area this year, the river water discharge was generally at a much lower level than in previous years.

3.4 Landscape monitoring

Morten Rasch, Charlotte Sigsgaard, Jørgen Hinkler, Steen B. Pedersen

The following landscape monitoring is carried out at Zackenberg:

1. photos of different dynamic landforms at 24 sites,
2. photomonitoring of snow cover in Zackenbergdalen in cooperation with BioBasis,
3. active layer depth measurements at two sites,
4. soil water chemistry measurements at two sites,

Table 3.1: Statistics on time series from the TinyTag/TinyTalk dataloggers operated by GeoBasis.

Type	Position Easting (m)	Northing (m)	Elevation (m)	1996 Mean (oC)	Min. (oC)	Max. (oC)	1997 Mean (oC)	Min. (oC)	Max. (oC)	1998 Mean (oC)	Min. (oC)	Max. (oC)	1999 Mean (oC)	Min. (oC)	Max. (oC)
TinyTag	512,388	8,263,490	20	-7.7	-37.6	29.9	-9.8	-40.7	30.7	-9.1	-40.7	28.1	-9.3	-40.7	30.3
TinyTag	512,388	8,263,490	20	-10.5	-32.6	15.0	-9.6	-39.1	19.1	-8.8	-37.6	17.0	-8.7	-36.3	19.5
TinyTag	512,388	8,263,490	20	-6.7	-25.2	7.3	-9.0	-29.4	8.8	-8.3	-28.4	7.3	-8.3	-27.5	8.8
TinyTag	512,388	8,263,490	20	-5.9	-15.6	-0.1	-8.1	-18.3	-0.1	-7.8	-17.6	0.6	-8.0	-17.0	0.4
TinyTag	512,713	8,264,257	23	-5.6	-30.5	34.1	-7.8	-29.4	25.9	-7.5	-24.1	22.0	-7.1	-22.6	22.7
TinyTag	512,713	8,264,257	23	-6.1	-24.6	12.4	-8.4	-25.7	12.8	X	X	X	X	X	X
TinyTag	512,713	8,264,257	23	-6.0	-19.1	2.3	-8.1	-19.6	2.3	X	X	X	X	X	X
TinyTag	512,713	8,264,257	23	-6.5	-14.6	-1.4	-8.6	-16.4	-1.8	X	X	X	X	X	X
TinyTag	515,917	8,268,224	ca. 420	-6.2	-31.5	25.2	-9.6	-36.3	23.4	-7.8	-34.8	-23.4	-10.5	-36.8	19.8
TinyTag	515,917	8,268,224	ca. 420	-5.9	-27.5	18.1	X	X	X	X	X	X	-9.0	-26.5	15.6
TinyTag	515,917	8,268,224	ca. 420	-5.5	-20.3	6.9	-8.7	-23.3	6.5	X	X	X	X	X	X
TinyTag	516,936	8,269,597	ca. 820	-8.5	-33.7	27.0	-10.6	-39.1	27.4	-8.2	-27.5	30.7	-10.9	-32.0	26.3
TinyTag	516,936	8,269,597	ca. 820	-8.0	-28.4	16.3	-10.5	-33.7	14.9	-8.0	-24.9	19.1	-10.4	-28.8	14.2
TinyTag	516,936	8,269,597	ca. 820	-7.6	-18.9	1.9	-10.4	-22.5	1.1	-8.6	-20.3	2.7	-9.7	-19.7	1.0
TinyTag	509,964	8,267,457	ca. 260	X	X	X	-9.2	-36.0	20.4	X	X	X	-9.9	-33.7	19.1
TinyTag	509,964	8,267,457	ca. 260	X	X	X	-8.9	-22.4	11.0	X	X	X	-9.2	-19.6	9.5
TinyTag	509,964	8,267,457	ca. 260	X	X	X	-8.6	-21.7	11.3	X	X	X	-14.8	-27.5	0.6
TinyTag	513,068	8,263,921	11	X	X	X	-10.1	-37.6	19.1	-9.5	-32.6	18.4	-8.2	-32.6	24.1
TinyTag	513,068	8,263,921	11	X	X	X	-9.9	-25.7	10.6	X	X	X	X	X	X
TinyTag	513,068	8,263,921	11	X	X	X	-6.0	-23.3	15.6	X	X	X	X	X	X
TinyTag	513,068	8,263,921	11	X	X	X	X	X	X	X	X	X	X	X	X
TinyTag	511,090	8,268,397	85	-7.3	-33.6	21.6	-9.8	-37.2	23.6	-9.2	-39.1	19.1	-9.8	-37.6	18.4
TinyTag	509,105	8,269,215	129	-7.8	-35.0	20.6	-10.3	-39.1	21.6	-9.8	-40.7	24.5	-11.1	-40.7	18.8
TinyTag	518,023	8,269,902	965	-8.9	-36.0	19.8	-10.4	-37.6	17.7	-10.2	-40.7	20.2	X	X	X
TinyTag	512,654	8,264,548	14	-2.5	-11.9	8.4	-5.1	-11.8	20.2	X	X	X	X	X	X
TinyTag	512,978	8,264,538	35	-10.8	-23.8	15.9	-8.0	-27.4	19.4	-7.1	-27.5	18.1	-7.4	-28.4	37.7
TinyTag	512,209	8,264,467	29	X	X	X	-12.0	-37.3	26.5	-12.5	-39.1	18.1	-10.0	-39.1	33.3
TinyTag	512,209	8,264,467	25	X	X	X	-5.2	-11.5	20.5	-5.9	-21.7	22.3	-6.5	-17.6	24.1
TinyTag	512,209	8,264,467	23	X	X	X	X	X	X	X	X	X	X	X	X
TinyTag	512,209	8,264,467	16	X	X	X	-5.2	-9.5	26.6	-8.0	-32.6	22.3	-13.0	-35.0	14.5

5. measurements of ice wedge growth rate at two sites,
6. measurements of cross shore landscape changes at six sites, and
7. measurements of salt marsh accretion at two sites.

The measurements of cross shore landscape changes consist of measurements of coastal cliff recession at four sites and measurements of cross shore profiles at two sites. Due to very limited cross shore profile changes in the period 1991-1999 the two cross shore profiles were not surveyed in 2000, and will only be surveyed every second year in the future.

Fig. 3.1: Pictures from the digital cameras covering the central part of Zackenbergdalen. The pictures illustrate the melt of snow from 83% snow-cover at 3 June to 20% snow-cover at 20 June.

Monitoring photos

Morten Rasch, Jørgen Hinkler, Steen B. Pedersen

The 24 monitoring photos of different dynamic landforms that are included in GeoBasis programme (see section 3.4.1 in Meltofte and Rasch 1998) were not taken in 2000. Due to very limited changes of the landforms from year to year, it has been decided to take these photos every second year.

The automatic photomonitoring of the snow cover in Zackenbergdalen (carried out with two cameras placed at c. 450 m a.s.l. on the eastern slope of the mountain Zackenberg) were continued in 2000. The technique of the cameras, the transformation of the oblique photos into orthophotos, the identification of snow in the pictures and the calculation of snow cover are described in details in Sections 3.4 and 5.12 in Caning and Rasch (2000). There have been no significant problems with the camera. Once in a while during the winter, the camera lenses were covered with snow, but during the very important period of snow melt, the cameras were generally working properly. Fig. 3.1 shows the snow melt in Zackenbergdalen between 3 and 20 June. At 3 June the snow cover was calculated to 88%. At 20 June the snow cover was reduced to 20%. Fig. 3.2 gives the snow depletion curves for the southern part of Zackenbergdalen in the period 1998-2000. You may notice that the disappearance of snow cover occurred much faster in 2000 than in the two previous years. This is probably due to less snow thickness in 2000.

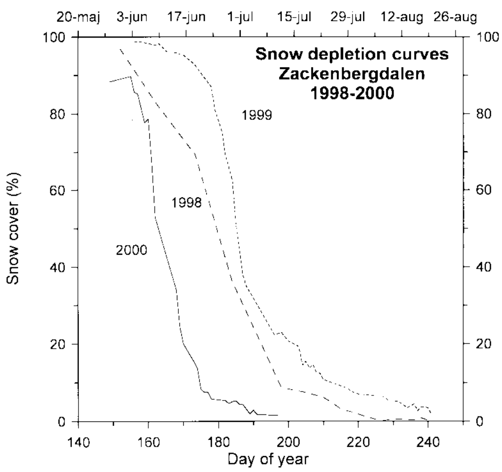


Fig. 3.2: Snow depletion curves for the southern part of Zackenbergdalen, 1998-2000.

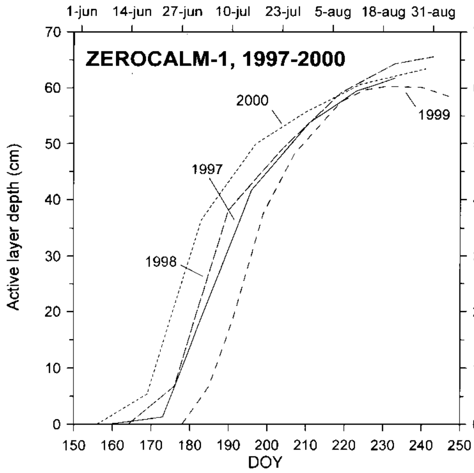


Fig. 3.3: Active layer development in ZEROCALM-1, 1997-2000.

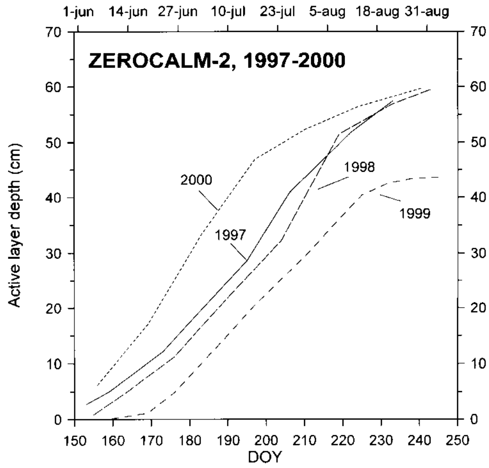


Fig. 3.4: Active layer development in ZEROCALM-2, 1997-2000.

Active layer depth

Morten Rasch

Active layer development is being monitored in two plots. One plot (ZEROCALM-1) consists of a 100 m x 100 m grid with a total of 121 measuring points on a horizontal and well-drained *Cassiope* heath near the climate station. The other plot is situated on a southerly exposed *Eriophorum* fen with a snow patch c. 500 m south of the runway. This plot consists of a 120 m x 150 m grid with 208 measuring points. More details about the plots are given in section 5.1.12 in Meltofte and Thing (1997).

Time series of active layer development for 1997–2000 are given in Figs. 3.3 (ZEROCALM-1) and 3.4 (ZEROCALM-2). You may notice, that the active layer in both plots developed earlier in 2000 than in the previous three years. This was probably due to the faster melt of snow in 2000.

Figs. 3.5 and 3.6 show the year 2000 maximum depth of the active layer in respectively ZEROCALM-1 and ZEROCALM-2. The measurements at the two Zackenberg sites are reported to the International Permafrost Association, and are incorporated in the database Circumpolar Active Layer Monitoring.

Soil water chemistry

Morten Rasch

Samples for determination of pH, conductivity, and content of water solutes (Na, K, Ca, Mg, Fe, Al, Mn, Cl, NO_3, SO_4, HCO_3) at different depths in the active layer were collected at the two soil water chemistry

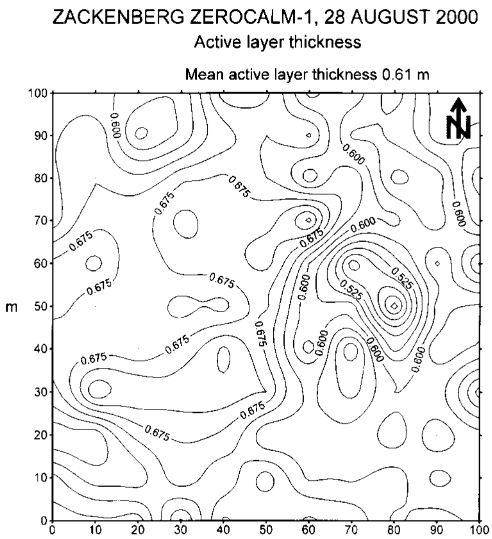


Fig. 3.5: Maximum active layer thickness in ZEROCALM-1, 28 August 2000.

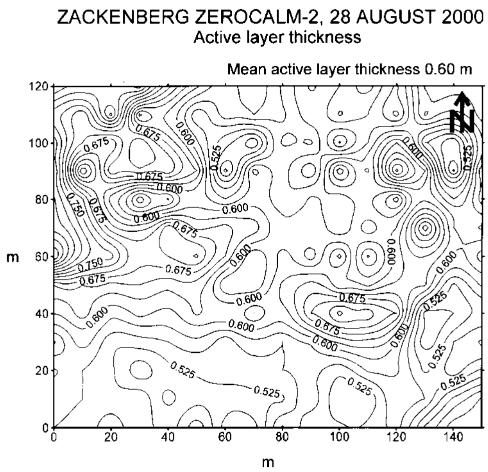


Fig. 3.6: Maximum active layer thickness in ZEROCALM-2, 28 August 2000.

	Recession (m)			
	Site 1	Site 2	Site 3	Site 4
1996-1997	0	0	0.3	1.0
1996-1998	0	0	0.3	1.3
1996-1999	0	0	0.5	1.3
1999-2000	0	0	0.7	1.4

Table 3.2: Total coastal cliff recession at the south coast of Zackenbergdalen in the period 1996-2000.

sites (Meltofte and Thing 1997). Due to restoration of the laboratory at Institute of Geography, University of Copenhagen, in late 2000 and early 2001 it has not been possible to finish the laboratory analyses of the soil water samples yet. A thorough evaluation of the seasonal changes in soil water chemistry at the two sites was given in the annual report for 1999 (Caning and Rasch 2000).

Fig. 3.7: Block slumping of old (Holocene) marine deposits in the delta of Zackenbergelven. A: Early July (Photo: Charlotte Sigsgaard). B: Late August (Photo: Morten Rasch).

Coastal geomorphology

Morten Rasch

A map indicating the GeoBasis coastal monitoring sites are given in Fig. 3.4.4.1 in Meltofte and Rasch (1998). Coastal cliff recession is measured at four sites along a cliff coast and changes of cross shore profiles on an accretionary part of the coast (a spit) are measured in two profiles. In year 2000, coastal cliff recession was measured at the four cliff recession sites. The results of the cliff recession measurements since 1996 are given in Table 3.2. Due to the very limited change of coastal geomorphology in the two cross-shore profiles in the period 1991-1999 these profiles were not surveyed in 2000. The profiles will be surveyed in year 2001.

Salt marsh accretion (established in 1996) will be measured every ten years.

Block slumping in the river delta

Charlotte Sigsgaard

During the summer 2000 erosion by block slumping was observed along the Zackenbergelven river bank at the tip of the delta on the western side of the river (Fig. 3.7). Combined effects of river water eroding the bank and melting of the permafrost resulted in the development of a thermo-erosional niche in the bank. At several occasions (26 June, 2 July, 10 July) the undercut frozen sediment collapsed along lines of weakness and big blocks of frozen sediment was detached. When exposed to the atmosphere the blocks were covered by a thin rime layer leaving them white until thawing began (Fig. 3.7).

The fresh exposures along the bank showed a profile of alternating horizontal layers of fine and coarse sediment. Erosion continued as long as water from Zackenbergelven cut into the cliff but after a few weeks the sediment/material at the foot of the cliff seemed to protect it from further direct erosion. As part of the monitoring programme, photographs were taken from marked positions and for measurements of further cliff recession four profile lines have been established.

3.5 General observations on ice conditions

Hans Meltofte

In accordance with the limited and thin snow layer this year (see e.g. section 3.4) the ponds north and south of the research station thawed earlier than recorded in previous years. Also the streams and rivers in the study area started to flow very early.

Lakes and streams

Already when the pioneer team arrived on 30 May, the ponds in Gadekæret and Sydkærene were partly ice free. When we arrived on 3 June, the western pond in Gadekæret was 95% ice free, but it was very shallow with exposed mud flats along the shores. On the same day, the eastern pond in Gadekæret was 75% ice free, and so was 80% of the large pond in Sydkærene, while the small pond west of it was totally ice free.

Although new ice formed on the ponds during night, the eastern pond in Gadekæret and the large pond in Sydkærene were already ice-free on 6 June. On 10 June practically all ice had disappeared from Gadekæret and the upper section of Sydkærene. This is as early as in 1996, but not fully as early as in 1997 (Meltofte and Thing 1997 and 1998).

Between 100 and 200 m^2 of open water had formed in the eastern end of Lomsø on 14 June, and on 21 June 20% of the lake was ice-free. On 1 July it was still half covered with ice, but on 7 July all ice had disappeared. This is the earliest recorded so far.

The ice on Store Sø had broken up by 8 July, and on 17 July only 5% ice remained.

After an initial low water level in several ponds, they filled up with melt-water during the first half of June, but several ponds dried up during late June and early July. Precipitation added a little during mid July, but in late July and early August, these ponds dried up again.

Already by 4 June, or earlier than previously recorded, Kærelv began to run, and a large area in Rylekærene appeared with water soaked snow. Zackenbergelven started to run on 8 June, while the remaining small streams on the slopes of Aucellabjerg did not begin to run until 9 June.

The fjord

The fast ice edge off the fjords in southern Northeast Greenland was considerably further out at sea than recorded for many years. Hence, off Young Sund the ice edge was many kilometres to the east, and not until 5 July, the ice broke around Sandøen.

As usual, large areas of open water formed outside Zackenbergelven during early July, and already on 8 July the fjord ice broke up from Zackenberg to Basaltøen, and Tyrolerfjord appeared largely ice free. However, the ice in the outer part of the fjord did not break up until 17 July, or within the range recorded in previous years (12-24 July).

In mid July, large amounts of drift ice entered Young Sund, but most of it disappeared soon after.

4 Zackenberg Basic: The BioBasis programme

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 Dancea, the Environmental Protection Agency, Ministry of Environment and Energy, Denmark. This does not include that evaluations presented in this report mirror the opinions of the Environmental Protection Agency.

The programme was continued with the extensions initiated in 1999 (Caning and Rasch 2000). Furthermore, the botanical ZERO-line, marking plant community zones from sea level to the top of Aucellabjerg, was reanalysed and further developed (see section 4.1). The same applies to the cryptogam monitoring plots. Vascular plant species with a northern distribution limit in the region were marked and their reproductive status was assessed. In early August, the distribution of plant communities in the entire study area was mapped by multi-spectral photos taken from a height of 6600 feet (see section 5.8).

In 2000, BioBasis personnel collected down and feathers from young waders for chemical 'fingerprints' of the origin of nutrients used to produce eggs (see section 5.8 in Caning and Rasch 2000), 200 live Greenlandic seed bugs *Nysius groenlandicus* for physiological studies (section 5.10) and three individuals of collared lemming *Dicrostonyx groenlandicus* for exhibition at the Natural History Museum of Aarhus.

Table 4.1. Inter- and extrapolated dates of 50% snow cover 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 flower plots 1996-2000. Interpolations based on samples of less than 50 buds/flowers are given in brackets.*

Plot no.	**1996**		**1997**		**1998**		**1999**		**1999**	
	50% snow	**50% flowers**	**50% snow**	**50% flowers**	**50% snow**	**50% flowers**	**50% snow**	**50% flowers**	**50% snow**	**50% flowers**
Cassiope 1	14.6	2.7	9.6	6.7	13.6	6.7	27.6	13.7	2.6	(28.6)
Cassiope 2	19.6	6.7	21.6	20.7	27.6	(21.7)	4.7	(26.7)	<4.6	-
Cassiope 3	15.6	9.7	21.6	18.7	20.6	(19.7)	3.7	(26.7)	13.6	-
Cassiope 4	20.6	15.7	15.6	15.7	20.6	(21.7)	4.7	(26.7)	13.6	-
Dryas 1	<3.6	19.6	<27.5	22.6	23.5	26.6	6.6	3.7	<4.6	26.6
Dryas 2	26.6	13.7	27.6	4.8	4.7	8.8	12.7	-	21.6	24.7
Dryas 3	6.6	2.7	<27.5	26.6	7.6	6.7	19.6	13.7	<4.6	27.6
Dryas 4	1.6	27.6	3.6	6.7	13.6	(9.7)	21.6	14.7	<4.6	26.6
Dryas 5	6.6	30.6	31.5	5.7	4.6	1.7	14.6	7.7	<4.6	22.6
Dryas 6	21.6	19.7	4.7	9.8	5.7	(7.8)	11.7	19.8	20.6	21.7
Papaver 1	20.6	14.7	18.6	20.7	21.6	24.7	3.7	2.8	1.6	4.7
Papaver 2	20.6	14.7	20.6	23.7	21.6	26.7	4.7	30.7	14.6	15.7
Papaver 3	21.6	14.7	15.6	19.7	20.6	26.7	3.7	1.8	13.6	10.7
Papaver 4	21.6	15.7	4.7	7.8	5.7	11.8	11.7	15.8	20.6	(20.7)
Salix 1	<3.6	6.6	<27.5	6.6	<27.5	12.6	<1.6	14.6	<3.6	11.6
Salix 2	14.6	21.6	20.6	29.6	23.6	10.7	1.7	17.7	13.6	28.6
Salix 3	7.6	20.6	8.6	25.6	12.6	(28.6)	24.6	5.7	<3.6	11.6
Salix 4	20.6	29.6	5.6	23.6	21.6	2.7	22.6	3.7	7.6	17.6
Saxifraga 1			<27.5	31.5	<27.5	5.6	<1.6	7.6	<3.6	6.6
Saxifraga 2			<27.5	2.6	<27.5	7.6	27.5	14.6	<3.6	9.6
Saxifraga 3	?	5.6	<27.5	1.6	27.5	9.6	6.6	16.6	<3.6	7.6
Silene 1	<3.6	20.6	<27.5	24.6	<27.5	21.6	<1.6	28.6	<3.6	26.6
Silene 2	<3.6	23.6	<27.5	29.6	<27.5	1.7	27.5	30.6	<3.6	2.7
Silene 3	?	30.6	<27.5	26.6	27.5	23.6	6.6	6.7	<3.6	28.6
Silene 4	24.6	26.7	28.6	10.8	20.6	20.8	6.7	-	21.6	28.7

Furthermore, BioBasis assistant Dorthe Prip Lahrmann made observations on time budgets of waders and took samples of their potential prey (see section 5.5).

Details on BioBasis methods and sampling procedures are presented in a manual (Meltofte and Berg 2000), which is available from the home page of NERI (http://biobasis.dmu.dk). A map with locality names used in this chapter is found at the same place. On the home page, even a synopsis of the entire BioBasis programme and all primary data are presented.

Unfortunately, a number of misprints appeared especially in the mammal section of the 1999 annual report. Corrections are given in the Erratum section of the present report (p. 80).

4.1 Vegetation

Hans Meltofte, Mikkel Tamstorf, Henrik Søgaard, Claus Nordstrøm, Morten Rasch, Charlotte Sigsgaard, Christian Bay and Eric Steen Hansen

The weekly records on amounts and phenology of flowering etc. were made by Dorthe Prip Lahrmann during the entire season.

Reproductive phenology

Hans Meltofte

Due to the limited amounts and extent of snow-cover and the consequently early snow melt, flowering was generally within +/-11 days of recorded values for the earliest of the previous four years.

Several plots that used to be snow-covered at the start of the season were already free from snow when we arrived in early June, and most of the remaining plots cleared 1-7 days earlier than during the early seasons of 1996 and 1997 (Table 4.1). In spite of this, flowering was earlier than previously recorded only in six plots, while 15 plots actually had later flowering than in the hitherto earliest seasons (Table 4.1).

Quantitative flowering

Hans Meltofte

Flower buds are established already the year before, so conditions in 1999 determined the numbers of flowers this year. In accordance with the unprecedented late snow melt in 1999, numbers of *Cassiope tetragona* flowers were extremely low for the third year in succession (Table 4.2). The same applies to a few other plots that were late snow free in 1999, but otherwise

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

Table 4.2. Area size (m^2) and pooled numbers of flower buds, flowers and senescent flowers of white arctic bell-heather Cassiope tetragona, *mountain avens* Dryas integrifolia/octopetala, *arctic poppy* Papaver radicatum, *arctic willow* Salix arctica, *purple saxifrage* Saxifraga oppositifolia, *moss campion* Silene acaulis, *arctic cotton-grass* Eriophorum scheuzerii *(corrected data for 1996) and 'dark cotton-grass'* Eriophorum triste *in flower plots in 1995-2000. Numbers in brackets have been extrapolated from 1995 and 1996 data to make up for enlarged plots (see Meltofte and Rasch 1998).*

Table 4.3. Peak ratio (per cent) of female Salix *pods infested by fungi in* Salix *plots in 1996-2000.*

Plot no.	1996	1997	1998	1999	2000
Salix 1	5	4	0	22	4
Salix 2	0	1	2	2	0
Salix 3	0	0	0	6	0
Salix 4	16	3	0	6	0

Plot no.	1996	1997	1998	1999	2000
Vegetation 1	13.6	30.5	6.6	13.6	<4.6
Vegetation 2	<3.6	22.6	24.6	20.7	4.6
Vegetation 3	20.6	20.6	20.6	28.6	13.6
Eriophorum 1		14.6	19.6	4.7	<4.6
Eriophorum 2		14.6	20.6	2.7	10.6
Eriophorum 3		27.6	21.6	7.7	14.6
Eriophorum 4		25.6	22.6	28.6	15.6

Table 4.4. Date of 50% snow cover in the three plant community study plots and in the four Eriophorum *plots.*

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

Table 4.6. Peak Normalised Difference Vegetation Indexes (NDVI) recorded in the flower plots in 1999 and 2000 together with date of maximum record. NDVI values presented are transformed averages of eight (four in very small plots) RVI measurements in each plot. Note that the greening measured accounts for the entire plant community, in which the taxon denoted may only make up a minor part.

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

Table 4.5. Area size (m^2) and numbers of berries recorded in three plots of alpine bearberry Arctostaphylos alpina, *Arctic blueberry* Vaccinium uliginosum *and crowberry* Empetrum nigrum *in 1998-2000.*

most plots produced amounts of flowers that were within the range from previous years. This may be related to the likewise 'normal' microclimate temperatures in July and August 1999 (Table 3.4 in Caning and Rasch 2000).

This year, only a few female Salix arctica pods were infested with fungi (Table 4.3).

Snow melt in 400 m² plant community study plots and Eriophorum plots

Hans Meltofte

Snow melt in the three plant community study plots and in the four *Eriophorum* plots followed the general trend of very early snow melt in 2000 (Table 4.4).

Berry production

Hans Meltofte

The study plots for alpine bearberry and Arctic blueberry production showed highly reduced numbers after the very late season of 1999, when the buds for these berries were initiated (Table 4.5). On the contrary, more crowberries were produced than in the year before.

NDVI in flower plots

Hans Meltofte

It appears from Table 4.6 that the 'greening' of the vegetation in 26 vegetation plots as expressed by Normalised Difference Vegetation Indexes (NDVI) reached higher values in most plots than the year before. Even more pronounced was the peak of greening that occurred 1-5 weeks earlier in almost all plots than in the unprecedented late season of 1999. This is in accordance with the measurements on plant respiration, where the growing season was found both to begin and end about 10 days earlier in 2000 than in 1997 (see Table 4.10), a year apparently with close to average phenology.

Section	Min.	Max.	Mean	S.D.
1	0.00	0.89	0.29	0.20
2	0.00	0.78	0.40	0.18
3	0.00	0.96	0.40	0.19
4	0.00	0.88	0.30	0.18
5	0.00	0.66	0.21	0.16
6	0.00	0.74	0.32	0.18
7	0.00	0.84	0.31	0.19
8	0.00	0.82	0.24	0.20
9	0.00	0.75	0.38	0.19
10	0.00	0.84	0.39	0.17
11	0.00	0.94	0.25	0.22
12	0.00	0.83	0.27	0.24
Lemming	0.00	0.78	0.39	0.16
Total area	**0.00**	**0.82**	**0.32**	**0.19**

Table 4.7. NDVI values for 12 sections of the bird and musk ox monitoring areas in Zackenbergdalen together with the lemming monitoring area (part of section 2) based on a Landsat TM satellite image from 29 July 1999. The image has been georectified and corrected for atmospheric humidity, aerosols, solar angle and terrain effects. All negative NDVI-values have been changed to 0, so that water and snow covered areas are given similar values from year to year.

Section	Min.	Max.	Mean	S.D.
1	0.00	0.78	0.39	0.17
2	0.00	0.86	0.46	0.15
3	0.00	0.79	0.49	0.13
4	0.00	0.78	0.41	0.13
5	0.00	0.97	0.35	0.18
6	0.00	0.77	0.42	0.15
7	0.00	0.73	0.41	0.14
8	0.00	0.96	0.33	0.20
9	0.00	0.78	0.48	0.14
10	0.00	0.82	0.50	0.11
11	0.00	0.84	0.39	0.18
12	0.00	0.98	0.30	0.24
Lemming	0.00	0.79	0.45	0.13
Total area	**0.00**	**0.83**	**0.41**	**0.16**

Table 4.8. NDVI values for 12 sections of the bird and musk ox monitoring areas in Zackenbergdalen together with the lemming monitoring area (part of section 2) based on a Landsat TM satellite image from 23 July 2000. The image has been georectified and corrected for atmospheric humidity, solar angle and terrain effects. All negative NDVI-values have been changed to 0, so that water and snow covered areas are given similar values from year to year.

NDVI in bird and mammal study plots

Hans Meltofte and Mikkel Tamstorf

Satellite images from late July 1999 and 2000 have now been analysed for Normalised Difference Vegetation Indexes (NDVI) by the National Environmental Research Institute, Department of Arctic Environment, after an agreement with Greenland Field Investigations (Asiaq). The analyses are funded by Dancea, the Environmental Protection Agency, Ministry of Environment and Energy, Denmark.

Our study area in Zackenbergdalen has been divided into 12 sections covering the bird and musk ox monitoring areas. Numbers 1-5 cover the bird monitoring area from south-west to north-east, while the remaining numbers cover the musk ox monitoring areas west (nos 6-8) and east (nos 9-12) of the bird monitoring area, respectively. Sections 1, 2 and 9 are below 50 m a.s.l. Sections 3, 6 and 10 are between 50 and 150 m a.s.l., sections 4, 7 and 11 are between 150 and 300 m a.s.l., and sections 5, 8 and 12 are between 300 and 600 m a.s.l. Besides these sections, the lemming monitoring area, situated within section 2, has been analysed separately.

In accordance with the plot measurements (see section above), the 'greening' of the vegetation in the 13 sections of the monitoring area was significantly more intense in the favourable season of 2000 than in the very late season of 1999 (Tables 4.7, 4.8 and 4.9). The difference holds good for all sections of the study area. Compared to 1998, the values for 2000 are somewhat lower, but this may at least partly be attributed to the earlier date of the satellite image from 2000. At a later stage, all values will be extrapolated to a fixed date.

Summertime carbon budget for the Zackenberg heath

Henrik Søgaard, Claus Nordstrøm, Morten Rasch and Charlotte Sigsgaard

In 1996, continuous measurements of carbon dioxide exchange were initiated at Zackenberg as part of a European research project run by the Institute of Geography, University of Copenhagen (see Meltofte

Table 4.9. Mean NDVI values for 12 sections of the bird and musk ox monitoring areas in Zackenbergdalen together with the lemming monitoring area (part of section 2) based on Landsat TM satellite images 1998-2000. Values from 1998 have been reanalysed using the same procedure as for 1999 and 2000 (see Tables 4.7 and 4.8). When comparing values, it should be noted that the data have not been corrected for differences in growth phenology between years.

	1998	**1999**	**2000**
Section	**30.7**	**29.7**	**23.7**
1	0.43	0.29	0.39
2	0.50	0.40	0.46
3	0.52	0.40	0.49
4	0.43	0.30	0.41
5	0.37	0.21	0.35
6	0.45	0.32	0.42
7	0.44	0.31	0.41
8	0.41	0.24	0.33
9	0.51	0.38	0.48
10	0.52	0.39	0.50
11	0.42	0.25	0.39
12	0.44	0.27	0.30
Lemming	0.49	0.39	0.45
Total area	**0.46**	**0.32**	**0.41**

and Thing 1997). Since then, measurements have been conducted each year as part of this research project. From year 2000, the measurements were integrated into the biological monitoring program, BioBasis, by installing and operating an eddy correlation systems at a heath site located about 100 m north of the climate station. This monitoring was established as a cooperation between the National Environmental Research Institute and the Institute of Geography. During the field season, the equipment is serviced by GeoBasis personnel.

The eddy correlation system was mounted in the beginning of June. The data collection started by 6 June, and it continued until 25 August with only few interruptions.

Methodology

At the heath site, the vertical fluxes of water vapour and carbon dioxide are measured by use of the eddy correlation technique. The instrumentation consisted of a three-dimensional (3-D) sonic anemometer (Solent 1012R2, Gill Instruments, Lymington, UK) for measuring wind speed and an Infrared Gas Analyzer (IRGA) (Li-6262, LI-COR, Nebraska, USA) for measuring water vapour and carbon dioxide concentrations.

The sonic anemometer and the sampling tube inlet of the IRGA are situated 3 m above ground level. Most of the flux (90%) originates from an area approximately 200 m by 40 m (8000 m^2) on the windward side of the mast, which during daytime is mostly SE-S. Data collecting and processing is based on the EdiSol software package (Moncrieff *et al*. 1997). As a supplement to the atmospheric fluxes, a number of micro-meteorological parameters are measured simultaneously. These data include air temperature and air humidity (MP100A, Rotronic, Campbell scientific, LTD, UK), soil temperature (thermocouple), IR surface/canopy temperature (KT-17, Heimann, Germany) and soil moisture (Delta-T Cambridge, UK).

Results

Fig. 4.1 shows the temporal variation in the daily net exchange of carbon dioxide also called the Net Ecosystem Exchange (NEE). Here, the daily values are expressed as g C per square meter per day. Basically, the net carbon budget consists of two main components, i.e. the CO_2 uptake caused by photosynthesis and the CO_2 emission from the soil mostly due to microbial activity in the upper 5 cm. The last term is also denoted the soil respiration. Besides weather conditions, the carbon assimilation depends on the amount and type of vegetation. Around the mast, the dominant species are *Cassiope tetragona*, *Dryas* sp. and *Vaccinium uliginosum*. The leaf area index is relatively low (0.2-0.3). Soil respiration is controlled by the amount of organic matter in the topsoil and increases exponentially with the soil temperature.

Examining the graph makes it possible to identify three different periods:

1. The end of the winter with temperatures below the freezing point and daily budgets mostly above zero, i.e. the heath functioned as CO_2 source, where the photosynthesis was small compared to the soil respiration. Large fractions of the area progressively became snow-free, and the snow cover had disappeared by 20 June. By comparison with the temperature plot it is found that there is a strong correlation between air temperature and CO_2 emission rates. This period lasted until 24 June.

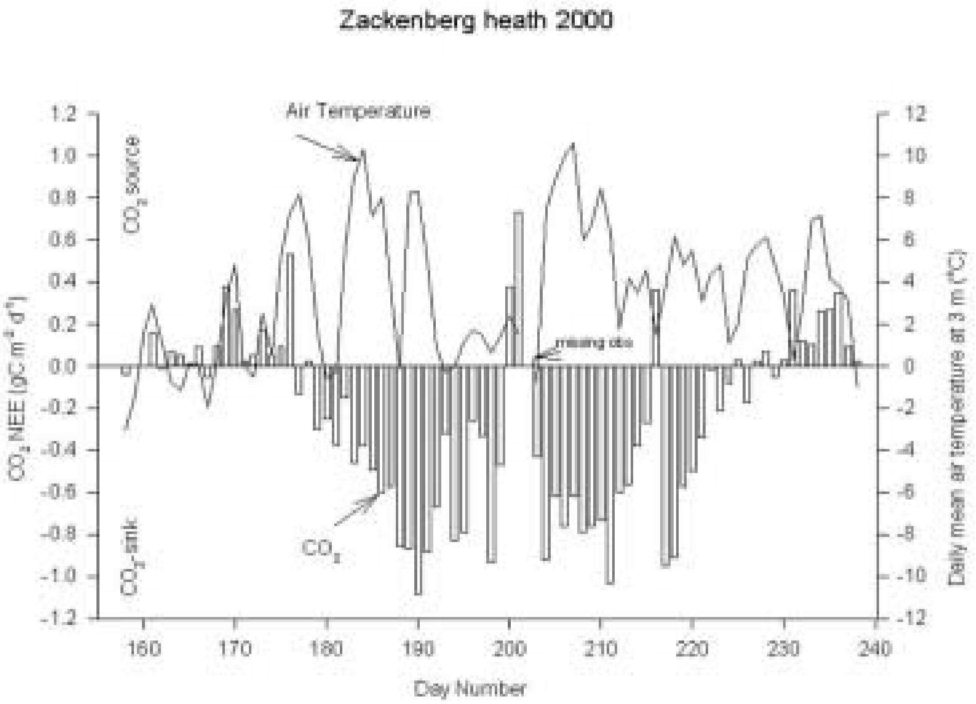


Fig. 4.1. Temporal variation in daily carbon dioxide exchange and mean air temperature on the Cassiope heath north of the climate station in 2000.

2. The summertime period was characterised by a net C accumulation. The period lasted until 11 August. During the peak growing season, daily accumulation rates were around 0.9 g C/m^2, only interrupted by a couple of occasions with bad weather, where the net exchange could even reverse and the ecosystem function as a C source. For dwarf shrub vegetation it has previously been reported that there is a very rapid transition from winter to summer conditions. Comparing the course of the air temperature and the course of the CO_2 exchange, it seems that the onset of the CO_2 accumulation was triggered by a warm period during 30 June-4 July having air temperatures above 5°C for several days.

3. The third and last period was characterised by C loss. The transition from summer to autumn in terms of C sink/source took place around 11 August. Even though photosynthesis continued until September, the magnitude of the carbon accumulation was clearly below the carbon loss due to soil and leaf respiration.

The general trends in the seasonal variation are summarised in Table 4.10. The corresponding figures for 1997 (Soegaard *et al*. 2000) are also given. When compared to 1997 values it is seen that the growing season of 2000 started earlier and reached a higher peak level resulting in a double as high C accumulation during the growing season.

From a technical viewpoint, this first year of flux measurements within the BioBasis programme has been a success. More than 1900 hours of consistent flux measurements were collected and less than 4% were lost due to malfunction, maintenance and calibration procedures. To get the full benefit of these data, a more intensive analysis should be done including comparisons with previous years and CO_2 exchange modelling.

The ZERO-line

Christian Bay

The ZERO-line, marking 128 vegetation zones from the shore of Young Sund to the peak of Aucellabjerg, was established in 1992 and 1994 (Fredskild and Mogensen

Table 4.10. General characteristics of the CO_2 exchange on the Cassiope heath north of the climate station in 1997 and 2000, respectively.

Year	1997	2000
Beginning of growing season	7 July	25 June
End of growing season	21 August	11 August
Length of growing season	46 days	47 days
Beginning of measuring season	7 June	6 June
End of measuring season	25 August	25 August
Length of measuring season	80 days	81 days
NEE for growing season (g C/m^2)	(-) 12.5	(-) 22.7
NEE for whole mesuring season (g C/m^2)	(-) 3.1	(-) 19.1
Avg peak daily accumulation (g C/m^2/d)	(-) 0.65	(-) 0.92

Table 4.11. Maximum growing altitude (m a.s.l.) recorded for dwarf shrub species along the ZERO-line.

Species	Max. altitude
Betula nana	47
Rhododendron lapponicum	74
Cassiope tetragona	267
Vaccinium uliginosum	278
Dryas sp.	580
Salix arctica	600

1997). At the same time, all vascular plant species were recorded in the different plant communities, and their frequencies were given according to the Böcher-modified Raunkiær method (Böcher 1935). However, the exact position of each of these Raunkiær-circles was not established during this initial analysis. The border between each zone was marked with a numbered plate on a peg.

This year, 1280 Raunkiær circle centres were established with aluminium tubes, and vegetation analyses were carried out at each of them by Christian Bay assisted by Henrik Gammelager during 27 July-14 August. The width of the zones varies from a few meters to several hundred meters and the permanent plots in each zone were established as follows: Five plots were established on the line at the beginning of each zone and another five plots at the end of each zone, with intervals of two meters between them. In case the zone was only few meters wide, as many as possible of the plots were established on the line with a distance of two meter and the rest were placed in the plant communities on a line perpendicular to the ZERO-line starting on the western side closest to the line.

Species and their frequencies were recorded, and it was also recorded if the species were reproductive (presence of buds, flowers or fruits) within the 1/10 m^2 circle. Photos were taken of all the permanent pegs (viz. vegetation borders) from the eastern side of the line. Reanalysing of the plots is planned to take place every five years in order to identify major vegetational changes.

Of the 152 species of vascular plants found in Zackenbergdalen, 96 species were recorded within the 1280 plots along the ZERO-line. The species diversity varied from a total of four species in the 10 plots in a salt marsh closest to the shore and up to 30 species in 10 plots (1 m^2) in the most diverse plant community, i.e. wet grassland. As a significant response to an increased summer temperature will be reflected in the altitudinal distribution of plants, Table 4.11 gives the maximum altitude (m a.s.l.) for the dwarf shrub species.

Since the previous records from 1992 and 1994 were not made on the same spots, no attempt to compare the results has been made at this stage.

Northernmost range species

The Zackenberg area is on the northern distribution limit of several low arctic vascular plant species (Bay 1992). Species growing close to their known northern distribution are vulnerable to environmental changes, primarily summer temperature, water availability and snow cover.

Five species, two dicots and three monocots, at their northern distribution limit or close to it were found and permanent plots were established by Christian Bay. The number of buds, flowers and fruits were assessed. Focus was on *Campanula gieseckiana*, *Salix herbacea*, *Carex lachenalii*, *C. glareosa* and *C. norvegica*. A total of 24 plots were established.

Lichens

Eric Steen Hansen

The fourteen plots established in 1994 by Michael Andersen and Eric Steen Hansen (Hansen 1995a) were inspected by Eric Steen Hansen from 28 July to 2 August. Two new rock-plots measuring 0.20 x 0.20 m were established in the area west of Zackenbergelven; one of them (P16) replaces P9 on a S-facing scree on Zackenberg, the other (P15) is located on a gneissic boulder just north of the old trapping station. In addition, three new plots (P17, P18 and P19) were established in epigaeic lichen vegetation in the lowland south-east of the research station. They were marked with aluminium pegs and measure 1 m^2 like the other permanent plots made in epigaeic vegetation. Three plots were made with the particular purpose of monitoring damages on *Cladonia mitis* and *C. amaurocraea* caused by increased UV-B radiation.

Twenty-five permanent stations were established along the ZERO-line from Young Sund to the top of Aucellabjerg, 1040 m a.s.l. during 3-8 August. Each station consists of ten Raunkjær-plots marked by alu-

Table 4.12. Degree of covering (A), number of thalli (B), maximum thallus diameter in mm (C) and presence of lichens (D) in plots in 1994 and 2000. P1-P8 & P10: epilithic lichen communities. P11-P14: epigaeic communities. The degree of covering was estimated using the following, modified scale of Hult-Sernander: 5=>1/2; 4=1/2-1/4; 3=1/4-1/8; 2=1/8-1/16; 1<1/16; +=just present, ++=dominating.

Plot 1	**1994**	**2000**
	D	D
Xanthoria elegans	*	*
Xanthoria sorediata	*	*
Umbilicaria virginis	*	*
Umbilicaria lyngei	*	*
Neuropogon sphacelata	*	*
Physconia muscigena	*	*
Pseudephebe minuscula	*	*
Sporastatia testudinea	*	*
Rhizocarpon geographicum	*	*
Lecanora polytropa	*	*
Lecidea atrobrunnea	*	*
Rhizoplaca melanophthalma	*	*
Aspicilia	*	*
Rock	*	*

* means that the lichen is present in the plot. The degree of covering and the number of thalli was not measured here. However, *Xanthoria* is the dominant lichen in P1.

Plot 2		**1994**			**2000**	
	A	B	C	A	B	C
Umbilicaria lyngei	2	100	2	2	100	2
Pseudephebe minuscula	+	1		1	2	
Sporastatia testudinea [1]	+	1		1	2	4.5
Rhizoplaca melanophthalma	+	1		1	2	
Rock	5			5		

[1] Infested by *Rhizocarpon pusillum*

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

Plot 4		**1994**			**2000**	
	A	B	C	A	B	C
Physcia caesia	++			++		
Umbilicaria decussata	13			40		
Xanthoria borealis	12			22		5
Lecidea atrobrunnea	4			6		1
Candelariella vitellina	2			7		0.5
Sporastatia testudinea	-			2		2
Acarospora	-			1		1.5

Plot 5		**1994**			**2000**	
	A	B	C	A	B	C
Dimelaena oreina	3			3		
Umbilicaria lyngei	1	15		1	15	1.5
Sporastatia testudinea [1]	1	10(6?)		1	6	
Rhizoplaca melanophthalma	1	7		1	7	3
Rhizocarpon geographicum		5			6	1
Rhizocarpon (gray thallus) [2]	1	2		1	2	
Pseudephebe minuscula	+	1		1	7	2
Umbilicaria decussata				+	2	2
Lecidea atrobrunnea				+	2	1
Rock	5			5		

[1] Infested by *Rhizocarpon pusillum.* Thalli somewhat fragmented.
[2] Infested by *Caloplaca epithallina*

→

Plot 6	**1994**			**2000**		
	A	B	C	A	B	C
Umbilicaria virginis		29			31	1.5
Lecidea atrobrunnea						3.2

Plot 7	**1994**			**2000**		
	A	B	C	A	B	C
Lecidea atrobrunnea	4			5		7
Umbilicaria decussata	2	12		2	20	
Rhizocarpon geographicum	1			1	32	
Candelariella vitellina	+			1		
Rock	4			4		

Plot 8	**1994**			**2000**		
	A	B	C	A	B	C
Parmelia saxatilis	4			5		
Umbilicaria decussata	+			-		
Pseudephebe minuscula	-			+		
Rock	4			4		

Plot 10	**1994**			**2000**		
	A	B	C	A	B	C
Umbilicaria lyngei	3		1.2	3		1.5
Sporastia testudinea [1]	2			2		
Rhizocarpon (yellow thallus)	1			1		
Pseudephebe minuscula	+			1		
Rock	4			4		

[1] Infested by *Rhizocarpon pusillum*

Plot 11	**1994**		**2000**	
	A	B	A	B
Cassiope	5		5	
Salix arctica	1		1	
Cetrariella delisei	1	7	1	5
Cetraria islandica	1	5	1	5
Stereocaulon alpinum	1	4	1	4
Peltigera malacea	+	2	+	2
Flavocetraria nivalis	+	1	+	2
Solorina crocea	+	1	-	
Cladonia pyxidata	+		+	
Cladonia borealis	+		+	
Ochrolechia frigida	+		-	
Psoroma hypnorum	+		+	
Moss	1		1	
Peltigera rufescens	-		1	4
Peltigera leucophlebia	-		+	1
Flavocetraria cucullata	-		+	1

→

minium tubes perpendicular to the ZERO-line with five plots on each side of the line. A yellow aluminium tube marks the intersection point.

Records from plots that were surveyed both in 1994 and 2000 are presented in Table 4.12.

Kirsten Caning and Gabrielle Stockmann assisted the author during the vegetation analyses along the ZERO-line. The vertical distribution of lichens on Aucellabjerg was investigated by Eric Steen Hansen and Michael Andersen in 1994 (Hansen 1996).

Epilithic lichens

P1, situated at the ZERO-line near the top of Aucellabjerg (Fredskild & Mogensen 1997), was established with the purpose of monitoring changes in snow melt at this high level of the mountain. The plot, which measures 2 x 5.80 m, was photographed, and the presence of lichens was noted. *Xanthoria*, which grow in a depression in the plot, is dependent on an ample water supply during part of the summer and probably will die, if the basaltic substratum is too dry in a number of summer periods. No significant changes in the lichen vegetation at this plot were observed in the 2000 season.

Like P1, P6 is located on basalt near the ZERO-line, but at a somewhat lower level. As expected, the number of thalli of *Umbilicaria virginis* had slightly increased since 1994. The species probably grows rather slowly at this altitude (c. 600 m a.s.l.).

P2-P5 are situated on four gneissic boulders on a ridge just above Oksebakkerne and near the ZERO-line. New thalli of *Pseudephebe minuscula*, *Sporastatia testudinea* and *Rhizoplaca melanophthalma* were recorded in P2. The number of thalli of *Umbilicaria lyngei* in P2 had remained unchanged since 1994, contrary to those occurring in P3. Here an increase in the number of thalli of *U. lyngei* was recorded. A significant increase in number of thalli of *Umbilicaria* was found in P4. This also applies to *Xanthoria borealis*, *Candelariella vitellina* and to some extent *Lecidea atrobrunnea*. These three lichens are distinctly nitrophilous and probably have been favoured by nutrients from musk ox dung. No guano was observed on the blocks, but this source of nitrogen probably has influenced the epilithic lichen communities,

Plot 12	**1994** A	B	**2000** A	B
Dryas	4		4	
Carex rupestris	3		3	
Hierochloë alpina	+		+	
Salix arctica	+		+	
Potentilla hyparctica	+		+	
Stellaria longipes	+		+	
Cerastium arcticum	-		+	
Flavocetraria nivalis	1	25	1	30
Cetraria islandica	1	20	1	20
Stereocaulon alpinum	1	10	1	10
Peltigera rufescens	1	10	1	<5
Candelariella placodizans	1	10	+	5
Ochrolechia frigida	1		1	
Cetraria muricata	+	10	+	4
Cladonia borealis	+	5	+	<5
Cladonia pyxidata	+		+	5
Baeomyces	+		+	
Arthrorhaphis alpina	-		+	5
Candelariella terrigena	-		+	2
Peltigera didactyla	-		+	
Psoroma hypnorum	-		+	

Plot 13	**1994** A	B	**2000** A	B
Kobresia myosuroides	5		5	
Carex bigelowii	+		+	
Luzula	+		+	
Polygonum viviparum	+		+	
Dryas	+		+	
Cladonia pocillum	+	25	+	25
Physconia muscigena	+		+	
Cladonia borealis	+		+	
Rinodina turfacea	+		+	

Plot 14	**1994** A	B	**2000** A	B
Dryas	4		5	
Carex rupestris	3		3	
Cladonia pocillum	1		1	
Thamnolia subuliformis	+		1	36
Flavocetraria nivalis	+	10	+	10
Hypogymnia subobscura	+	4	+	3
Alectoria nigricans	+	2	+	
Bryoria chalybeiformis	+	2	+	3
Ochrolechia upsaliensis	+	2	+	
Peltigera rufescens	+	1	-	
Rinodina venosa	-		+	2
Rinodina turfacea	+	1	+	
Baeomyces	+	1	+	
Catapyrenium cinereum	+		+	
Cladonia pyxidata	+		+	
Lecanora epibryon	+		+	
Phaeorrhiza nimbosa	+		-	
Ochrolechia frigida	+		-	
Physconia muscigena	+		-	
Solorina bispora	+		-	
Flavocetraria cucullata	-		+	3
Cetraria muricata	-		+	
Caloplaca cerina	-		+	
Caloplaca tirolensis	-		+	
Moss	+	5	+	

too. *Sporastatia testudinea* and Acarospora are new species recorded in P4. In P5, the dominant crustaceous lichen, *Dimelaena oreina*, had increased its size only to a small extent. The most important change since 1994 was the increase in the number of thalli and size of *Pseudephebe minuscula*. It is a black macrolichen with high heat absorption capacity. New thalli of *Umbilicaria decussata* and *Lecidea atrobrunnea* had appeared in P5. Undoubtedly, musk oxen have influenced the lichen vegetation in P2-P5 to a very considerable extent.

P7 is located on a gneissic boulder just west of the old trapping station. A rather big increase in the size of *Lecidea atrobrunnea* was recorded. It is probably due to influence of guano from birds resting on the boulder. The number of thalli of *Umbilicaria decussata* had increased considerably. Apparently this species reproduces itself quickly in the Zackenberg area. It is common on rocks manured by birds in all parts of Greenland and is able to cover large areas on such rocks (Hansen 1995b).

The occurrence of *Parmelia saxatilis* on a two metre high gneissic boulder west of Zackenbergelven is of great interest, as it represents the northern limit of distribution in East Greenland of this species. P8 was established in 1994 to monitor this lichen. Although growing on N-facing rock *P. saxatilis* has increased its size considerably, and presumably it has overgrown *Umbilicaria decussata* on the rock. *Pseudephebe minuscula* was noted as new in the plot.

P10 is situated at the northern end of Ulvehøj. Only minor changes of the lichens were observed. *Umbilicaria lyngei* and *Pseudephebe minuscula* have increased their size, but no more than should be expected.

Epigaeic lichens

P11-P13 were established on Ulvehøj in different heath types dominated by *Cassiope*, *Dryas-Carex rupestris* and *Kobresia myosuroides*, respectively. As regards P11, three lichens, viz. *Peltigera leucophlebia*, *P. rufescens* and *Flavocetraria cucullata* have appeared, and two lichens, viz. *Ochrolechia frigida* and *Solorina crocea*, have disappeared since 1994. Some thalli of *Cetrariella delisei* probably also have been overgrown by *Cassiope*. In P12, five species, viz. *Arthrorhaphis alpina*, *Candelariella terrigena*, *Peltigera didactyla*, *Psoroma hypnorum* and *Cerastium*, have colonised the soil since 1994. In addition, the number of thalli of *Flavocetraria nivalis* had increased, while other lichens, for example, *Cetraria muricata*, showed a reduced number of thalli. Totally, these changes indicate that the plot had been disturbed, either by wind or animals passing through it. In P13, *Cladonia borealis* had disappeared, while *Rinodina turfacea* had appeared.

P14 is situated in lowland just south of the research station. Five lichens, viz. *Cetraria muricata*, *Flavocetraria cucullata*, *Peltigera venosa*, *Caloplaca cerina* and *C. tiroliensis*, were new in the plot, while five other species, viz. *Peltigera rufescens*, *Physconia muscigena*, *Solorina bispora*, *Ochrolechia frigida* and *Phaeorrhiza nimbosa*, had disappeared since 1994. Probably, *Cetraria muricata*, *Flavocetraria cucullata* and *Thamnolia subuliformis* had been transported to the plot by wind as thallus fragments or whole thalli. *Caloplaca cerina* and *C. tiroliensis* had colonised musk ox dung.

Conclusion

Apart from a number of lichens growing on rocks manured by musk oxen and/or birds most lichens have followed the normal pattern of growth and reproduction since 1994. Climatic changes such as elevated temperatures and enhanced precipitation and UV-B radiation are expected to influence the lichens significantly. Thus the metabolism (photosynthesis, respiration etc.) and growth of the lichens will change and this is likely to result in lethal stress in some lichens. In the same way, a prolonged snow cover will damage many lichens.

4.2 Arthropods

Dorthe Prip Lahrmann

Two window traps and five pitfall trap stations with eight yellow traps each, were operated during the 2000 season. Station 7 was used for the second year, while station 6 was discontinued. Collecting procedures were concurrent with preceding years, and the first traps were opened on 4 June. The minimal snow cover of this year (Table 4.13) allowed for an early start of the arthropod traps. The two last pitfall traps could be opened on 17 June. During the summer, there was one incident of flooding of a pitfall trap (station 2 on 14 June), and three traps were destroyed, when a group of musk oxen walked over them (station 7 on 17 June). Dorthe P. Lahrmann did all sampling and sorting, and all collected specimens are kept at the Zoological Museum, University of Copenhagen. Like earlier years, Ceratopogonidae was not separated from Chironomidae, and Anthomyiidae not from Muscidae in 2000, due to difficulties in determination.

Station no.	1996	1997	1998	1999	2000
1	3.6	30.5	6.6	15.6	1.6
2	<3.6*	28.5	29.5	8.6	<4.6*
3	14.6	19.6	18.6	27.6	9.6
4	14.6	22.6	26.6	2.7	7.6
5	4.6	<29.5*	1.6	12.6	<4.6*
7	-	-	-	<3.6**	<4.6*

*0% snow

**7% snow

Table 4.13. Date of 50% snow cover (ice cover on pond at Station 1) in the arthopod plots 1996-2000.

Window traps

The two window traps in Gadekæret were opened on 4 June and remained open until 26 August. There was no disturbance of the traps by musk oxen during this season. Catches from the two traps were pooled, and the results are presented in Table 4.14.

This year saw the highest number of arthropods caught so far. Chironomidae, Cecidomyiidae and Muscidae all were caught in unprecedented high numbers. Mycetophiliidae and Culicidae are the only two groups caught in relatively low numbers in 2000. No new additions to the list were made this year, but it can be noted that six flies of the Tachinidae family were caught. This family showed up in the window traps for the first time with a single specimen in 1999. Phoridae, which was also trapped in 1999 for the first time, was

DATE	10.6	17.6	24.6	1.7	8.7	14.7	22.7	29.7	5.8	12.8	19.8	26.8	2000	1999	1998	1997	1996
No. of trap days	12	14	14	14	14	12	16	14	14	14	14	14	166	153	174	184	182
COLLEMBOLA	2	4	9	11	17	7	2	1	40	3	5	1	102	61	5	15	65
COLEOPTERA																	
Latridius minutus	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
HEMIPTERA																	
Nysius groenlandicus	0	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	2	1	0	0	3	0	0	0	14
THYSANOPTERA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
LEPIDOPTERA																	
Colias hecla	0	0	0	0	0	0	1	1	0	0	0	0	2	0	0	0	1
Clossiana sp.	0	0	0	0	0	0	0	2	0	0	0	0	2	2	1	1	6
Noctuidae	0	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	0	1	3
DIPTERA																	
Nematocera larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Tipulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Trichoceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Culicidae	0	0	3	7	22	4	19	46	5	4	1	0	111	322	138	142	98
Ceratopogonidae													*	1799	*	*	*
Chironomidae	23	1208	3959	847	851	85	465	529	289	107	103	56	8522	5787	3743	7725	6477
Cecidomyiidae	0	0	0	1	7	0	8	8	1	5	2	0	32	6	0	0	1
Mycetophiliidae	0	0	0	1	2	4	2	6	4	1	1	1	22	16	624	240	64
Sciaridae	1	0	1	0	0	0	0	0	0	0	0	0	2	171	*	*	*
Empididae	0	0	0	2	3	0	1	4	0	0	0	0	10	9	9	1	77
Phoridae	0	0	0	0	0	0	0	1	1	0	0	0	2	3	0	0	0
Syrphidae	0	0	0	0	0	0	2	1	0	0	1	1	5	1	8	16	4
Agromyzidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Anthomyiidae													*	3	26	11	*
Calliphoridae	0	0	0	0	0	0	0	0	0	2	0	2	4	5	7	6	2
Heleomyzidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Muscidae	4	3	75	288	412	136	203	244	21	47	14	8	1455	754	745	809	1355
Scatophagidae	0	0	0	0	0	0	1	0	0	1	0	0	2	10	0	30	11
Tachinidae	0	0	0	0	0	0	0	4	0	0	1	1	6	1	0	0	0
HYMENOPTERA																	
Braconidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Ichneumonidae	0	0	0	0	9	14	6	15	1	1	2		48	24	18	44	43
Chalcidoidea	0	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	0	0	0	0	0	1	2	6	5
ACARINA	3	14	16	16	76	6	17	12	18	49	14	5	246	191	826	189	299
ARANEA																	
Linyphiidae	0	0	2	0	1	0	0	3	0	2	1	1	10	6	1	1	8
Lycosidae	0	0	0	0	0	0	0	0	1	1	0	0	2	0	0	1	0
UNIDENTIFIED	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**33**	**1229**	**4065**	**1173**	**1400**	**256**	**727**	**877**	**383**	**224**	**145**	**76**	**10588**	**9177**	**6155**	**9248**	**8547**

Table 4.14. Weekly totals of athropods caught at the window trap station in 2000. The station holds two window traps situated perpendicular to each other. Each window measures 20 x 20 cm. Values from each date represents catches from the previous week. Totals from 1996-1999 are given for comparison. An asterisk marks that the group was not separated from a related group in that year.

DATE	10.6	17.6	24.6	1.7	8.7	14.7	22.7	29.7	5.8	12.8	19.8	26.8	2000	1999	1998	1997	1996
No. of active stations	3	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
No. of trap days	114	241	280	280	280	240	320	280	280	280	280	280	3155	2706	2702	2797	(1512)
COLLEMBOLA	335	1713	2048	1858	1766	1220	5655	1791	3871	708	499	262	21726	23443	8957	10830	4636
HETEROPTERA																	
Nysius groenlandicus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	40
Aphidoidea	0	0	0	0	0	0	0	0	0	0	2	1	3	11	185	10	6
Coccoidea	1	5	26	34	238	86	67	151	76	42	35	20	781	431	3	548	254
THYSANOPTERA	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
LEPIDOPTERA																	
Lepidoptera larvae	1	0	0	4	1	1	1	6	0	2	2	0	18	21	106	168	354
Colias hecla	0	0	0	1	15	4	13	34	6	4	0	0	77	42	12	19	88
Clossiana sp.	0	0	0	2	18	10	40	211	25	23	0	0	329	82	56	180	1052
Lycaenidae	0	0	0	0	0	1	1	2	0	0	0	0	4	1	0	0	0
Plebeius franklinii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Noctuidae	0	0	0	0	1	0	0	1	2	0	0	0	4	6	2	45	68
DIPTERA																	
Nematocera larvae	0	6	230	22	3	1	11	2	3	1	0	0	279	105	58	39	52
Tipulidae larvae	0	0	0	0	1	0	2	0	0	0	1	0	4	1	0	0	0
Tipulidae	0	0	1	0	1	0	0	0	0	0	0	0	2	4	1	4	14
Trichoceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0
Culicidae	0	0	3	1	2	6	18	31	0	0	0	0	61	83	22	16	2
Chironomidae	13	256	569	1189	927	117	276	237	35	26	13	8	3666	8542	2402	3337	3292
Ceratopogonidae													0	68	*	*	*
Cecidomyiidae	0	0	0	0	4	2	2	7	3	6	0	0	24	0	1	0	0
Mycetophiliidae	0	1	1	190	264	72	117	147	9	13	2	4	820	205	1764	1194	526
Sciaridae	1	2	1	0	0	0	0	0	0	0	0	0	4	796	*	*	*
Brachycera larvae	0	0	4	0	0	0	0	0	0	0	0	0	4	3	0	0	0
Empididae	0	0	1	4	1	0	3	2	0	3	0	0	14	21	10	6	8
Phoridae	0	0	0	0	8	51	624	446	120	43	20	4	1316	435	344	214	118
Syrphidae	0	1	3	2	2	1	11	16	1	4	1	1	43	50	28	81	72
Cyclorrhapha larvae	0	2	3	0	0	0	1	1	0	0	0	0	7	7	19	75	16
Agromyzidae	0	0	1	0	0	0	0	0	0	0	0	1	2	0	0	1	0
Anthomyiidae													*	88	416	573	*
Calliphoridae	3	2	0	0	2	0	5	32	5	66	41	62	218	26	49	48	48
Fannidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Heleomyzidae	0	0	0	1	0	0	0	0	0	0	0	0	1	7	0	0	0
Muscidae	37	33	800	1997	2028	596	2796	3594	188	487	132	117	12805	10005	5463	6217	8114
Scatophagidae	0	0	0	0	0	0	0	0	0	0	1	0	1	41	0	385	26
Tachinidae	0	0	0	0	3	3	6	16	4	5	0	0	37	37	0	19	0
HYMENOPTERA																	
Hymenoptera larvae	0	0	0	1	1	1	0	1	0	0	0	0	4	0	2	0	0
Ichneumonidae	0	0	5	32	224	60	91	98	40	53	42	65	710	386	297	567	954
Braconidae	0	1	1	0	4	0	1	3	0	1	3	1	15	10	105	59	44
Ceraphronoidea	0	0	0	0	1	0	3	3	1	3	2	2	15	5	0	0	0
Chalcidoidea	0	0	1	1	4	0	3	5	0	2	2	3	21	9	2	123	48
Cynipoidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Scelionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	101	0	0	0
Bombus sp.	0	4	1	0	1	3	0	1	0	0	0	0	10	2	6	12	2
ACARINA	136	311	756	1100	2097	1504	1255	3620	1505	1508	880	584	15256	8263	6304	19781	8182
ARANEA																	
Dictynidae	0	0	0	0	0	0	0	0	0	0	0	0	0	79	0	53	0
Linyphiidae	432	366	326	117	162	94	89	325	270	419	408	515	3523	2243	1108	1644	1436
Lycosidae	48	214	334	290	367	36	139	734	309	412	176	195	3254	2118	2123	3806	4548
Lycosidae egg sac	0	0	4	7	42	2	5	8	3	1	9	20	101	160	160	138	82
Thomisidae	13	9	10	8	12	3	4	20	2	21	17	15	134	144	89	245	198
OSTRACODA	0	0	44	0	0	0	1	0	0	1	0	0	46	84	0	0	0
SIPHONAPTERA	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0
NEMATODE	0	0	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0
UNIDENTIFIED	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	120
TOTAL	**1020**	**2926**	**5173**	**6861**	**8200**	**3874**	**11243**	**11545**	**6478**	**3854**	**2289**	**1881**	**65344**	**58174**	**30095**	**50446**	**34404**

Table 4.15. Weekly totals of arthropods caught at the five pitfall trap stations in 2000. Each station holds eight yellow pitfall traps measuring 10 cm in diameter. Values from each date represent catches from the previous week. Totals from 1996-1999 are given for comparison. Data from 1996-1998 have been extrapolated to fit the sampling design from 1999 onwards (see Caning and Rasch 2000). Asterisks mark groups that were not separated from closely related groups in that year.

again present in the traps, while the beetle *Latridius minutus* did not have a second showing after last years first occurrence.

Pitfall traps

With 3155 trap days, 2000 had the highest number of trap days so far. Maybe partly as a result of this, 2000 was also the year with the highest number of specimens trapped until now. Weekly totals are presented in Table 4.15. At several instances, traps were contaminated with a fungus. It was growing in the water as well as on trapped specimens. There seems to be some connection between this fungus and the capture of *Bombus*, and quite possible the fungi arrived in the traps carried by *Bombus*.

The decline in numbers of Lepidoptera over the previous years was halted somewhat in 2000. The highest numbers of the butterflies arctic clouded yellow *Colias hecla* and fritillary *Clossiana* sp. since 1996 were caught, together with four individuals of Lycaenidae. Lycaenidae was found in the samples for the first time with a single individual in 1999. However, only 19 lepidoptera larvae were found this year, an all time low. It is therefore possible that the higher number of Lepidoptera in the traps is not a sign of actual increase in numbers, but an effect of the relative warm and sunny weather of 2000, facilitating a higher over all activity level of the butterflies.

Chironomidae, which were found in record numbers in the window traps, did by far not reach the level from 1999 in the pitfall traps. It seems to appear that the circumstances favourable to the Chironomidae living around the pond with the window traps, did not have the same effect on the species living in dryer habitats. Three groups of flies, Phoridae, Calliphoridae and Muscidae, were all found in surprisingly high numbers this year. Fannidae, which were found in small numbers in some previous years, did not show up in the samples, while the amount of Tachinidae is similar to last year. Several small wasps of the super family Ceraphronoidea were trapped, a group that was first found in 1999. All individuals belonged to one single family. Also Chalcidoidea and *Bombus* were found, in both cases the highest number since 1996.

Ostracoda were once again present at station 2, as were a few Nematoda for the first time. Individuals from both groups are most likely flushed into the traps by surface water.

Two important factors were probably responsible for the high numbers of insects in the traps this year. Besides the warm and sunny weather during most of the summer, the limited snow cover in the valley during the 1999-2000 winter resulted in an early start and a long season.

Very large differences are apparent between the five pitfall trap stations. Station 2 is in wet marsh dominated by mosses and *Eriophorum*. Stations 3 and 4 are in level mesic heathland, while stations 5 and 7 are in dry and early exposed heathland. Some clear differences in catches from the stations are shown in Fig. 4.2.

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

Larvae of *Sympistis zetterstedtii* were not encountered in the *Dryas* study plots in 2000, and no depredation was recorded during the season (Table 4.16).

Woolly-bear *Gynaephora groenlandica* caterpillars were not recorded inside the *Salix arctica* plots this year, but the bird census worker encountered 12 larvae during June and July (Table 4.17).

A number of larvae depredating *Salix arctica* seeds were collected this year. They were previously thought to be of a lepidoptera, but turned out to be of a sawfly Tenthredinidae. They were again this year found in ripe female *Salix* pods (Table 4.18).

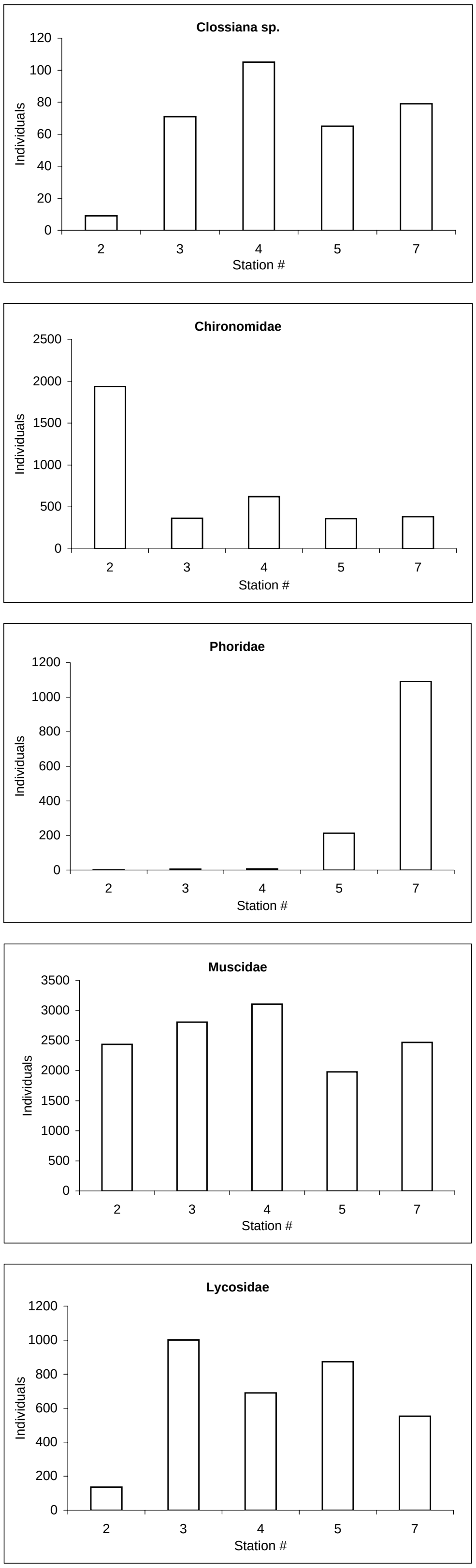


Fig. 4.2. The number of specimens of five key taxa caught at each pitfall trap station in 2000.

Table 4.16. Peak ratio (per cent) of Dryas *flowers predated by larvae of* Sympistis zetterstedtii *in* Dryas *plots in 1996-2000.*

	1996		1997		1998		1999		2000	
Plot	Date	Pred.	Date	Pred.	Date	Pred.	Date	Pred.	Date	Pred.
Dryas 1	17.7	2	24.6	6	15.7	3		0		0
Dryas 2		0	05.8	5		0		0		0
Dryas 3	01.7	11	24.6	18	08.7	3		0		0
Dryas 4	24.6	17	15.7	1	15.7	7		0		0
Dryas 5	08.7	2	08.7	8	15.7	2		0		0
Dryas 6		0		0		0		0		0
Dryas 7		-		-		0	21.8	26		0
Dryas 8		-		-		0	21.8	27		0

Table 4.17. Numbers of woolly-bear Gynaephora groenlandica *caterpillars recorded by one observer (Hans Meltofte) in study area 1A (the bird monitoring area) in June and July 1996-2000.*

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

Table 4.18. Peak ratio (per cent) of female Salix arctica *pods infested by sawfly larvae in 1996-2000.*

Plot no.	1996	1997	1998	1999	2000
Salix 1	+	0	0	43	2
Salix 2	3	0	0	6	0
Salix 3	9	0	0	3	5
Salix 4	0	0	0	1	7

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

	West of river	East of river	Total
June	7; 23	16; 66	23; 89
July	11; 38	23; 68	34; 106
Total	**18; 61**	**39; 134**	**57; 195**

Bumblebees *Bombus* spp.

The first bumblebees Bombus polaris/hyperboreus were recorded already on 5 June. During bird census work in June, a total of 59 individuals were recorded by Hans Meltofte and a further 34 in July (for effort, see Table 4.19). In 1999, 35 were recorded in July (Caning and Rasch 2000).

During the line transects in mid July only one bumblebee was seen (see section 4.4).

4.3 Birds

Hans Meltofte

Bird observations were recorded by myself during 3 June-3 August and by T. B. Berg during 4 August-1 September. Valuable observations were provided by several other researchers and staff during the entire season.

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

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

Breeding populations

The 18.8 km^2 census area in Zackenbergdalen was covered on almost daily trips between mid June and early August (Table 4.19). The very early snow clearance (see sections 3.4 and 4.1) meant that the initial total census of the potentially breeding populations was performed already during 11-18 June, and when most waders had started egg laying or were already incubating (see next chapter). This initial mapping of territorial birds took 30 hours, and was largely made on foot.

Based on records made during the initial census supplemented by records during the rest of the season (see Meltofte and Berg 2000), population estimates for five sections of the census area are presented in Table 4.20. Most populations were within the range estimated for previous years, except for red knot that seems to have declined during 1996-2000, and dunlin that may have increased (Table 4.21). The ptarmigan population was the lowest recorded so far, and common eider was found nesting for the first time (see section on Other observations pp. 35-39).

In spite of the reduced snow-cover early

	West of river	East of river			
	< 50 m (3.39 km^2)	< 50 m (7.52 km^2)	50-150 m (3.34 km^2)	150-300 m (2.49 km^2)	300-600 m (2.06 km^2)
Red-throated diver	0	2-3	0	0	0
Pink-footed goose	1	0	0	0	0
Common eider	0	1	0	0	0
King eider	0	2-4	0	0	0
Long-tailed duck	0-1	5-7	0	0	0
Rock ptarmigan	0	0-2	1	0	0
Great ringed plover	7-9	6	5	7	16
Red knot	1-2	9-10	10	3-4	1
Sanderling	14-15	20-26	2	16-17	6
Dunlin	26-27	52-54	17-19	2	1
Ruddy turnstone	3	24-26	15	6	0
Red-necked phalarope	0	1-2	0	0	0
Long-tailed skua	4	10-14	5-7	2-3	0
Snow bunting	16-17	4-6	10-11	10	2-3

Table 4.20. Estimated numbers of pairs/territories in three sectors of the 18.8 km^2 census area in Zackenbergdalen, 2000.

	1996	1997	1998	1999	2000
Red-throated diver	1-2	2	3	2-3	2-3
Pink-footed goose	0	1	0-1	2	1
Common eider	0	0	0	0	1
King eider	2-3	2	1	2-3	2-4
Long-tailed duck	5-8	4-6	6-8	7-8	5-8
Rock ptarmigan	3	11-15	4-6	7-8	1-3
Great ringed plover	54-56	40-48	38-45	53-67	41-43
Red knot	33-43	35-44	27-32	25-33	24-27
Sanderling	51-63	55-70	62-70	60-67	58-66
Dunlin	69-82	75-91	75-94	75-89	98-103
Ruddy turnstone	42-52	49-58	56-63	43-48	48-50
Red-necked phalarope	0-1	0-2	1-2	1-2	1-2
Red phalarope	0	0	0-1	0	0
Long-tailed skua	25-29	22-25	21-24	19-24	21-28
Northern wheatear	0	0	1	0	0
Snow bunting	45-55	45-56	41-46	52-65	42-47

Table 4.21. Census results from the 18.8 km^2 census area in Zackenbergdalen, 1996-2000.

in the season also the distribution of the waders (shorebirds) was very similar to other years. Hence, apparently suitable and snow-free habitats were often uninhabited. The fact that the waders show so little annual variation in numbers and distribution, could be an indication that their populations are adjusted to average conditions in the area. Most of the species involved are highly site tenacious and monogamous enabling such an adjustment. This involves that numbers of wader territories remain the same in an optimal year like 2000, and that parts of the birds refrain from breeding in unfavourable seasons like 1999, when the snow cover cleared considerably later (see section 4.3 in Caning and Rasch 2000).

Reproductive phenology in waders

In accordance with the limited extent of snow cover early in the season, the waders bred as early as recorded in any previous year and highly synchronously (Tables 4.22 and 4.23). The bulk of first egg dates

	Median date	Range	N
Great ringed plover	14.5 June	9-17 June	4
Red knot	9 June	-	1
Sanderling	16 June	11-25 June	13
Dunlin	11.5 June	9 June - 4 July	24
Ruddy turnstone	11 June	8-27 June	23

Table 4.22. Median first egg dates for waders at Zackenberg 2000 as estimated from incomplete clutches, egg floating, hatching dates and weights of pulli.

	1995	1996	1997	1998	1999	2000
Great ringed plover			(15 June)			
Sanderling		(16 June)	18 June	18 June	23.5 June	16 June
Dunlin	(18 June)	11.5 June	13 June	16.5 June	22 June	11.5 June
Ruddy turnstone	(12 June)	18.5 June	13 June	12.5 June	24 June	11 June

Table 4.23. Median first egg dates for waders at Zackenberg 1995-2000. Data based on less than 10 nests/broods are in brackets, less than five are omitted.

in dunlin and ruddy turnstone was as early as 9-12 June and 8-11 June, respectively, while laying in sanderling was more extended. The latter could be a result of double brooding (see section on Other observations p. 37).

As usual, a number of late clutches e.g. in dunlin (Table 4.22) must have been relaid.

	1995	1996	1997	1998	1999	2000
Great ringed plover	(4.00)	(4.00)	(3.50)	(4.00)	(3.50)	(4.00)
Red knot	130			(4.00)	(4.00)	
Sanderling	(4.00)	4.00	3.86	4.00	3.67	4.00
Dunlin		(4.00)	(3.75)	3.90	3.70	3.93
Ruddy turnstone		3.71	3.79	3.81	3.58	3.75

Table 4.24. Mean clutch sizes in waders at Zackenberg 1995-2000. Samples of less than five clutches are given in brackets.

	1996	1997	1998	1999	2000
Great ringed plover	(100)	(0-25)	0	(25)	(0-25)
Red knot			(0-100)	(50)	
Sanderling	17	0-40	0-11	21-29	17-33
Dunlin	(0)	0	11-33	0-33	13
Ruddy turnstone	0-29	0-8	27-47	18-55	33-38
Red-necked phalarope				(100)	
All species pooled	**13-27**	**0-17**	**14-34**	**20-39**	**22-28**
N	15	24	35	41	46
Foxes encountered	3	1	6	6	5

Table 4.25. Predation rate in wader nests at Zackenberg 1996-2000 expressed as minimum and maximum per cent nests predated of those found with eggs throughout the nesting period. Partially predated nests are given as successful, if at least one young hatched, and so are nests eventually controlled with starred or pipped eggs found empty and without indications of predation later on. Nest failures for other reasons are omitted. Samples of less than five nests are given in brackets. Also given are numbers of encountered foxes during bird monitoring (by one field worker) in June-July.

Breeding success in waders

After the significantly reduced average wader clutch sizes recorded in the climatically late season of 1999 (see section 4.3 in Caning and Rasch 2000), four eggs were again present in the vast majority of nests found (Table 4.24).

Predation rates were within the range recorded in previous years (Table 4.25). Considering the fact that nests were found at all stages of incubation, true predation rates were certainly higher – possibly double as high. Most predation is by arctic foxes, and the number of foxes encountered during bird census work was close to average. The 'normal' predation rate is remarkable considering the fact that the lemming population was at an absolute low, and that at least three fox dens in the valley held pups (see section 4.4). Again an indication that the close correlation between lemming numbers and tundra bird breeding success found in northernmost Siberia is not prevalent in Northeast Greenland (see section 4.3 in Caning and Rasch 2000).

No other cases of nest failure were recorded this year, and only one infertile egg was left behind in each of two ruddy turnstone nests and in one dunlin nest.

However, what should have been a good breeding season for waders at Zackenberg was interrupted by a fierce snow-storm during the night of 17-18 July, i.e. in the middle of the chick-rearing period. The slopes of Aucellabjerg were almost completely covered in 5-30 cm of snow down to an altitude of 50-100 m, and during a survey flight on 19 July, we saw that the northern parts of Wollaston Forland were largely covered with new snow. During the following days, the weather was still rainy, windy and cold, so that even three days later, much snow remained down to 200-500 m a.s.l. More than 250 adult waders appeared in the river deltas at the coast off Zackenbergdalen during the first days after the snow-storm (see section on Other observations p. 37), which may be an indication that many broods had been lost. In one nest in the lowland, two out of four hatching sanderling chicks died during the snow-storm, but some young waders even high up on the slopes must have survived, since a few alarm calling adult great ringed plovers were recorded at 400-500 m a.s.l. until early August. At least some families moved down from the slopes, but generally few alarm calling adults were recorded after the snowstorm. Numbers of alarm calling adults always decrease markedly in late July, however.

In spite of this incident, close to average numbers of juvenile waders appeared in the deltas during August (Table 4.26). This means that the devastating effect of the snow storm did not hit the entire region from where these juvenile waders were recruited.

Reproductive phenology and success in long-tailed skuas

In accordance with the low number of lemmings (see section 4.4), few long-tailed skuas nested for the second year in succession. Of the 21-28 pairs in the census area (Table 4.21), nests were recorded only in five (one of them just outside the border). First egg dates were between 15 June and 21 June, which is as late as in 1999, when snow melt generally was 2-3 weeks later (see section 4.3 in Caning and Rasch 2000). Three nests held two eggs, two nests only one egg. Three nests were predated, one was deserted after 10 days of incubation, and the last was deserted just after hatching of both young.

Breeding barnacle geese

On 27 June, the first barnacle goose pair with three small goslings appeared in the delta of Zackenbergelven. This means that egg laying must have started around 26 May, or close to the date in other 'normal' years. During the following 7-10 days, more families arrived, so that on 8 July a total of eight pairs with goslings and one adult pair without young were present at Lomsø and in the fens east thereof. One further pair with three goslings were found along Zackenbergelven close to Østerport. The mean brood size of the nine successful families was 3.22, or a bit higher than recorded in any of the previous years (Table 4.27). A few more pairs appeared later, so that a total of 11 pairs with 34 goslings were recorded in the valley in late July besides three adult pairs without young. No families were found around the peninsula to the east, where several families gathered last year (see section 4.3 in Caning & Rasch 2000), but a pair with 4-6 gosling was encountered at the coast north of Daneborg on 16 July. In upper Store Sødal, four families with a total of 10 goslings were recorded on 23 July (see next chapter).

Flying juveniles were seen from 17 August, but still on 31 August a pair with one unfledged gosling was encountered (see also section on Other observations p. 36).

The lower number of families that brought their young to Zackenbergdalen in 2000 as compared to the last few years, may have been due to the very limited snow cover this year, and the consequently early vegetation growth, enabling the geese to utilise many other areas.

The brood size and juvenile percentage on the wintering grounds in Scotland also indicate a good breeding season (Table 4.27).

Line transect

The results of the line transect counts in mid and late July through Store Sødal and between Daneborg and Zackenberg are generally in good accordance with the

	1995	1996	1997	1998	1999	2000
Great ringed plover	96	126	249	42	44	142
Sanderling	304	726	149	333	445	366
Dunlin	325	360	323	232	509	273
Ruddy turnstone	80	108	82	109	23	73
Total	**810**	**1342**	**803**	**722**	**1021**	**854**

Table 4.26. Cumulative numbers of juvenile waders recorded at low tide in the old and the present deltas of Zackenbergelven during counts every third day in the period 1-31 August, 1995-2000. In case of missing counts etc., data have been interpolated.

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

Table 4.27. Average brood sizes of barnacle geese in Zackenbergdalen during July and early August, 1995-2000, together with the total number of broods brought to the valley. Samples of less than 10 broods are given in brackets. Data from autumn on the Isle of Islay in Scotland are given for comparison, including per cent juveniles in the population (M. Ogilvie in litt.).

	Store Sødal 22-24 July	Daneborg 16 July
Red-throated diver		2
Pink-footed goose	56	
Barnacle goose	259/10	2/4-6
Common eider		10
Great ringed plover	93	(12/4)
Red knot		3
Sanderling	4/2	7/4
Dunlin	39	8
Ruddy turnstone	1	5
Long-tailed skua		4
Glaucous gull	6	(1)
Arctic tern	3	
Common raven	2	(3)
Snow bunting	25/6	(5)

Table 4.28. Birds recorded (adults/young) during line transect surveys through Store Sødal and from Daneborg to Zackenberg (see map in Meltofte and Thing 1997) in July 2000. Data for the Daneborg transect given in brackets have been extrapolated to cover the missing first section (see the text).

records from previous years (Tables 4.28 and 4.29). Numbers of moulting immature pink-footed geese in Store Sødal were still low (see section on Other observations p. 35). The snow bunting seems to be on the decrease in Store Sødal, while numbers of great ringed plovers were higher than in previous years.

The first two sections of the transect from Daneborg were not walked this year, due to ice in the fjord preventing us from reaching Daneborg. Figures presented in the tables have been extrapolated for these sections, based on figures from previous years (see also section 4.4).

Sandøen

Only the high parts of Sandøen were free from snow, when we flew over the island on 3 June, and still on 4 July it was surrounded by fast ice (see section 3.5).

When the island was visited by Hans Meltofte on 29 July, very large numbers of arctic terns and Sabine's gulls were breeding – in spite of the late ice break up this year. In the order of 1000 arctic terns were estimated to be present, and a total of 88 Sabine's gulls were counted from one point on the high part. The gulls were either incubating, tending young, displaying or flying just over the ground, while birds higher up or around the island were not included. This means that probably more than 100 Sabine's gulls were present. Most tern chicks were less than one week old, but a few were older – maybe 10-14 days. Two nests held one egg each. Furthermore, a common eider nest with five eggs was fund.

In 1999, about 2000 arctic terns and 300 Sabine's gulls were estimated to have been present, as the highest numbers ever recorded (see section 4.3 in Caning and Rasch 2000).

	1997	1998	1999	2000
Red-throated diver	3	2		2
Pink-footed goose	263	123	27	56
Barnacle goose	182	250/23	227/23	261/14-16
Goose sp.	25			
Common eider	390	119/5	55/6	10
Long-tailed duck	13		2	
Rock ptarmigan	2	1		
Great ringed plover	71	70	(78)	(105/4)
Red knot	1			3
Sanderling	14/1	10	33	11/6
Dunlin	64/1	62/1	(56)	47
Ruddy turnstone	6	8	8	6
Long-tailed skua	13	9	14	4
Glaucous gull	11	11/2	8	(7)
Arctic tern	3	9	1	3
Common raven	10	9	2	(5)
Snow bunting	104	64/2	(54)	(30/6)

Table 4.29. Total numbers of birds recorded (adults/young) during line transect surveys through Store Sødal and from Daneborg to Zackenberg, July 1997-2000. Brackets denote interpolated figures (see the text).

Other observations

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

Red-throated diver *Gavia stellata*

On 6 June, the first three red-throated divers circled calling over the valley, and a pair landed in Sydkærene the same evening. One more pair appeared on the next day, whereupon both pairs were seen regularly in the area during the rest of the summer.

These and other birds were feeding in the deltas of Zackenbergelven already from the appearance of the first open water on 8 June. In June, no more than two birds were present here, in July up to four, and in August up to nine.

On 18 June, a bird was sitting on a nest in Sydkærene. By 21 July, a chick had hatched, and it remained on the pond until it flew out to the fjord off the deltas between 27 and 30 August.

A bird was incubating on the northern shore of Lomsø on 21 June, but it may have started some days earlier. The nest was predated by 1 July, whereupon the pair was building on a new nest a week later. A bird was incubating here from 11 July until at least 11 August. On 15 August, a chick was seen, whereupon it was recorded regularly until we left at the end of the month. Occasionally, up to four adults were seen on the lake.

A third pair was sitting on Ryledammene on 26 July, but there was no further activity here.

Outside the census area, a pair nested at Vesterport Sø. They had two eggs in late July, but there was no young in mid August, so most likely, the nest was predated. Pairs were also seen on Gåsesø and Lindemannssø, but no indication of breeding was recorded. So, most likely a total of five pairs were present in Zackenbergdalen this year, which is the normal figure.

Three pairs were encountered in upper Store Sødal in late July; one of them close to Tyrolerfjord.

Great northern diver *Gavia immer*

A pair with one chick was sitting on a small lake east of the large lake in westernmost upper Store Sødal on 30 July. A pair was present on the same lake in July 1998 (Rasch 1999), but this is the first proof of breeding in our study area.

Whooper swan *Cygnus cygnus*

Four individuals landed on open water in the old delta of Zackenbergelven on 7 June. This is one of the northernmost observations of the species in East Greenland (Boertmann 1994).

Pink-footed goose *Anser brachyrhynchus*

Pink-footed geese were probably present in the study area already before our arrival. Five were seen on 4 June, and on 7 June, a gander was giving alarm calls in the westernmost part of the census area, where a pair also nested in 1997 and probably even in 1999. The nest was found on 11 June, and it hatched between 29 June and 2 July. Most likely, the same pair was seen with three goslings on the coast on 21 July.

Mainly single individuals were recorded until the moult migration of immatures from Iceland began on 16 June, when a flock of 40 circled over the valley. A total of 726 pink-footed geese migrated north up until 1 July, and an accumulated total of about 325 rambled over the valley or were staging during the same period. A further 10 migrated north on 6 July. Small flocks of flying birds were recorded in the study area until 12 July, but only 35 flightless individuals were found at the peninsula in late July. This may have been the result of human disturbance in the area just prior to the count (see section 6).

Also numbers in Store Sødal were low. Only 56 were found in the upper part of the valley during the line transect on 23 July (Table 4.28).

In late August, flocks of up to 180 were staging in Zackenbergdalen, and a flock of 100 migrated south on 25 August.

Snow goose *Anser caerulescens*

Two snow geese – one blue and one white – moulted together with the immature barnacle geese at Lomsø. They were seen for the first time on 29 June, and our last record was on 2 August. On 28 July, the blue bird could fly again, but not the white.

They were only slightly larger than the barnacle geese, and hence they may have been of the lesser subspecies *A.c. caerulescens*, of which many free flying (introduced) birds occur in Britain, where the barnacle geese winter. The snow goose is a rare but annual visitor to Northeast Greenland (Boertmann 1994).

Barnacle goose *Branta leucopsis*

In early and mid June, flocks of up to 47 barnacle geese were recorded in Zackenbergdalen. In late June, they began to gather at the moulting site at Lomsø, where a maximum of 111 was counted on 30 June. During most of July, 80-90 moulting immatures stayed at Lomsø and 27 at Zackenbergelven/Morænebakkerne. In late July, when most of the geese had regained flying capacity, up to 162 were recorded in Kystkærene and around the peninsula to the east.

During the line transect through Store Sødal, a total of 150 immatures were recorded at Store Sø and 78 in the upper part of the valley. Hence a grand total of about 410 immature barnacle geese moulted in the greater study area this year, which is a little more than the previous record of last year (Caning and Rasch 2000). The increase in numbers of moulting immature barnacle geese especially at Lomsø may be related to the high numbers of families bringing their goslings to this site during recent years. This again, may be related to our expelling of moulting pink-footed geese from the area.

In August, up to 300 barnacle geese were regularly feeding in Rylekærene.

Common eider *Somateria mollissima*

Two females appeared in the delta of Zackenbergelven on 11 June, whereupon none were seen until up to two pairs more permanently were present from 26 June. On 18 July, a nest was found with one egg just above the shore of the delta, but a fox soon predated it.

Many more birds arrived from 20 July. Up to 24 adult females and one male were recorded off the coast in the second half of July and up to 151 adult females in August. The first ducklings were seen on 26 July, and during the last days of July and in August up to 16 ducklings were recorded several times.

Just east of the peninsula, about 60 adult females and four ducklings were found on 30 July, and some hundreds of adult females with many broods were seen along the coast towards Daneborg the day before. In the colony at Daneborg, where more than 1000 eiders nest, many females were still incubating on 29 July, several nests were hatching, and the young sled dogs ate a lot of eggs and newly hatched ducklings.

The last male was seen on 5 August.

King eider *Somateria spectabilis*

The first pair of king eiders was recorded in Kystkærene on 22 June, but they may have arrived several days before. More birds arrived during late June and early July, so that a maximum of four males and four females were seen during this period.

A female was seen in Gadekæret on 1 July, and on 10 July it was found to incubate on top of a turf in the middle of the eastern pond. On 26 July it was attacked unsuccessfully by two ravens, and on 1 August six ducklings had hatched. This means that egg laying must have started just after 1 July. The family walked about 500 m down to Sydkærene already two days later, and they must soon have continued 800-900 m further on to Lomsø, where they were seen for the last time on 16 August.

The last male was seen on 1 August.

Long-tailed duck *Clangula hyemalis*

The first pair of long-tailed ducks arrived in the census area on 6 June. More birds appeared up until mid June, when a maximum of four pairs and one male were recorded on the 14th.

A female was prospecting for a nest-site in Gadekæret on 20 June, and a nest was found here on 29 June. The bird was incubating until at least 16 July, but by the 19th the nest had been predated. Another predated nest was found south of Kærdal on 14 July, but on 1 August a female was seen with five ducklings on Lomsø.

Just east of the census area, a predated long-tailed duck nest was found on 14 August.

During July, the pairs disintegrated, and groups of up to 11 were recorded on Lomsø and along the coast in July, and 21 in August. Around the peninsula, 16 males and (mainly) females were present in late July.

Merlin *Falco columbarius*

An immature merlin was seen at the research station on 1 July and again west of the river on 14 July. This is the first record of the species in Northeast Greenland, and it has not been seen in East Greenland since 1933 (Boertmann 1994). The nearest breeding area is on Iceland, where the subspecies *subaesalon* is found.

Feathers from a snow bunting found on 14 July and from two found on 30 August may have been the remains of birds killed by the merlin or gyr falcons (see further below).

Gyr falcon *Falco rusticolus*

A white individual was hunting waders in the census area on both 5 and 6 June. On 23 June, the remains of a long-tailed skua was found, probably killed by a gyr falcon. The same apply to feathers from a snow bunting found on 21 June, from a ruddy turnstone found on 30 June and from a female ptarmigan in breeding plumage found on 14 July. Single gyr falcons were recorded four times in July and seven times in August, besides two together on 18 August.

Smaller and darker falcons were recorded both on 6 June and 28 August. On the latter date, the bird was mobbing a clearly larger gyr falcon.

Rock ptarmigan *Lagopus mutus*

Very few ptarmigans were seen this year. A male flew past the research station on 31 May, a female was seen at Østerport on 8 June, two males were displaying at the research station on 16 June and a male was stationary in Oksebakkerne on 17 June. As the last record, the latter male was seen in heavy moult on 5 July.

A pair was encountered on Zackenberg on 5 June.

Waders *Charadrii*

All the common waders, great ringed plover *Charadrius hiaticula*, red knot *Calidris canutus*, sanderling *Calidris alba*, dunlin *Calidris alpina* and ruddy turnstone *Arenaria interpres* were present at our arrival on 3 June. Song and other display was recorded from the very first days, but during the first week of June, the birds were mainly feeding in communal feeding areas such as Gadekæret. Here, up to six great ringed plovers, three red knots, five sanderlings, 77 dunlins and 12 ruddy turnstones were recorded. Most of the dunlins were feeding on exposed mud in the ponds, while most of the other species were feeding in the fen area (see further in section 5.5). Breeding was very early (see section on Reproductive phenology in waders p. 31), and no pre-breeders were recorded after 8-9 June.

The first post-breeders were recorded on 30 June, when groups of 2-4 red knots, one sanderling, 1-8 dunlins and two ruddy turnstones were seen. Flocks of up to 25 waders were present in the old delta of Zackenbergelven already from early July, and maximum numbers of adult waders here in the first half of July were nine great ringed plovers, 17 sanderlings, 25 dunlins and six ruddy turnstones. Right after the snow-storm 17-18 July (see section on Breeding success in waders p. 32), 12 great ringed plovers, 28 sanderlings, 99 dunlins and nine ruddy turnstones were feeding intensively in the old delta. On 20 July, numbers had increased to 80 sanderlings, 160 dunlins and 25 ruddy turnstones, besides 11 great ringed plovers. Numbers remained high at the waterbird count in the deltas on 23 July, whereas maximum figures for adult waders during the rest of the season were 31 great ringed plovers (on 4 August), 32 sanderlings (1 August), 112 dunlins (1 August) and six ruddy turnstones (10 August).

Peak numbers of juveniles in the deltas were 41 ringed plovers on 19 August, 69 sanderlings on 19 August, 41 dunlins on 22 August and 19 turnstones on 10 August. First observation dates of independent juveniles were: ringed plover 4 August, sanderling 29 July, dunlin 28 July and turnstone 29 July or 1 August. On 1 August, four out of five juvenile sanderlings and three out of four juvenile dunlins carried rings, indicating that they were from the study area in Zackenbergdalen.

The only red knots seen after the last observation of a family on 18 July, were two probably juvenile individuals on 31 August.

Sanderling *Calidris alba*

To get an idea on the possible extent of double-clutching in sanderlings at Zackenberg (Parmelee and Payne 1973 *versus* Pienkowski and Green 1976), four nests, each of them with four eggs, were checked a number of times for the coloration of the incubating bird.

Nest 1 was found on 24 June, when it had been incubated for about 11 days. The incubating bird was caught by hand, and it carried a ring that it had been marked with the year before on a nest about 600 m away. The bird was relatively 'red', which could indicate that it was a male. Up until hatching on 7 July, the nest was checked 31 times. At 13 occasions, no bird was present, at 14 occasions the marked bird was incubating, and at four more occasions a bird with the same colour was incubating, but it was not checked for rings. The nest was checked at all times of the day, i.e. between 8 a.m. and 11 p.m. No other birds were seen at the nest.

Nest 2 was found on 26 June, when it

had been incubated for about eight days. It was checked eight times until it apparently had been predated by 8 July. Three times a 'red' (male?) bird was incubating, and five times a 'grey' (female?). At one occasion, when the grey bird was incubating, a red bird was performing distraction display about 100 m away.

Nest 3 was found on 27 June, when it had been incubated for about three days. It was checked five times until hatching on 15 July. At all five times, an intermediately coloured bird was incubating.

Nest 4 was found on 29 June, when it had been incubated for about four days. Up until hatching on 18 July, the nest was checked 12 times. At two occasions, no birds were noted, at two occasions a 'grey' bird was recorded, while at the remaining eight occasions, a 'red' bird was seen. I did not see the grey bird myself, so I never had the chance to check how different the adults were.

Summing up these observations, one nest was definitely attended by one adult only (nest no. 1), one nest was definitely incubated by both adults (nest no. 2), one nest was apparently only incubated by one adult (nest no. 3), while the situation at nest no. 4 is a little uncertain. In the yeas to come, we will try to obtain more data on this question.

Whimbrel *Numenius phaeopus*

A whimbrel was seen twice flying past the runway on 22 June. This is the northernmost record so far in East Greenland (Boertmann 1994). The species is a local breeder in Jameson Land, 400-500 km south of Zackenberg.

Red-necked phalarope *Phalaropus lobatus*

A female appeared in Gadekæret on 7 June, and on the next day, a pair was present. They were seen together here and in Sydkærene for about a week, whereupon only the female was seen until 26 June. A pair was seen at lower Kærelv on 21 June.

On 18 July, a male was feeding in the old delta of Zackenbergelven, indicating that it may have lost its young during the snowstorm.

Arctic skua *Stercorarius parasiticus*

On 2 July, two long-tailed skuas mobbed a dark arctic skua, and on 20 July, a light bird was seen together with three long-tailed skuas.

Long-tailed skua *Stercorarius longicaudus*

On 4 June, eight individuals came in from the east, performing territorial display as they arrived. On the next day, 15 were seen, whereupon territories were established in the usual areas. But by the middle of the month, single birds were often seen rambling over the terrain. On 5 July, a congregation of 15 birds was encountered, and during mid July, similarly groups of 10-14 were seen. 13 migrated south over the fjord on 10 July, and the last birds were recorded on 26 July. On 8 July, an immature (3rd calendar year?) was seen.

Lesser black-backed gull *Larus fuscus*

One adult lesser black-backed gull was preying on eggs and chicks of arctic tern and Sabine's gull on Sandøen, 29 July.

Glaucous gull *Larus hyperboreus*

During June, up to seven glaucous gulls were feeding along Zackenbergelven and in the delta, and flocks of up to six migrated up through the valley. Immatures were recorded from 20 June. Similarly, up to 10 were feeding in the deltas and along the river in July. During the waterbird counts in the deltas in August, up to 14 adults and two immatures were recorded. No juveniles were seen this year.

Great black-backed gull *Larus marinus*

A great black-backed gull flew down along Zackenbergelven on 30 June.

Arctic tern *Sterna paradisaea*

14 terns migrated east over the delta of Zackenbergelven on 13 August.

Snowy owl *Nyctea scandiaca*

A single male was seen on Aucellabjerg on 17 July, 6 and 9 August.

Northern weathear *Oenanthe oenanthe*

A mummified adult was the only record of northern weathear this year.

Common raven *Corvus corax*

In early and mid June, up to three ravens were seen at Zackenberg, and on 25 June a group of four appeared – probably a family. Anyway, juveniles were recorded from the next day. In July, up to seven were seen together, and most likely, two broods of two juveniles were involved. In August, up to 11 were counted.

Arctic redpoll *Carduelis hornemanni*

Five records of single redpolls were made between 4 and 26 June. This is the lowest number recorded so far.

Snow bunting *Plectrophenax nivalis*

The first juvenile was recorded on 14 July, whereupon juveniles were seen regularly during the rest of July and in August. The largest flock of snow buntings was of 20 individuals on 6 August.

4.4 Mammals

Thomas B. Berg

Observations on mammals were recorded by Hans Meltofte (3 June-4 August) and Thomas B. Berg (30 June-1 September). Most other personnel supplied additional random observations during the entire field season. The 2.5 km^2 census area for collared lemming was censused for winter nests and summer burrows during 6 July-18 August. The total number of musk oxen was censused once a week within the 40 km^2 census area during 3 July-22 August. During the entire season, additional counts were made (whenever weather conditions permitted it) from a fixed elevated point at the station covering the area from Lindemannsdalen along the coastline to Lille Sødal north of Daneborg. The line transect Daneborg – Zackenberg was walked by T.B. Berg and Dorthe Prip Lahrmann on 16 July and the line transect Zackenberg – Store Sødal was walked by T.B. Berg and Aka Lynge during 22-24 July. One new arctic fox den and a single new burrow entrance were recorded, and all known dens were checked regularly for occupation. All observations other than lemmings, foxes and musk oxen are presented in the section on Other observations p. 44, where scientific names for all species are also given.

	Winter nests category 1	Winter nests category 2	Summer burrows	Number of animals
1996	161	263	-	0
1997	342	109	710	1
1998	711	109	327	43
1999	305	57	403	9
2000	184	70	405	1

Table 4.30. Annual numbers of recorded winter nests and summer burrows within the 2.5 km^2 census area in Zackenbergdalen 1996-2000. Category 1 denotes nests from the previous winter, category 2 are nests from earlier winters that were not recorded previously. The numbers of animals were recorded by one person (same effort each year) in the field during June-July.

Collared lemming population

A total of 184 fresh winter nests and 405 active summer burrows were recorded within the 2.5 km^2 census area (Table 4.30). Numbers of winter nests continued the decrease from 1998 to 1999 and declined

		Winter nests		Summer burrows	
		No.	No./km	No.	No./km
Lower St. Sødal					
1996	90 km	1	0.011	0	0
1997	180 km	8	0.044	9	0.050
1998	90 km	8	0.089	0	0
1999	90 km	2	0.022	0	0
2000	90 km	0	0	0	0
Upper St. Sødal					
1996	60 km	1	0.017	1	0.017
1997	120 km	3	0.025	0	0
1998	60 km	13	0.217	6	0.100
1999	70 km	1	0.014	0	0
2000	70 km	1	0.014	0	0
DNB-Zackenberg					
1997	50 km	22	0.440	21	0.420
1998	50 km	17	0.340	1	0.020
1999	50 km	1	0.020	0	0
2000	40km	0	0	1	0.025

Table 4.31. Records of lemming winter nests and active summer burrows obtained along the transects Zackenberg – Store Sødal (90 km) and Daneborg – Zackenberg (25 km). Nests and burrows were recorded within 3 m on each side of the track by each of the two observers walking the transect, giving total lengths of 160 km and 50 km, respectively. Deviations from this appear from the table.

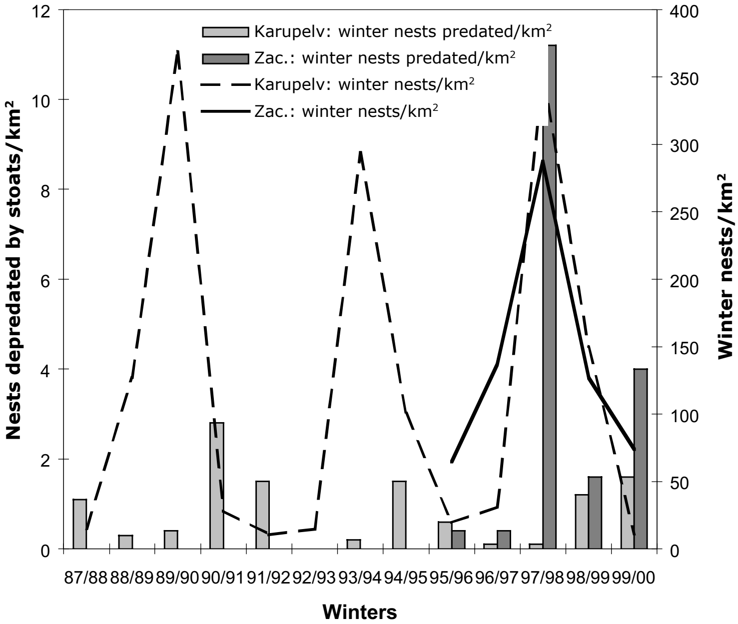


Fig. 4.3. Lemming winter nests (right axis) and stoat predation on lemming winter nests (left axis) at Karupelv, Traill Ø (10 km²) and in the 2.5 km² census area in Zackenbergdalen. Data include nests built from October to May. Data from Karupelv were kindly provided by Benoît Sittler (partly published in Sittler 1995, 2000).

by 42% as compared to 1999. Hence, the number of winter nests in 2000 was comparable to the figure from the previous low phase in 1996, whereas the numbers of summer burrows equalled the number recorded in 1999. The marked decrease is also indicated by the reduction in number of lemmings observed by Hans Meltofte during bird census work in June and July (Table 4.30). The decline of the lemming population found in Zackenbergdalen was also apparent along the two line transects (Table 4.31).

The continued population decrease showing a two-year decline of the lemming population is equivalent to the pattern found at Karupelv (Fig. 4.3). However, as discussed in section 4.4 in Caning and Rasch (2000), there are differences in the lemming population dynamics between Karupelv and Zackenbergdalen. If the density of winter nests in Zackenbergdalen in 1996 and 2000 represent the average density during a lemming low phase, then the amplitude of the fluctuations of the lemming population at Karupelv may be up to eight times larger than in Zackenbergdalen (Fig. 4.3). The maximum amplitude recorded at Karupelv is 35.2 against 4.5 at Zackenberg.

The numbers of lemming winter nests that had been predated by stoats and afterwards used as winter quarter by the predator, showed a slight increase from 4 to 10 from 1999 to 2000. This was also the case at Karupelv, where the figures increased from 12 to 16. The ratio of winter nests taken over by stoats in relation to the total amount of winter nests fluctuate more dramatically at Karupelv than it does in Zackenbergdalen (0-16% and 0.29-5.43%, respectively). On the other hand, the density (nests/km²) is much lower at Karupelv (0-1.6 nests/km²) than in Zackenbergdalen (0.4-11.2 nests/km2).

The 29 fixed sample sites for predator casts and scats were checked on 30 August (Table 4.32). Except for the absence of stoat scats, the figures from 2000 correspond well with those from 1999. Only the number of scats from foxes increased compared to the previous years, but that relates well to the increased number of fox records (see Table 4.40). One of the two snowy owl casts consisted entirely of chitin from fly larvae, which indicate that the owl might have visited a musk ox carcass.

	Skua casts	Owl casts	Fox scats	Stout scats
1997	44	0	10	1
1998	69	9	46	3
1999	31	3	22	6
2000	33	2	31	0

Table 4.32. Numbers of casts and scats from predators collected from 29 permanent sites within the 2.5 km² lemming census area in Zackenbergdalen. The samples represent the period from mid August the previous year to mid August in the year denoted.

	1996	1997	1998	1999	2000
June	455	290	534	371	484
July	496	1111	652	408	900
August	2241	1343	1047	1216	1545
Total	**3192**	**2744**	**2233**	**1995**	**2929**

Table 4.33. Average number of 'musk ox days' (see the text) per month within the 40 km² census area in Zackenbergdalen based on the daily counts from a fixed elevated point at the station 1996-2000. The figure for June 1996 is interpolated.

Musk ox population biology

The daily censuses of musk oxen in Zackenbergdalen from a fixed point at the station showed the same picture as in previous years starting with less than 20 animals in June (16.3±7.4 S.D. in 2000 compared with a 5 yrs. average of 13.2±8.0

during 1996-2000) and increasing to an average of around 50 in August (48.2±23.6; 5 yrs. average: 53.3±27.4 during 1996-2000). The maximum numbers of musk oxen recorded within the 40 km^2 census area on the weekly censuses were 84 individuals on 25 July and 83 on 20 August. The maximum numbers of musk oxen recorded in one day within the entire visible area (c. 135 km^2) were made on the same dates with 124 and 122 individuals, respectively (see Table 4.35).

The grazing pressure by musk oxen within the census area expressed as 'musk ox days' (sum of weekly averages of numbers of animals counted per daily census) increased to a level equivalent to the figures from 1996 and 1997 (Table 4.33), which like 2000 were years with limited snow cover. In years with little snow, musk oxen tend to use the census area more intensively during the summer as compared to the two adjacent areas, Store Sødal and Daneborg-Zackenberg (see Table 4.39).

Two demography tables can be calculated. The first one (Table 4.34) is based on all animals sexed and aged within the 200 km^2 line transect area in one week around mid July (see text for Table 4.34). The order of the three censuses is planned to minimise the risk of double registrations. The other table (Table 4.35) is based on seven to eight weekly censuses of musk oxen within the 40 km^2 census area. In the latter case double counts and migration patterns are not considered.

In order to illustrate the reproductive potential and success only the demography data from August is taken into account. Although there seems to be examples of cows having calves in two consecutive years and that cows can have twins, these occasions are assumed to be rare.

	F-calf	M-calf	F1	M1	F2	M2	F3	M3	F4+	M4+	Total
1997	6.3	6.3	4.9	5.8	12.6	13.6	7.8	1.9	31.1	9.7	103
1998	4.5	4.5	4.9	5.7	6.6	6.6	6.6	5.7	36.1	18.9	122
1999	7.0	7.0	0.0	0.0	5.3	4.7	7.6	4.1	33.9	30.4	171
2000	8.5	8.5	4.1	4.8	2.7	0.7	4.8	4.1	32	29.9	147

Table 4.34. Sex and age distribution (%) of musk oxen based on total counts along the two line transects and the related census in Zackenbergdalen 1997-2000. All counts were made within 16-25 July and covered an area of about 200 km^2. It is assumed that no double counts were made within this period.

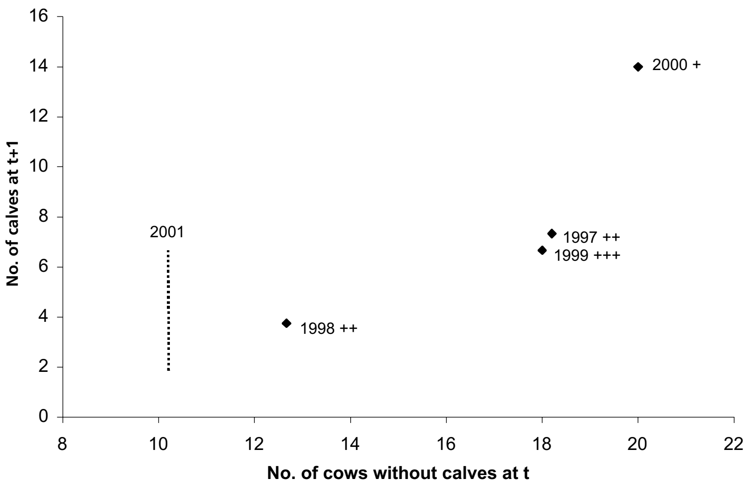


Fig. 4.4. Average number of calves in year t+1 plotted against the number of cows without calves in year t. All data are from August within the 40 km^2 census area. The dashed line indicates the range of the expected number of calves in 2001. The number of +-signs represent the amount of snow (+=poor, ++=intermediate, and +++ rich in snow).

Fig. 4.4 illustrates the relation between the number of 3+ yr. old cows (three years or older) without a calf occurring inside the 40 km^2 census area in August and the number of calves recorded the following year. The average number of cows with reproductive potential (cows without a calf) inside the 40 km^2 area in August 1996-2000 was 17.4 ± 4.12 SD (range: 10.3-20.0). This means that on average 62.1% (range: 42.5-82.8%) of the total number of adult females (F3+) inside the 40 km^2 area in August are accessible to the bulls during the

	F-calf	M-calf	F1	M1	F2	M2	F3	M3	F4+	M4+	N	Max
1996	8,9	8,9	11,4	11,4	3,3	9,2	5,3	1,1	24.8	15.8	456	153
1997	6,8	6,8	5,1	6,1	10,2	8,8	(6.3)	(3.7)	29.0	16.6	411	135
1998	4,3	4,3	2,5	2,5	8,4	9,2	5,3	6,1	30.3	27	393	94
1999	4,3	4,3	0,9	0	2,5	2,8	5,7	6,6	30.8	42.1	318	148
2000	10,3	10,3	4,5	4,8	1,8	0,3	3,6	3,3	32,4	28,5	330	124

Table 4.35. Sex and age distribution (%) of musk oxen in Zackenbergdalen as it appears from all weekly censuses 12 July-28 August 1996-2000. N is the total number of sexed animals. Sex of calves could not be assessed in the field but is assumed to be 1:1. Max gives the maximum number of musk oxen visible on one census the given year (i.e. also animals outside the 40 km^2 census area). For 1997, data on age class 3 year and 4+ year have been interpolated.

ID no.	UTM East	UTM North	Sex	Estim. age	General remarks
00-1	514900	8265600	F	3	Eaten by wolf, only skin left
00-2	514800	8266100	M	15+	No sign of wolf. Open in left caudal ventral side. Filled with larvae
00-3	513450	8264900	?	<1	Eaten by wolf
00-4	512800	8266450	M	12+	No sign of wolf. Open dorsally. Filled with larvae
00-5	489657	8269558	M	15+	Eaten by wolf, stomach full of grass
00-6	513902	8266571	M	15+	Belly open, no signs of wolf, filled with larvae
00-7	513867	8271402	M	4	Hole two cm in diameter present in the right side of the stomach, belly open
00-8	512150	8267050	M	12+	All flesh removed, some mummified skin remains, no wolf marks

Table 4.36. Fresh musk ox carcasses recorded during summer 2000 incl. estimated age of the dead individual in years.

Table 4.37. Fresh musk ox carcasses recorded during the field seasons 1995-2000. F=females, M=males. The number of "+" in the "Snow" column represent poor (+), intermediate (++) and snow rich (+++) winters. Thaw days are number of days during October-April with positive temperatures, which may have caused ice crust on the snow.

Year	Snow	Thaw days	Total carcasses	4+ yrs F / M	3 yrs F / M	2 yrs F / M	1 yr F / M	Calf
1994-1995	?	?	2	0 / 1				1
1995-1996	++	5	13	7 / 1	0 / 1	0 / 2	1 / 1	
1996-1997	++	3	5	0 / 2		1 / 0	1 / 0	1
1997-1998	++	6	2	0 / 2				
1998-1999	+++	5	1	0 / 1				
1999-2000	+	3	8	0 / 6	1 / 0			1

rut season. The reproductive success as it appears the following year (four years of data) is 0.44 ± 0.09 SD (range: 0.30-0.70). In this sense the reproductive output from 1999 to 2000 was high with 70% of the females giving birth to a calf that was still alive by August 2000 (Fig. 4.4). The low amount of snow during the winter 1999/2000 and the following early access to favourable forage may be an important explanation, but migration constitutes a major potential bias.

Based on the correlation presented, the number of calves in 2001 will be low (between two and six) compared with the maximum average number of calves (20.6) recorded on weekly censuses in August 1996.

A total of eight fresh musk ox carcasses were encountered (Table 4.36), of which five were found inside the 40 km^2 census area (ID. nos: 1, 2, 3, 4 and 6). Two were situated just outside the area (ID. nos. 7 and 8) while one was found on the line transect through Store Sødal (ID. no. 5). Only three of the eight carcasses had signs of having been eaten by wolfs. Carcass no. 7 was found on the last weekly census and the time of death must have been between 15 and 18 August. The cause of death was not clear, but it could well be interference with an older bull during the rut season. The variation in the number of musk ox carcasses from year to year is presented in Table 4.37.

On 19 July, an aerial survey for musk oxen was made over Storsletten (Fig. 4.5). Observations were made from the front windows as well as from both sides in a Twin Otter. The total flying time was 75 minutes at midday. The survey over Storsletten took c. 30 minutes, and was made 2-300 meter above ground with a speed of 150 km per hour. All musk oxen on Storsletten were recorded in the western part (west of Rødryggen dividing the area into two distinct parts). In total, 24 musk oxen (incl. one calf) were recorded on the plain. Day old snow covered 70-90% of the western part of the plain and 30-50% of the eastern part, which made

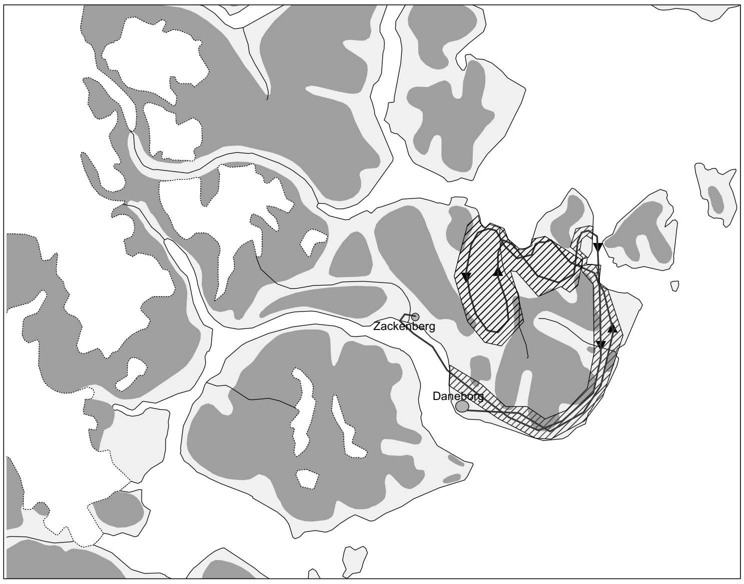


Fig. 4.5. Aerial survey area and route for musk ox census over Storsletten south of Albrecht Bugt and along the outer coast.

survey conditions poor. Several tracks indicated that not all musk oxen were detected. Further observations along the outer coast (235 km^2) along two neighbouring transects of 133 km in total revealed 11 musk oxen (incl. one calf). An aerial survey made in the same area (Storsletten) between 5 and 8 July 1988 revealed 82 musk oxen (incl. 17 calves) (Bay and Boertmann 1989). The aerial survey in 1988 covered also Store Sødal and Slettedal as well as the coastline between Daneborg and Zackenberg. In total 207 musk oxen (incl. 47 calves) were recorded at that time. Despite of the larger area, these 207 animals may be compared with the total of 182 musk oxen that were recorded in 2000 inside almost the same area. This might indicate that the musk ox density on Wollaston Forland and A.P. Olsen Land in 2000 was comparable with the figures from 1988. Data from the sledge patrol Sirius show a maximum number of musk oxen recorded on Wollaston Forland and A.P. Olsen Land of 348 during winter 1983-1984, when all major valleys were checked by dog sledge teams (Boertmann and Forchhammer 1992). The three most important musk ox areas in Northeast Greenland are Jameson Land, Hold With Hope and Wollaston Forland (Boertmann *et al.* 1992)

Arctic fox dens

One new active den (no. 8) with five entrances was found under a big stone along a riverbed in Morænebakkerne (UTM zone 27: 8,267,065 m N, 511,477 m E). Three dens were used as breeding dens: nos. 1, 2, and 8 with a minimum of three, three and two pups, respectively. All pups were of the white colour phase. Despite the low lemming abundance, no records of die off were made. Free moving juveniles were seen up to six km from their maternal den on 14 August. Den no. 5 situated 250 m a.s.l. was used throughout the summer, presumably by a lonely adult fox, as no sign of pups could be found. None of the other dens seemed to have been in use during the summer.

Line transects

At the start of the line transect Daneborg – Zackenberg on 16 July, pack ice prevented us from reaching Daneborg, and accordingly the first section (DZ-1) was cancelled. According to the previous four years this section is the least important in terms of fauna, and it may be assumed that the missing data were minimal. Besides a lonely arctic hare recorded on section DZ-2, the first records of mammals were made at the end of the transect along the boarder of the 40 km^2 musk ox census area in Zackenbergdalen.

The transect through Store Sødal was

	Store Sødal	Zackenberg-dalen	Daneborg-Zackenberg
M4+	7	25	4
M3	1	1	0
M2	0	1	0
M1	1	6	0
F4+	9	25	2
F3	1	4	0
F2	0	3	0
F1	0	4	0
Calves	3	15	2
Unsp. yearlings	2	0	0
Winter piles	373	-	45
Summer piles	60	-	11

Table 4.38. Musk ox data from the 90 km line transect through Store Sødal 22-24 July and the 25 km transect from Daneborg to Zackenberg on 16 July 2000 together with musk ox data from Zackenbergdalen 25 July. Faeces piles of musk oxen were recorded by both observers giving total transect lengths of 180 km and 50 km, respectively. Only faeces piles within one meter from the transect were counted. M=male, F=female, 4+= 4 years or more.

	Store Sødal	Zackenberg-dalen	Daneborg-Zackenberg
Muskoxen/km^2			
1996	0.37	0.35	-
1997	0.39	1.61	0.13
1998	0.62	1.18	0.86
1999	0.78	1.20	0.70
2000	0.25	2.10	0.22
Faeces piles/km			
1997 winter/summer	1.59/0.49	-	4.90/0.82
1998 winter/summer	1.55/0.39	-	1.14/0.68
1999 winter/summer	6.26/1.63	-	3.66/2.46
2000 winter/summer	2.33/0.38	-	0.90/0.22

Table 4.39. Musk ox densities (animals/km^2) in Store Sødal (92 km^2 in 1996-1998 and 125 km^2 in 1999-2000), the census area in Zackenbergdalen (40 km^2) and in the coastal region between Daneborg and Zackenberg (37 km^2) in mid July 1996-2000. The density of faeces piles (no. of faeces piles/km walked) in Store Sødal (no./150 km in 1997-1998 and no./160 km from 1999 and on) and from Daneborg to Zackenberg (no./50 km).

Table 4.40. Minimum number of individual foxes recorded in Zackenbergdalen (50 km^2) divided into colour phase (W=white; B=blue) and age class 1996-2000, including pups at dens. "Total number of records" gives records of all adults and those of juveniles encountered in the field away from their maternal den. Also foxes visiting the research station are included.

1.6 –31.8	White phase adult	White phase juvenile	Blue phase adult	Blue phase juvenile	Total number of records	Total number of carcasses
1996	3	6	1	3	31W + 3B	
1997	2	1	1		17W + 5B	1W + 1B
1998	3	5	1	1	21W + 2B	1W
1999	3-4		1		18W + 1B	2W
2000	5-6	8			28W	2W

walked during 22-24 July. Data from both transects are presented in Tables 4.38 and 4.39. The musk ox density found in Store Sødal was the lowest ever recorded, which correspond well with the assumed scenario that early access to the rich feeding grounds in Zackenbergdalen makes the musk oxen leave the inland grounds earlier that in snow rich springs. Along the coast from Daneborg to Zackenberg the density was low as well. It is noteworthy that the two snow rich springs so far (1998 and 1999) made the musk oxen use the total area (200 km^2) more evenly than in snow poor years (Table 4.39).

For bird observations, see section 4.3.

Other observations

Collared lemming *Dicrostonyx groenlandicus*

Despite the low phase of the lemming population (see above), a total of eight animals were recorded in the field between 5 July and 30 August. Besides these eight animals three were caught in live traps ("Ugglan Special"). It was evident from those juveniles seen during the field period that summer breeding took place in the area and that litters were born at least in early June and in late July.

Arctic wolf *Canis lupus*

Besides tracks seen in the area during 15 June-18 August, a lonely adult female was encountered near the old delta on 17 July. From there it passed north to Oksebakkerne, where it was found resting later the same day. On 18 July fresh tracks were found 250 m a.s.l. in fresh snow.

Arctic fox *Alopex lagopus*

A total of 20 independent records of adult foxes were made in Zackenbergdalen during the field season, in addition to the eight pups mentioned above. All animals were of the white phase. According to the location and individual characters of the recorded animals, the minimum number of foxes recorded within Zackenbergdalen was 5-6 white phase adults. One carcass of an adult white phase fox in winter coat was found at Tørvedammen in June. Additional fragments of at least one other winter coloured white phased fox was found south of the airstrip. An overview of dead foxes recorded each year 1996-2000 is presented in Table 4.40.

Arctic hare *Lepus arcticus*

A total of 13 Arctic hares were recorded in Zackenbergdalen between 31 May and 24 August. Additional records were made 28 July-26 August during the census for musk oxen from a fixed point at the station. The east-facing slope of Zackenberg mountain was censused by means of a 30 x spotting scope. The hares appeared within a well-defined area on the hillside about 1000 meter wide and between 50 and 450 m a.s.l. The maximum count within this area was 11 animals. Additional spotting scope records outside this area include one animal in Morænebakkerne and eight on the slopes of Palnatoke Bjerg. In total, a minimum of 28 individual arctic hares were recorded during the field season, of which two were recorded during the line transects.

Stoat *Mustela erminea*

Two animals were recorded, one in Morænebakkerne on 14 July and one east of Okseelv in Kuhnpasset carrying a newly caught lemming on 31 July.

Walrus *Odobenus rosmarus*

High numbers of walruses, up to 24 individuals, were again present at Sandøen after the low abundance in 1999 (see section 5.9). On 6 August, a walrus was seen foraging east of Halvøen. Between 11 and 19 August, three observations of up to two individuals were made in front of the old Zackenberg trapping station. At one occasion, a walrus was seen lying on a sandy spit in the new delta.

Seals Pinnipidae

During the musk ox counts from 6 June until the fjord ice broke up in the inner part of Young Sund on 8 July, a total of 230 seals were counted during 16 censuses, giving an average of 14.38 ± 7.00 SD per count (Table 4.41).

Year	Average±SD	Range	Counts
1997	8.52 ± 4.98	3 - 21	23
1998	7.42 ± 4.50	0 - 18	18
1999	25.05 ± 12.32	2 - 61	22
2000	14.38 ± 7.00	2 - 28	16

Table 4.41. Numbers of seals counted daily from a fixed point at the station from 1 June until the fjord ice broke up around mid July 1997-2000. Counts were only made when sight conditions were good.

Bowhead whale *Balaena mysticetus*

On 27 July, two bowhead whales were seen in Young Sund near Daneborg. This is one of the few sightings of this rare species in East Greenland in recent decades (More and Reeves 1993).

4.5 Lake monitoring

Kirsten Christoffersen and Erik Jeppesen

A standardised monitoring programme in two of the shallow lakes in Morænebakkerne has now been in action for two years. Details about the monitoring programme are given in section 4.5 in Caning and Rasch (2000). The lakes have also been studied prior to the monitoring programme (see section 5.3 in Meltofte and Rasch 1998 and section 5.4 in Rasch 1999).

These lakes have clear water originating from melted snow in the catchment area, and they are very nutrient poor. One lake, Langemandssø, with a maximum depth of 6.1 m, has a population of dwarf Arctic char *Salvelinus alpinus*, while no fish have been found in the other lake, Sommerfuglesø, with a maximum depth of 1.8 m.

The lakes were sampled three times between 25 July and 17 August 2000. Physico-chemical data are presented in Table 4.42 and in Table 4.43, they are compared with data from 1997-1999. First of all, the thawing of the ice in 2000 was much earlier than in previous years and consequently, water temperatures reached higher values than in the other years. In 2000, water temperatures ranged from 8.2 to 11.8ºC, with mean water temperatures of 10.4 and 9.5ºC in Sommerfuglesø and Langemandssø, respectively. The conductivity of Sommerfuglesø (16-20 µS/cm) was slightly higher than in Langemandssø (9-10 µS/cm) and higher in 2000 than in the previous years, while concentrations of total nitrogen were highest in Sommerfuglesø. In both lakes, total nitrogen was substantially higher than in 1999. Total phosphorus concentrations were similar in the two lakes, ranging from 7 to 16 µg P/l. pH varied between 5.2 and 6.1. The chlorophyll a concentration varied between 0.57 and 1.2 µg/l during the sampling period, but averaged almost the same level in Sommerfuglesø and Langemandssø, (0.78 and 0.90 µg/l, respectively), which is twofold higher than in 1999. Generally, the basic physico-chemical conditions were found to be within the range observed in previous years, except for high water temperatures and higher total nitrogen concentrations, most likely owing to the early melting of the ice compared to previous years.

Table 4.42. Physico-chemical conditions and chlorophyll a concentrations in Sommerfuglesø (SS) and Langemandssø (LS) during July and August 2000.

Lake	SS	SS	SS	LS	LS	LS
Date	25.7	7.8	17.8	25.7	7.8	17.8
Ice cover (%)	0	0	0	0	0	0
Temperature (ºC)	11.8	10.4	8.2	10.2	9.2	9.0
Conductivity (µS/cm)	16	17	20	9	10	10
pH	5.5	5.7	6.1	5.4	5.2	5.9
Total nitrogen (µg/l)	0.83	0.44	0.25	0.51	0.22	0.15
Total phosphorous (µg/l)	16	8	6	9	13	7
Chlorophyll a (µg/l)	0.79	0.82	0.67	0.57	0.95	1.26

Lake	SS	SS	SS	SS	LS	LS	LS	LS
Year	1997	1998	1999	2000	1997	1998	1999	2000
Date of 50% ice cover	ND	9.7	18.7	24.6	ND	23.7	21.7	30.6
Temperature (ºC)	6.3	6.5	6.5	10.4	6.8	6.4	4.1	9.5
Conductivity (µS/cm)	15	13	9.9	17.3	8	6	6.6	9.7
pH	6.5	7.4	6.7	5.7	6.5	8	6.3	5.4
Total nitrogen (µg/l)	ND	0.13	0.21	0.51	ND	0.08	0.12	0.29
Total phosphorous (µg/l)	4	9	11	10	8	7	7	11
Chlorophyll a (µg/l)	0.84	0.24	0.45	0.78	1.04	0.63	0.36	0.90

Table 4.43. Weighted average values for physico-chemical conditions in Sommerfuglesø (SS) and Langemandssø (LS) in 1999 and 2000 (July-August) compared to single values from mid-August 1997 and 1998. ND = no data.

Table 4.44. Density (cells l-1) of phytoplankton taxa in Sommerfuglesø and Langemandssø, respectively, during July-August 1999.

Lake	SS	SS	SS	LS	LS	LS
Date	23.7	3.8	16.8	23.7	03.8	16.8
Nostocophyceae	46	0	0	0	0	0
Dinophyceae	18	79	112	139	35	30
Chrysophyceae	0	77	27	220	476	68
Chlorophyceae	13	34	5.6	21	15	13
Others	530	2185	3790	80	179	232

Unfortunately, the phytoplankton samples from 2000 were damaged, but the phytoplankton species composition for 1999 has now been examined and shows that Dinophyceae (*Gymnodinium* spp. and *Peridinium umbonatum*-group) and Chrysophyceae (mainly *Dinobryon bavaricum* and *D. divergens*) are the main components of the phytoplankton communities (Table 4.44). Other species such as the chlorophycean *Koeliella longiseta* and several types of unidentified phytoflagellates were also present, especially in Sommerfuglesø. In terms of biomass, Dinophytes were most important in both lakes. In 1999, the biodiversity did not seem to differ much between the two lakes, but the densities were higher in Sommerfuglesø than in Langemandssø (Table 4.44).

The zooplankton species diversity is poor (Table 4.45). In the fishless Sommerfuglesø, the zooplankton is dominated by *Daphnia pulex* and the rotifer *Polyarthra dolicopthera*, while *Daphnia* is completely absent in Langemandssø probably due to the population of Arctic char that preys upon this large species of cladocerans. In the absence of competition from *Daphnia*, the number of rotifers and advanced stages of copepods is higher in Langemandssø. A similar pattern has been observed in other lakes in Northeast Greenland (Jeppesen *et al.* in press). In years with high abundance of *Daphnia* or cyclopoid copepods, the number of rotifers was relatively lower than in the other years.

The abundance has varied widely from year to year (Table 4.45) depending upon differences in climate, but probably also related to the fact that sampling was restricted to one sample per year is of significance. The number of cyclopoid copepods in Langemandssø was thus high in 2000, a warm year, and the number of advanced stages much higher than in previous years, which may be ascribed to a temperature-conditioned faster development than in previous years. Likewise, the number of *Daphnia* was high in Sommerfuglesø in 2000 compared to 1997 and 1999. It was, however, even higher in the cooler year of 1998, their size being, though, smaller than in 2000.

The biological structure of the two lakes appears to fit very well with those described recently for numerous arctic lakes in Greenland (Jeppesen *et al*. 2000). There seem to be year-to-year variations in zooplankton, which can be partly ascribed to inter-annual climatic differences among years.

Table 4.45. Density (no l-1) of zooplankton in Sommerfuglesø (SS) and Langemandssø (LS), respectively, in mid-August 1997-2000.

	SS	SS	SS	SS	LS	LS	LS	LS
	1997	1998	1999	2000	1997	1998	1999	2000
Cladocera								
Daphnia pulex	0.3	10.5	0.3	4.5	0	0	0	0
Macrothrix hirsuiticornis	0.1	0	0	0	0	0.2	0.2	0
Chydorus sphaericus	0.05	0	0	0	0	0	0	0.5
Copepoda								
Cyclops abyssorum alpinus (adults+copepodites)	0.8	0.5	0.5	0.2	3.3	2.9	4.1	22
Nauplii	5.7	1.3	6.5	0.7	5.2	3.8	6.4	3.1
Rotifera								
Polyarthra dolicopthera	171	90	184	65	316	330	274	168
Keratella quadrata group	5	3	17	0	4	28	34	0
Conochilius sp.	0.05	0	0	0	0	0	0	0

5 Research projects

5.1 Methane emission in relation to vascular plant production: summary of results from three years of field manipulations in the fen area.

Anna Joabsson, Torben Røjle Chistensen and Lena Ström

The experiments have been carried out as part of a larger EU funded project called CONGAS (Biospheric controls on trace gas fluxes from northern wetlands) with comparable field manipulation schemes at four other northern wetland and tundra sites. The site in the fen area in Zackenberg was established in 1998 with intensive field campaigns during the 1999 and 2000 growing seasons.

The objective of the study has been to investigate the linkage between vascular plant production and methane (CH_4) production and emission. It is well recognised that vascular plants mediate CH_4 transport from waterlogged soil to the atmosphere, which greatly increase efflux rates. It is also believed that vascular plants provide substrates for CH_4 production via root turnover and exudation of various labile carbon compounds, but these processes are less well known. Our experimental plots have been subjected to shading in order to lower net ecosystem carbon dioxide (CO_2) exchange (NEE) and therefore the amount of recently fixed substrate carbon that would become available to the CH_4 producers. Chamber measurements of CO_2 and CH_4 fluxes were carried out one to three times per week during 1999 and 2000 and photosynthetic active radiation (PAR), air temperature and soil temperatures at different depths were continuously logged. Concentration profiles of dissolved CH_4 were sampled four times in 1999 and two times in 2000, potential CH_4 production was measured at two different occasions in 2000. In order to investigate root exudation of organic acids, plant shoots were grown in water filled capsules, first in the lab and later in the field, and the water was sampled at regular intervals during a campaign in 2000. Depth profiles of organic acid concentrations in pore water were also sampled at three occasions in connection to this campaign. Final harvest of the site (leaf and root biomass) took place in late August 2000.

We conclude that CH_4 emissions in the fen area were sensitive to changes in NEE induced by the shading treatment (Fig. 5.1). In 1999 the correlation was relatively straightforward with higher plant production (more negative NEE) leading to higher CH_4 efflux. The correlation was not as clear-cut in 2000, but a storm event with high wind speeds and heavy rainfall on 17 July 2000 might have caused long lasting methanotrophic CH_4 consumption and inhibition of methanogenesis due to oxygenation of the soil and intrusion of alternative electron acceptors in the form of nitrate or sulphate salt particles. Organic acid concentration profiles and potential

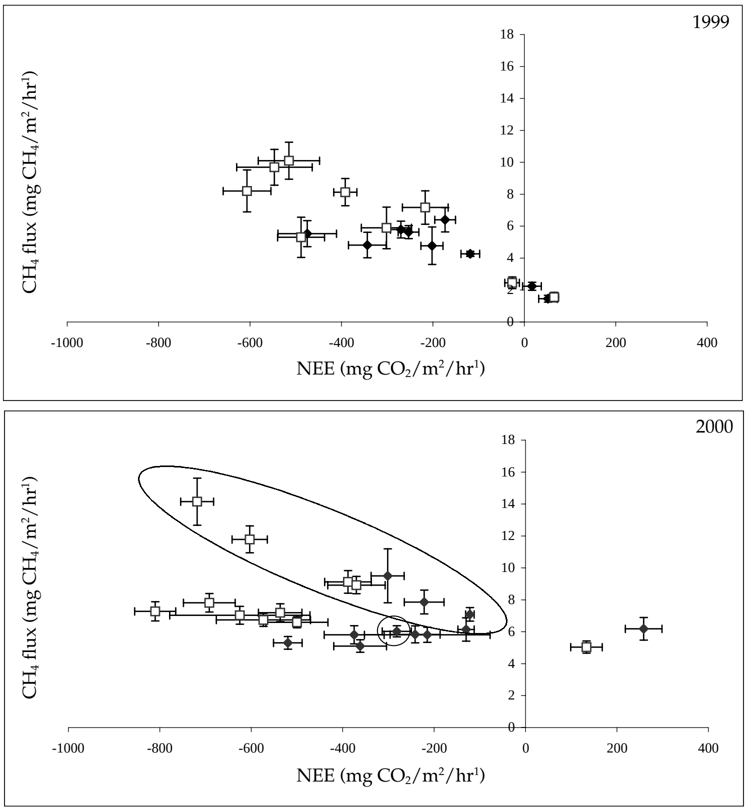


Fig.5.1. Net ecosystem exchange (NEE) plotted against CH_4 flux in 1999 (top) and in 2000 (bottom). The marked points in the bottom graph are sampling occasions carried out before a storm event on July 17, 2000. Filled symbols represent shaded plots and open symbols represent controls. Error bars are standard errors (n=6).

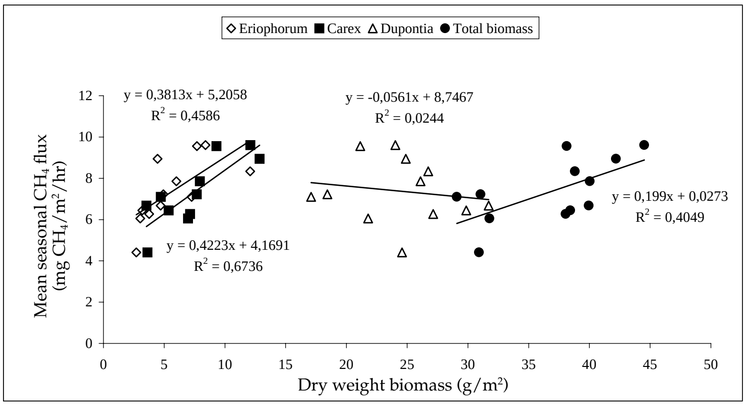


Fig. 5.2. Aboveground biomass plotted against mean seasonal (2000) CH_4 flux.

CH_4 production peaked at the same depth as maximum root density and treatment differences suggest that access to labile substrate carbon was tightly coupled to vascular plant production rates. Data from the "capsule-experiment" are currently being analysed, but preliminary results confirm that root exudation was a strong source of easily degradable carbon compounds. Total aboveground biomass explained about 40% of the variation in mean seasonal CH_4 emission, but separation into species indicates that the correlation might have been highly species-dependent (Fig. 5.2). The most likely explanation is that the ability to act as gas transporting conduits was different for the three species present in our plots.

5.2 CO2 concentrations in arctic soil gas

Charlotte Sigsgaard

In July 1999 measurements of the soil carbondioxide (CO_2) gas concentrations were initiated in three different vegetation communities in the Zackenbergdalen (Caning and Rasch 2000). Those measurements were continued through the summer 2000. From early June to late August temperature, soil moisture content and vertical CO_2 concentrations were measured at different depths within the soils. The aim of this project is to improve the understanding of the carbon dynamic in the active layer in relation to different soils and plant communities.

In addition to the metal tubes installed in the soil last year for gas sample collection, plastic bottles were installed this year. Perforated 250 ml bottles were inserted horizontally into a vertical soil pit at depths of 5, 10, 15, 25, 40 and 60 cm with a copper tube leading to the surface. From these bottles, gas samples were collected twice a week and analysed in the field using an infrared gas detector (Gas Data Ltd.). Furthermore, thermocouples and mini temperature datalogggers were installed for temperature measurements and a Delta-T probe was used for TDR soil moisture measurements.

Fig. 5.3 shows results from the site south of Zackenberg Station which is a dry heath area dominated by *Dryas*. The site was free of snow and the active layer had developed to a depth of 25 cm when measurements were initiated in the beginning of June. During the entire field season concentrations were increasing with depths which could be caused both by variation in the soils diffusive characteristic and changes in the CO_2 production within the soil. A deep source of CO_2 production would be respiration from either roots or

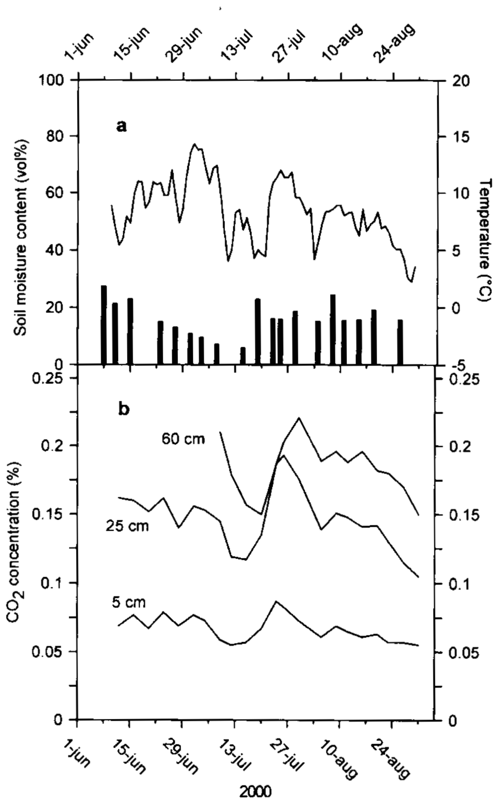


Fig. 5.3. (A) Soil parameters from the Dryas dominated site from early June to late August 2000. The curve shows soil temperature at a depth of 2.5 cm and bars show soil moisture content measured by TDR in the upper 6 cm of the active layer. Measurements are made around midday (note the different scaling on axes). (B) Variation in carbon dioxide concentrations in the active layer at depth of 5, 25 and 60 cm. Concentrations are increasing with depth throughout the entire field season.

microbes. Respiration from micro-organisms decomposing organic material have been studied in the laboratory at temperatures ranging from -12°C to 37°C and soil samples from different horizons all showed activity at temperatures below 0°C.

Over the season the CO_2 concentrations show a distinct decline in mid July followed by a peak in the end of July (Fig. 5.3 B). The relatively low concentrations are associated to a period of low temperatures and very dry soil, and the relatively high concentrations seem to reflect the rising soil temperature and the increasing soil moisture content after a rain event 17 July (Fig. 5.3 A). The carbon dioxide response to the warm temperatures in June is not as pronounced as the response in the end of July which probably is due to the low moisture content in the soil at that time.

When measurements were initiated at the *Dryas* site, the *Cassiope* and the *Salix Arctica* dominated sites were still covered by around 40 cm of snow. Using a Dräger probe system the air CO_2 concentration in the snow pack was measured and slightly elevated concentrations near the bottom were observed. Compared to the atmospheric CO_2 concentration, around 0.037%, values were increasing through the snow to values of 0.08% CO_2 near the soil surface showing that the soil acts as a source of CO_2 at that time.

Variations over the season observed for the *Cassiope* and the *Salix Arctica* dominated sites show the same overall pattern as seen for *Dryas* in Fig. 5.3. But a local maximum around 15-20 cm in the vertical CO_2 gradients are often observed at these sites as well (Caning and Rasch 2000).

5.3 Hydrology, solute fluxes and Sr isotope composition of stream water

Birgit Hagedorn, Ron Sletten, Bent Hasholt, Morten Rasch

Some of the largest changes in air temperature due to an increase of greenhouse gases in the atmosphere are expected to occur in the Arctic. Recently, long-term data (>30 years) have confirmed this postulate (Martin *et al*. 1997, Rigor *et al*. 2000). The ecological consequences of these changes in Arctic areas, however, are unclear as we lack information and understanding of the hydrological, physical and chemical processes in the Arctic environment. In this perspective the investigations of water and solute fluxes and related weathering processes are important.

Hydrology and solute composition

The Zackenberg catchment is divided in two main lithologies. East of the Zackenberg river and south of Lindemannsdalen sedimentary rocks occur which are drained by the Lindemannelv, Palnatokeelv and Aucellaelv. The catchment area north of Lindemannsdalen and northwest of the river Zackenbergelven consists of crystalline rocks. Glaciers cover about 20% of this crystalline region and the major outflow of the crystalline area is the Store Sødal stream. In 1997, 1998, and 1999 sampling and discharge measurements of the streams were carried out. Chemical and Sr isotope measurements were performed in order to identify source regions of solutes and suspended matter (SDM), and to estimate solute fluxes and weathering rates. Discharge, sediment load and total dissolved solutes (TDS) of streams in the catchment areas are listed in Table 1. Streams draining sedimentary rocks are fed by snow and active layer water and have TDS values between 450 and 11360 µmol/L with highest values at the end of the season. The large Store Sødal stream is mainly fed by glaciers and has TDS values between 160 and 550 µmol/L. The relative silicate concentration is higher in waters from the crystalline area ($Si_{(aq)}/\Sigma$cations ratios between 0.6 and 0.2) indicating that silicate weathering is the major source of solutes. In the sedimentary catchment area low $Si_{(aq)}/\Sigma$cations ratios between 0.2 and 0.01, high amount of dissolved sulfate, cal-

Table 5.1. Discharge (Q), sediment load (SPM), and total dissolved solutes (TDS) of streams draining the sedimentary catchment area (Lindemannelv, Palnatokeelv, Aucellaelv) and crystalline catchment (Store Sødal). Values from 1997 are from Hasholt and Hagedorn (2000).

Date	Stream	Area (km²)	Q (m³/s)	SPM (mg/L)	TDS (µmol/L)
17-07-97	Lindemann	69,5	2,77	183	1200
03-08-98	Lindemann		4,82	270	970
19-07-97	Aucellaelv	8,3	0,24	259	1460
03-08-98	Aucellaelv		0,49	340	1447
13-07-97	Palnatokeelv	18,4	1,4	201	871
03-08-98	Palnatokeelv		0,71	---	495
13-07-97	Store Sødal	421	19*	15	224
15-08-98	Store Sødal		---	9	188

*) calculated as difference between major outflow and streams of sedimentary (Lindeman, Aucellaelv, Palnatokeelv).

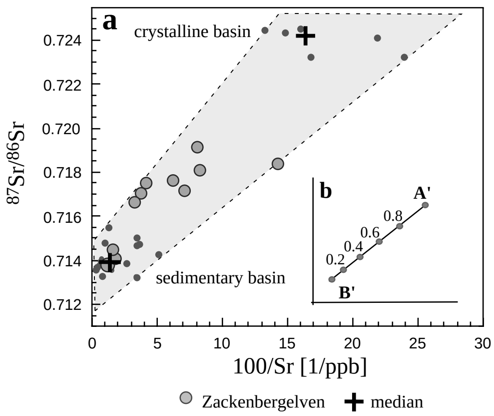


Fig. 5.4. Sr isotope ratios versus 1/Sr of the streams draining the crystalline and sedimentary rocks and the major outflow Zackenbergelven (a). Schematic map of mixing of the two components A and B and calculated fraction in mixture (circles) (b).

cium, magnesium, and high alkalinity indicate the contribution of evaporites and carbonates to solute concentration.

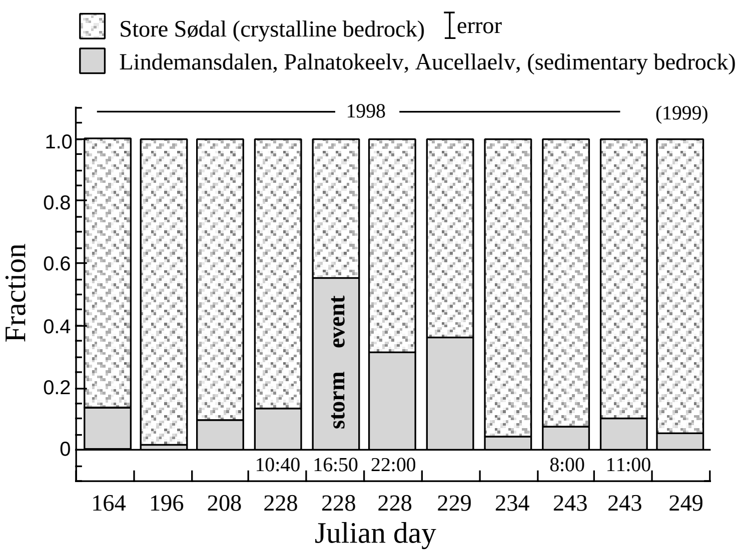
Strontium composition of stream water

In order to quantify the amount of water and solutes of each drainage basin to the major outflow and to identify the sources of weathering products, we investigated strontium isotope ratios ($^{87}Sr/^{86}Sr$) of the stream water. Strontium (Sr) has 4 natural occurring isotopes ^{88}Sr, ^{87}Sr, ^{86}Sr, ^{84}Sr with abundance 82.23%, 7.04%, 9.87%, 0.54%, respectively. The isotope abundance is constant except for ^{87}Sr that is produced by $ß^-$ decay of ^{87}Rb with a halflife of $4.8*10^{10}$years. Therefore, the $^{87}Sr/^{86}Sr$ ratio (Sr-isotope ratio) of minerals, rocks and rock units depends on their Rb concentration and age. With the knowledge of $^{87}Sr/^{86}Sr$ ratios and Sr-concentration in each reservoir (e.g. mineral, rock, water) sources and sinks of solutes and solids in ecological systems can be identified and quantified. The primary sources of Sr in aquatic systems are mineral dissolution and atmospheric deposition (dry & wet).

The potential of Sr isotopes to quantify the contribution of each drainage basin to the major outflow in Zackenbergelven is demonstrated in Figs 5.4 and 5.5. As shown in the Sr-mixing diagram in Fig. 5.4, the water from the crystalline basin has high $^{87}Sr/^{86}Sr$ ratios (0.724-0.725) and low Sr concentrations (4-6 µg/L). The water from the sedimentary area has low $^{87}Sr/^{86}Sr$ ratios (0.713-0.715) and high Sr concentrations (200 µg/L). The $^{87}Sr/^{86}Sr$ ratios and Sr concentrations of water from the Zackenbergelven lie between the crystalline and sedimentary area. In this type of diagram (Fig. 5.4 b) a mixture of two components A and B is lying on a line between the components. If the $^{87}Sr/^{86}Sr$ ratio and Sr-concentration of the pure components and of the mixture are known, the fraction of each component in the mixture can be calculated. In the Zackenberg drainage basin the so-called endmembers (A, B) are the streams of the sedimentary area and of the crystalline area. Fig. 5.5 shows the result of such a calculation for the Zackenberg drainage basin in 1998. During the rainstorm the contribution from the sedimentary catchment area is increasing while the rest of the time the crystalline catchment contributes more than 90% to the discharge of the entire Zackenberg drainage basin. However, as seen in Fig. 5.4, the Sr isotope ratios and Sr concentrations are variable due to seasonal changes in stream chemistry. The use of median, minimum and maximum values, respectively, indicates a relative uncertainty of about 10%. Furthermore, a third component of this system is the atmospheric deposition. Since the Sr concentration of rain and snow are very low (0.1 and 0.5 µg/L), their influence on stream chemistry is negligible.

The results show that solute fluxes in the Zackenberg drainage basin are correlated with lithology. The daily solute flux is between 7.3*103 and 1.6*103 mol/km²/d in streams from the sedimentary area, and 1.9*103 mol/ km²/d in the Store Sødal stream. These values are comparable with solute fluxes measured in large streams from Siberia (Lena and other), Alaska (Mackenzie, Yukon), and Canada (Fraser River) (Huh *et al*. 1998).

Fig. 5.5. Fraction of water and solutes from the sedimentary catchment area and the crystalline catchment area. Calculated from Sr concentration and $^{87}Sr/^{86}Sr$ isotope ratio.



5.4 Global change effects on unicellulars and plants

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

This project started in 1998 and involves a study on global change effects on unicellulars and plants. For more information please refer to the ZERO 4th Annual Report 1998 (Rasch 1999). We present a short summary of the fieldwork in 2000 followed by results from fieldwork done in previous seasons.

The 2000 fieldwork

The fieldwork in the summer of 2000 focused on collecting samples from the Store Sødal area. During a four day expedition into Store Sødal, 39 samples were collected from 19 waterbodies, mainly lakes. In addition, 90 samples were taken from 38 sites in the Zackenbergdalen and Lindemannsdalen which were not sampled in the two previous field seasons. A new core for palaeoecological analysis was taken from the thermokarst at the edge of Rylekærne.

Communities and ecology of unicellulars

Testate amoebae. A total of 45 taxa, belonging to 12 genera, were recorded in 36 moss samples. Three taxa (*Difflugia pristis*, *Euglypha strigosa* f. *heterospina* and *Heleopera rosea*) that were found for the first time in the Arctic in previous years, were also recorded in these moss samples. The most abundant species, *Trinema lineare* (Fig. 5.6 A), was found in every sample. It has a mean relative abundance of 42.9% (16.7%. Other important species were (ordered by decreasing importance) *Euglypha rotunda* (Fig. 5.6 B), *Corythion dubium* and *Assulina muscorum*. Most taxa were found in the genera *Euglypha* (10 taxa) and *Nebela* (10 taxa). Two major groups of samples could be distinguished. The environmental force behind this division seems to be the moisture content of the moss habitat. Taxa with higher abundances in group 1 were *Trinema lineare*, *Euglypha rotunda* and *Centropyxis aerophila* indicating a higher moisture content. Taxa mainly occurring in group 2 were *Assulina muscorum*, *Corythion dubium* and *Nebela minor*. These taxa point towards a drier state of the sampled mosses in this group.

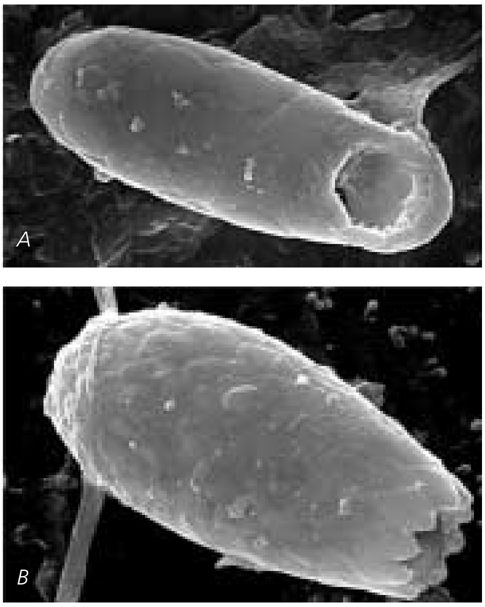


Fig. 5.6. (A) *Trinema lineare* Penard (25 µm); (B) *Euglypha rotunda* Wailes (35 µm).

Diatoms. 179 different diatom taxa, belonging to 29 different genera, were found in 54 aquatic samples. The most important genera were *Achnanthes*, *Nitzschia* and *Navicula*. Important taxa were *Nitzschia perminuta*, *Achnanthes marginulata* and *Diadesmis gallica*. Two taxa, which were first described in 1999 from arctic Siberia, occurred in our samples (*Neidiopsis vekhovii* (Fig. 5.7 A) and *Pinnularia bullocostea*). The samples from rivers and brooklets contain diatom taxa that prefer running water conditions (e.g. *Meridion circulare* (Fig. 5.7 B) and *Hannaea arcus* (Fig. 5.7 C)). These taxa were seldom observed in the other samples. Strange was the occurrence of *Hannaea arcus* in Hjerte Sø.

Although the lakes from the moraine area have a different water chemistry, the diatom flora is not different. Consequently, other parameters must be important in determining the species composition. It can be hypothesized that some extra species variance can be due to differences in substrate, predation, succession and sediment type.

A different diatom group occurred in ponds which dry out during the growth season. In these ponds diatom taxa which can tolerate low moisture levels dominates the flora (e.g. *Diadesmis gallica*, *Caloneis arctica* (Fig. 5.7 D)).

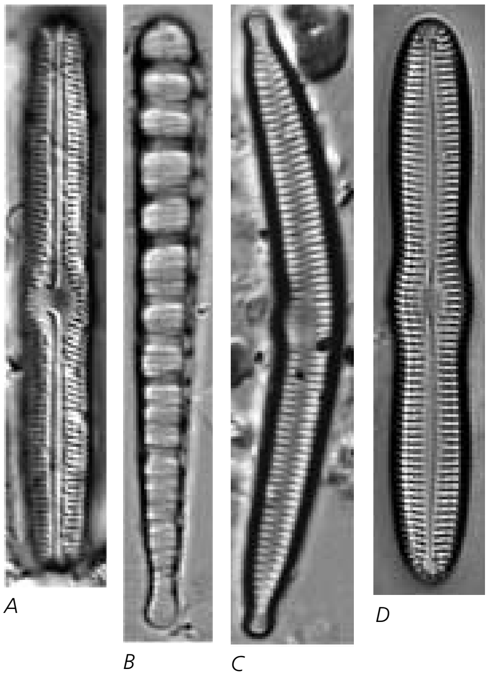


Fig. 5.7. (A) Neidiopsis vekhovii Lange-Bertalot & Genkal (43 µm); (B) Meridion circulare (Greville) Agardh (48 µm); (C) Hannaea arcus (Ehrenberg) Patrick (49 µm); (D) Caloneis arctica (Krasske) Lange-Bertalot (44 µm).

Palaeoecology

A total of 7 peat or soil cores were taken for palaeoecologial analysis. The base (-38 cm) of the oldest core was dated at 5790 ±35 years BP. Additional samples from other depths are currently being ^{14}C-dated. The core consists of a mixture of soil and organic matter, the layer between -19 cm and -26 cm however had a very low organic content. The upper 4 cm of the core contains diatom taxa indicating extremely dry conditions (characteristic genera: *Luticola* and *Diadesmis*). Between -5 cm and -28 cm the diatom flora reflects dry conditions (*Pinnularia borealis*, *P. obscura*). Only a few taxa were found in the layer between -19 cm and -26 cm. *Achnantes* species between -27 cm and -38 cm point towards a wetter environment. The appearance of the testate amoeba Arcella rotundata in the same layer supports this suggestion.

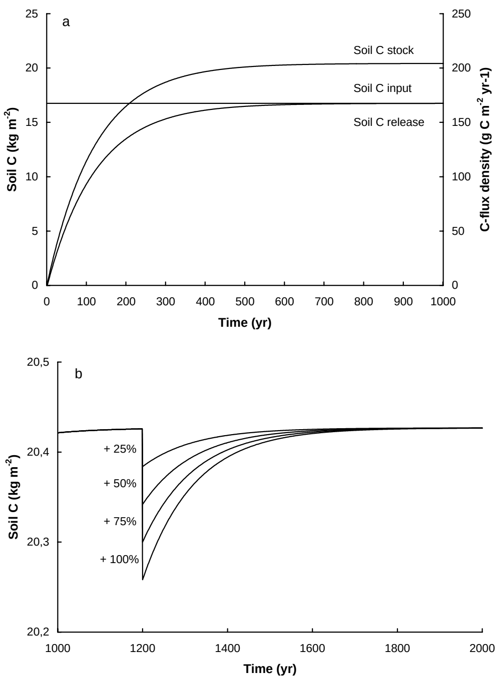


Fig. 5.8. (A) Time course of yearly soil C release and soil C stock in a system starting with empty stores and constant annual soil C input. (B) Recovery of soil C stock after a disturbance of 25%, 50%, 75% and 100% more soil respiration in one particular year, after the ecosystem has reached its equilibrium state.

Heating experiment

In 1998, three of six plots were exposed to infrared radiation to increase the surface temperature by 2.5°C. The reconstructed carbon balance for 18-29 August 1998 shows that both sets of plots were a source of carbon. The unheated plots released 19 g C/m^2 whereas the heated plots released 29 g C/m^2 over the heating period (Caning and Rasch 2000).

To evaluate our results from this isolated warm period on net ecosystem CO_2 exchange during autumn, a simple model was used that predicts the effects of a transient warm period on soil carbon pools in a particular year and in the following ones.

The model starts with an empty system that gains carbon through net photosynthesis and loses carbon by respiration (Fig. 5.8 A). It is reasonable to assume that the carbon released by soil respiration is proportional by a factor, k, to the amount of carbon held in store. Under these conditions the system will eventually reach its steady state, where input equals output. At the steady state we create one disturbance-year by increasing the amount of efflux from the soil system to simulate a warm period as in the 1998 experiment. Fig. 5.8 B shows that the isolated temperature disruption that we applied will only have a minor impact on total carbon pools, even when the amount of respiration would double. Although the effect on soil C stock is small, complete recovery of the disturbance requires several centuries. The effects on the soil C may be small, the impacts on the atmosphere however, could be significant.

In another experiment, we collected data during eight weeks in 1999, when we increased the surface temperature by 2.5°C in three plots, while three other plots served as controls. We are currently processing the carbon fluxes we measured over this longer period. Also the data anal-

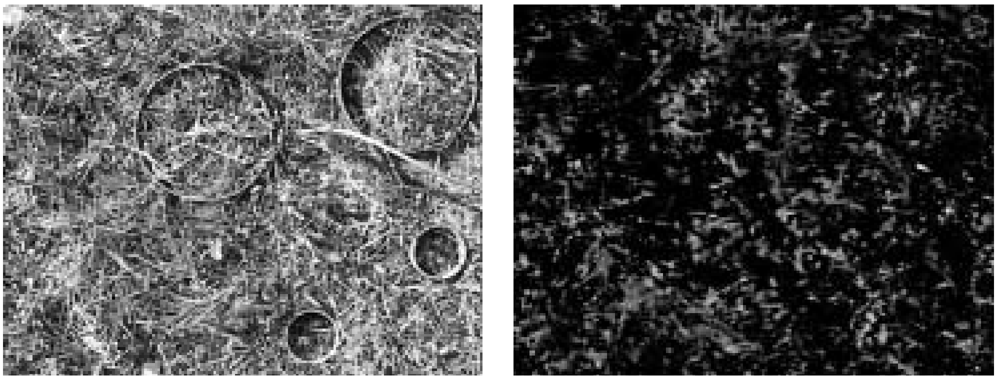


Fig. 5.9. Digital image of a heated plot on 29 July 1999. The left picture is unprocessed, the right picture is a processed image of the same plot.

yses on plant biomass, leaf extension rates, chlorophyll content, and NDVI (Normalised Difference Vegetation Index) are in progress.

To monitor changes in "greening" we recorded digital images of the plots on a regular basis during the field season. The images were subjected to digital colour filters to end up with only the greeny tinges and black. Fig. 5.9 shows digital pictures we took on the 29 July of plot 2, a heated one. The picture on the left is just the regular digital image and the on on the right is the same picture after the filtering. In the analysis we calculated the percentage green pixels in the image. We observed an evolution in the "greening" over the growing season. In the beginning there was little green in the plots (11% green pixels in plot 2 1 July), whereas in the middle of the growing season, the green component in the pictures was at its highest (28% green pixels in the right picture of Fig. 5.9). To the end of the growing season, the "green" in the pictures fell again because of a senescing vegetation (the picture on 31 August of plot 2 counted only 5% green pixels).

5.5 Observations on waders breeding in Zackenbergdalen

Dorthe P. Lahrmann

Time allocation patterns

In the 2000 season time allocation patterns of waders breeding in Zackenbergdalen were studied from the time they arrived in the valley in June till they left the area in August. A total of more than 125 hours of observations were carried out. Observations were split unevenly between the five species breeding in the valley. Preliminary results are presented here.

When waders arrive at summer breeding grounds in the Arctic, they immediately start preparing for the short and hectic breeding season. This study is investigating how the birds allocate time between feeding, resting, territorial behaviour and other activities. Individual birds were studied in 2 min. bursts, and their activity noted every 10 seconds. For groups of birds at common feeding grounds, sweep observations were done several times per observing hour, and the activity of each individual bird was scored.

Dunlins dominate in both pre-and post-breeding, while Turnstones dominate the incubation period. Knots were only observed during pre-breeding. This corresponds well with the fact that Knots are very discrete during breeding, while Dunlins and Turnstones are much more vocal and aggressive in territorial defence. Sanderlings and Great Ringed Plovers were observed during pre-breeding and incubation, but not post breeding.

During pre-breeding preliminary results show that the birds spend the larger part of their day and night fouraging. However, the conditions seem to allow for extensive resting as well. The amount of aggressive behaviour is much lower than expected. Hardly any intra-specific aggressions are observed at common breeding grounds. The 2000 season was mild and with very limited snow cover, and this has influenced the breeding conditions for the waders making more food accessible early and leaving more ground uncovered and suitable for nesting.

During incubation both members of a couple are followed at the same time. Also here the level of aggression was low. Very few examples of intra-specific aggressions were observed. While one bird is incubating, the other fourages near by, rests, or simply sits and observes, and chases or lures away potential predators like skuas and gulls.

Only Dunlins were observed during post breeding when they move around in the valley with chicks. While the chicks are fouraging, the adults spend most of their time resting, observing, preening, and occasionally alarming. The difference from the two previous periods is obvious, the birds spend much less time fouraging when with young. Due to the amount of time spent resting, it is suggested that the birds were in such good condition by the end of the 2000 season, that intensive fouraging while tending chicks was not necessary.

Food item sampling

During pre-breeding and incubation, soil samples were taken at common fouraging sites to estimate the nature and amount of food available to the birds. During post breeding, silt samples were taken from the main feeding area in the delta at low tide. In the first week of June, samples taken from two shallow pond areas show large amounts of nematocera larvae available to the arriving birds. Samples taken in the fourth week of June were very similar, with many springtails available as well. Samples taken on the mudflats in the second week of July show very little food available to the birds, only few nematodes and copepods. However, many potential food items like flies, spiders and copepods are highly mobile, and therefore do not get caught in the sampling. End of July the amount of available food at the ponds and on the mudflats increased slightly. Further data on the 2000 season insect levels can be found in the BioBasis chapter. Due to snow and weather conditions in 2000, plenty of food items were available to the breeding birds throughout the season.

5.6 Diversity and composition of the spider fauna in different vegetation types at Zackenberg

Sidsel Larsen

(This report is a contribution to the ZERO 5th Annual Report 1999 and was for technical reasons not included there.)

Biological diversity is an important issue in conservation decisions and land use planning. The Arctic is a simple ecosystem with very few species and provides great possibilities to test methods and hypothesis on diversity.

Spiders are top predators among the arctic terrestrial invertebrates and as such an important component of the ecosystem. Their activity is not as dependent on weather conditions as is the case for flying insects, and because they are generalist predators they are independent on specific food sources. These conditions make spiders a good testgroup.

The BioBasis programme at Zackenberg samples invertebrates during the entire summer season in five different vegetation types; in 1999 a total of 4353 spiders were caught in the eight pitfall traps on each of the five stations (see chapter 4, Caning and Rasch 2000). 1907 of the spiders were juvenile, and as identifying juvenile spiders in many cases is ambiguous, the juvenile specimens were only identified to family level. The 2446 adult spiders were identified to species level.

The Zackenberg spider fauna counts eight species from four different families. The Lycosidae (wolf spiders), Dictynidae and Thomisidae (crab spiders) are only represented by a single species each. Five linyphiid species occur in Zackenberg, making Linyphiidae the most specious family – a trend common in cold areas.

The preliminary results suggest that the trap stations can be grouped in three distinct types from the composition of the spider fauna. The fen (station 2), the early snow free heaths (stations 5 and 7) and the late snow free heaths (stations 3 and 4).

The fen is the most outstanding of the vegetation types both regarding numbers of specimens and species. The station is situated in a very wet and tussocky area dominated by mosses and graminoids. The diversity is low compared to all other areas (1-D = 0.360; H = 0.710), but the abundance of spiders is very high, especially of the species *Erigone psychrophila* (976 specimens in 1999). This species is dominating on station 2 and is only occurring as a “tourist” (single specimens) in the other vegetation types. On all other stations, the lycosid *Pardosa glacialis* is the dominating species in the traps.

The family Linyphiidae is the dominating group in the fen (98%), the Lycosidae only wander late in the season, when the area is drying out, and the Dictynidae were only represented by a few juvenile specimens.

Station 5, a tufted *Dryas* heath, has the most diverse spider fauna (1-D = 0.520; H = 1.088). All eight species of spiders present in the samples occurred in this area.

The crab spider, *Xysticus deichmanni*, was present on all heath localities, but the abundance was highest on the early snow free heaths (stations 5 and 7). The early snow free areas held two additional characteristic species: *Mecynargus borealis* which was only found here, and *Collinsia thulensis* which had the highest abundance on these stations. The occurrence of adult *C. thulensis* seems to follow the snow cover. On late snow free heaths (stations 3 and 4) the peak abundance of *C. thulensis* was delayed by one to two weeks. The reason for the delay and the low abundance on stations 3 and 4 can be the late snow melt, causing a slower development rate and a higher mortality.

Erigone arctica and *Hilaira vexatrix* are found on all stations, but are most abundant in the fen and in the late snow free heaths.

Judged from the densities of webs, *Emblyna borealis* was present in very high numbers on the heaths but the occurrence of the species is very limited in the traps. The sampling method with pitfall traps is obviously not suitable for this relatively sedentary species.

By applying species richness estimators and statistical tests to the data it will be possible to evaluate some of the methods used in biodiversity assays. An interesting theme is the correlation of biodiversity of one group of organisms with other groups and with the productivity of the area.

5.7 Collared Lemming Project – Zackenberg

Thomas B. Berg

The project has entered the second phase in which focus will be on the linkage between the dynamics of the lemming population and the quality of their food plants, as well as their habitat use.

The feeding experiment

Three subadult lemmings (one female and two males) were caught between 5 and 6 July (weight: 25-30 g). Time of birth was estimated to be within the first weeks of June. On 15 August another subadult male was caught (15 g) with an estimated time of birth within the last weeks of July. This animal was in poor feeding condition but gained 14 g during the following seven days with food ad libitum. All animals were kept in cages until the end of the field season.

Three lemmings were used within a feeding experiment including *Salix arctica* (male and female separately), *Dryas sp.*, *Vaccinium uliginosum*, *Kobresia myosuroides* and *Poa glauca*. *Salix*, *Dryas* and *Poa* made up 92-95% of the biomass eaten. *Salix* dominated with 47-60% followed by *Dryas* (17-35%) and *Poa* (10-18%). Except for *P. glauca* all plant species were also used in a simulated grazing experiment at three different intensities (one, two and three clippings during the field season with two weeks interval). *Poa* was absent in the experimental area and therefore not included in the experiment.

Chemical analyses of plant samples will give information of the phenol concentrations expected to be influenced by the level of grazing. High levels of phenol reduces the nutriment quality of the plants. Observations did not give any clear indication of the lemmings being able to select plants with low phenol concentration. Hence the reduced food quality may force the lemming to use more time in foraging and/or lose weight.

The habitat use

The snow distribution is assumed to be the most important factor affecting the habitat use by lemmings. Little snow in winter is expected to make lemmings aggregate in the best snow rich habitats, which may lead to over-exploitation of the food resources and an increased negative feedback from secondary plant components.

The habitat choice of lemmings seems to be unaffected by the presence and number of predators. In several cases lemmings have used burrows in the close vicinity of breeding long-tailed skua or even within the burrow complex of an active arctic fox den.

Spatial distribution of nests

As a result of the sparse amount of snow during winter 1999/2000 the winter nests clustered within areas supposed to be the optimal winter habitat (Fig. 5.10). The active summer burrows were distributed within the areas known from previous years (Fig. 5.11). The northeastern part of

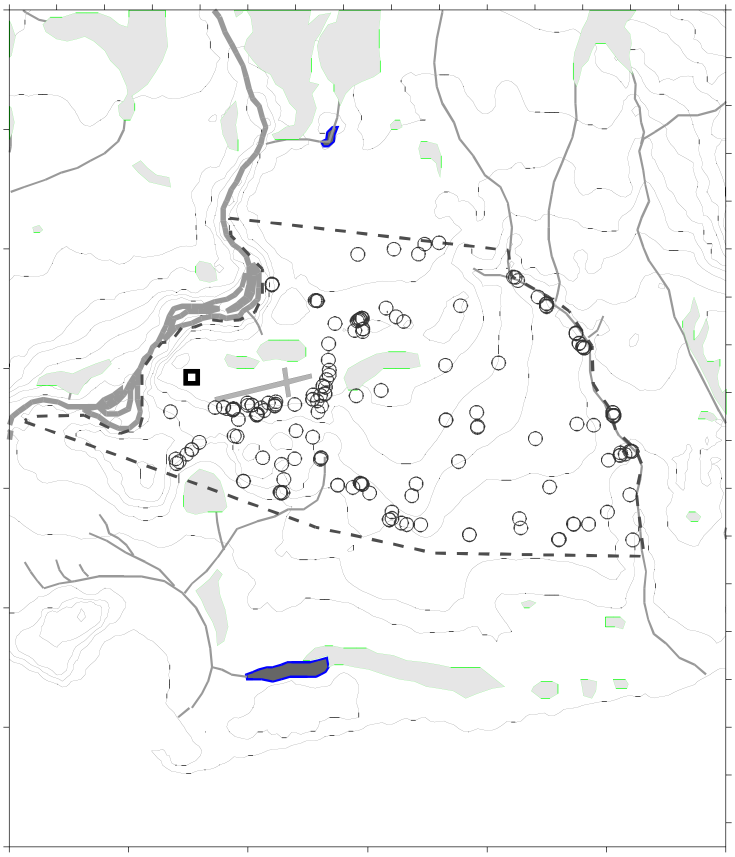


Fig. 5.10. Spatial distribution of the 184 winter nests build during the winter 1999/2000 and recorded during the summer 2000 within the 2.5 km² lemming census area. The circles around each nest represent diameters of 30 m. The scale of the map does not allow separation between nests placed only few meters apart. The shaded areas represent meadows, and the dark areas are lakes. The square is the station, and the cross is the 450 m airstrip.

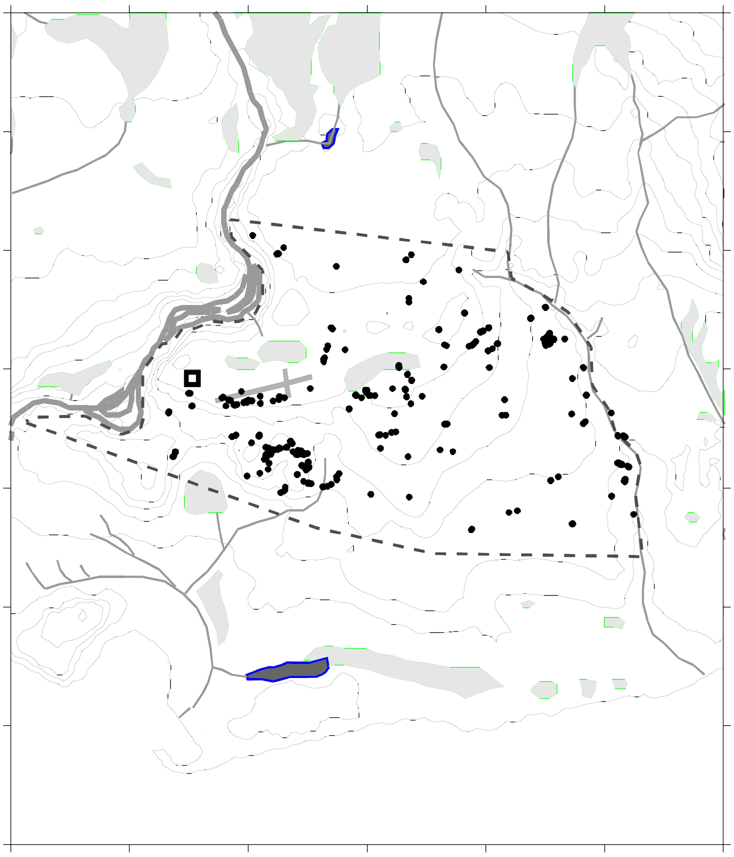


Fig. 5.11. Spatial distribution of the 405 active summer burrows recorded during the summer 2000 within the 2.5 km² lemming census area. The scale of the map does not allow separation between entrances placed only few meters apart. The shaded areas represent meadows, and the dark areas are lakes. The square is the station, and the cross is the 450 m airstrip.

the 2.5 km² study area was again intensively used after two years (1998 and 1999) with no or only a few active burrows. This pattern may be explained either as a result of over-exploitation in 1997 revealing a highly defensive plant response to grazing or it may simply be a matter of soil humidity and/or snow distribution.

The fraction of winter nests used for breeding was low, as was the fraction of winter nests with lemming pellets (Table 5.2). These figures correspond well with the fraction of nests that was build after the soil froze (less than 50%). All these figures are characteristic for a declining population or at least a population at low density.

Initial investigations of summer burrows by means of an optical fibre scope capable in entering and viewing the burrow systems were carried out with success. A survey with improved equipment will be carried out in 2001.

5.8 Hyperspectral campaign at Zackenberg

Mikkel P. Tamstorf and Birger Ulf Hansen

An airborne hyperspectral data sampling was carried out at Zackenberg on 7 August 2000 with the HyMap scanner. Field collection of spectral signatures in the Zackenberg area was done during the same period as ground truth for the hyperspectral campaign.

During the last two decades monitoring and analyses of vegetation and other terrestrial surfaces in the Arctic have been carried out using medium and high spatial resolution satellites with relatively few spectral channels, e.g. Landsat MSS, TM, SPOT HRV, NOAA. Landsat and SPOT images, which have been widely used for snow and vegetation cover monitoring in the Arctic and at Zackenberg, cannot be used for subpixel quantification. It has therefore been difficult to monitor and analyse small but important habitats.

Table 5.2. Data from the winter nest examination. "In surface" indicates that the nest was dug into the surface/vegetation (often less than one cm) before it froze. "On surface" indicates that the nest was build after the soil was frozen. "Breeding" is indicated by small slender pellets (length <2 mm) within the nest or along the edge of the nest. "Pellet" indicates that the nest contained faeces and may have been left in favour of a new nest. "Grey fur" indicates that the nest was build before the winter moult (mid October/November). "White fur" indicates that the nest was in use during the spring moult in mid May/June.

N /%	1995/1996	1996/1997	1997/1998	1998/1999	1999/2000
In surface	-	151/45	349/50	179/61	124/67
On surface	-	181/55	348/50	114/39	60/33
Breeding	22/14	37/11	163/23	23/7.5	12/6.5
Pellet	36/23	158/37	257/36	74/24	48/26
Grey fur	23/14	58/17	105/15	18/6	21/11
White fur	1/0.6	1/0.3	30/4.2	3/1	9/5

Fig. 5.12. The area covered by the hyperspectral campaign includes the Zackenbergdalen, Aucellabjerg and Lindemannsdalen.

Herp-slopes and snowpatches are examples of such habitats. They have a typical areal extent of less than 20 by 20 m and due to their high species diversity and variation related to snow cover and climate, they are important elements in the ecosystems of the Arctic. Hyperspectral data will, as opposed to traditional multispectral data, give the opportunity to quantify surface types within a pixel. Currently there are no hyperspectral sensors deployed on commercial satellites but during the next 5 years there will be several deployed on satellites, allowing greater differentiation between surface types. Coming hyperspectral sensors include amongst others: OrdView-4 from OrbImage, PRISM from ESA and HRST from NASA. The hyperspectral HyMap data from this campaign will be used to model the future hyperspectral satellites and assess their abilities for biophysical monitoring and modelling at Zackenberg.

Data

The hyperspectral data collected with the HyMap scanner covers approx. 625 km^2 of the Zackenberg area as shown in Fig. 5.12. The data were collected with a Dornier 228 aircraft from DLR (Deutsches Zentrum für Luft und Raumfahrt) (Fig. 5.13). HyMap has 126 spectral bands covering from 0.4 µm to 2.5 µm with a spectral resolution of approx. 15 nm. The flight resulted in 12

Fig. 5.13. The HyMap scanner was carried on a Dornier 228 from DLR, here shown at Constable Pynt Airport (Photo Birger Ulf Hansen).

Fig. 5.14. Flight strip from the hyperspectral campaign. Band 27 shown in vblack and white. Vegetation is thereby visible as bright areas, and water as dark. The Rylekærene can be seen in the bottom of the strip.

image strips, each 3.5 km wide and 27 km long with an overlap of approx. 40% (see the back of this publication). An example of an image strip of the central valley is shown in Fig. 5.14 with spectral band 27 (829.2 nm). The spatial resolution will be 5 m. Traditional airphotos were also aquired during the flight and will be used to produce a digital terrain model with a similar spatial resolution.

Fieldwork

Spectral signatures for ground truthing of the HyMap data were collected during the time of overflight. Fig. 5.15 shows a comparison of the spectral signatures for grassland and fell field at Zackenberg for HyMap and Landsat TM data. As seen from the signatures, HyMap data (small dots) give more information on the shape of the spectral signatures than can be extracted from Landsat TM data (large circles and squares). The spectral signatures were collected at the BioBasis ITEX sites and at all points in the ZEROCALM-2 grid.

5.9 Changes in Arctic marine production (CAMP)

Søren Rysgaard, Ronnie Nøhr Glud, Frank Wenzhöfer, Michael Kühl, Dorte Krause-Jensen, Peter Bondo Christensen, Jens Borum, Morten Foldager Pedersen, Jens Würgler Hansen, Mikael K. Sejr, Jens Kjerulf Petersen, Mikkel Sand, Ole Fristed Kunnerup, Mario Acquarone, Erik W. Born and David Griffiths, Göran Ehlmé and Allan Falk

Introduction

CAMP is a three-year project studying the response of Arctic marine ecosystems to global warming. The investigations have been carried out both under ice cover and in open-water periods. This year the studies in the open-water period was continued in a field campaign from late July to mid August.

The fieldwork this year focused on:

1. Benthic microalgae
2. Benthic macroalgae
3. Sediment
4. Bivalves
5. Arctic char
5. Walrus
6. Film activities

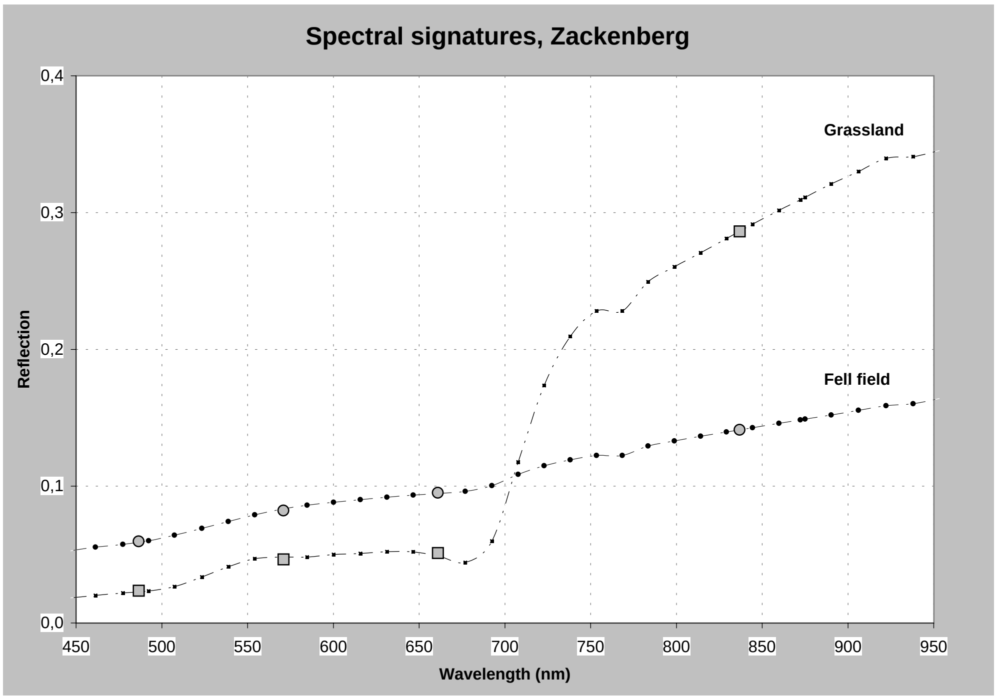


Fig. 5.15. Spectral resolution of typical arctic surfaces for Landsat TM with 4 bands (large symbols) and HyMap data with 33 bands (small symbols).

The marine study area covered the outer parts of Young Sund (from Basaltøen to the mouth of the fjord) and Dove Bugt (most of the walrus work). Young Sund is situated just south of the area permanently covered by ice and represents a region most affected by global warming.

Benthic microalgal distribution and production

Søren Rysgaard, Ronnie Nøhr Glud, Frank Wenzhöfer and Michael Kühl

Benthic microalgae, primarily pennate diatoms, live on and among sand grains on the seafloor and bloom in Arctic regions during summer when light reaches the sediment surface. During preliminary investigations last year it became clear that these algae might be an important contributor to total primary production and that their production was not only restricted to the open water period but also occurred in sediments below 1.5 m sea ice cover. Thus, in order to obtain a complete picture of the carbon fixation in the marine ecosystem of Young Sund these primary producers were investigated in further detail during the August field campaign.

The investigations covered both measurements in the laboratory and *in situ*. Since benthic microalgal primary production on an annual scale is regulated primarily by light due to the extensive sea ice cover it is important to establish a relation between light and primary production. This relationship is necessary when predicting the effect of future alterations in sea ice thickness and distribution on primary production. Thus, as background data light penetration (irradiance and spectral distribution) in the water column (cm to m resolutions) and surface sediment (50-200 µm resolutions) were investigated at regular time intervals during August. These measurements will complement previous measurements and thus increase the database of light conditions in sea ice, water column and sediment on an annual basis for Young Sund.

The benthic microalgal distribution and production with depth was investigated *in situ* using different techniques: (a) Digital photos of the sea floor were recorded at various water depths along different transects from Basaltøen to the mouth of Young Sund. These photos will be used to estimate the percentage coverage of benthic microalgae at different water depths and found the basis for extrapolating biomass and activity measurements to a larger scale of Young Sund. (b) Using chlorophyll-fluorescence techniques we measured Chl. *a* and photosynthetic activity *in situ* at different water depths (5, 10, 20 & 30 m). Furthermore, measurements of algal primary production at different irradiances (0-250 µmol photons/m^2/s) were obtained. This was accomplished with a newly developed underwater fluorometer (Diving-PAM) operated by a diver. The heterogeneity in biomass and production were investigated in further detail at a water depth of 15 m but on different horizontal scales. Thus, measurements were performed at centimeter to decimeter to meter to tens of meters to hundred meter and kilometer scales to calculate the horizontal patchiness of the benthic microalgae. (c) Measurements of *in situ* oxygen microprofiles with a benthic lander (Profilur) were performed every two or three days throughout the field campaign, at the same depth intervals as the Diving-PAM measurements. Depth profiles (100 µm resolution) were recorded in the upper 2 cm of the sediment with 3-8 microsensors every 8 minute from noon to midnight cycles in order to calculate *in situ* net-photosynthesis at various light intensities covering minimum to maximum light conditions. Thus, the relation between production and irradiance could be established at different water depths.

In parallel to the *in situ* work, several investigations in the laboratory were performed: (a) The biomass and production of benthic microalgae were investigated with the chlorophyll-fluorescence technique on freshly collected sediment cores in order to include water depths that could not be reached by divers. Furthermore, measurements on sediment cores collected at the same water depths as investigated *in situ* showed that it is possible to obtain measurements of biomass and productivity in the laboratory that are comparable to that measured *in situ*. (b) Benthic microalgal brutto-photosynthesis was measured in the laboratory with oxygen microelectrodes using the light-dark-shift technique. Furthermore, oxygen microprofiles were used to calculate net-photosynthesis and the autotroph-heterotroph coupling. (c) The sediment-water exchange rates of oxygen, dissolved inorganic carbon and nutrients were investigated on freshly collected sediment cores using traditional batch incubation techniques.

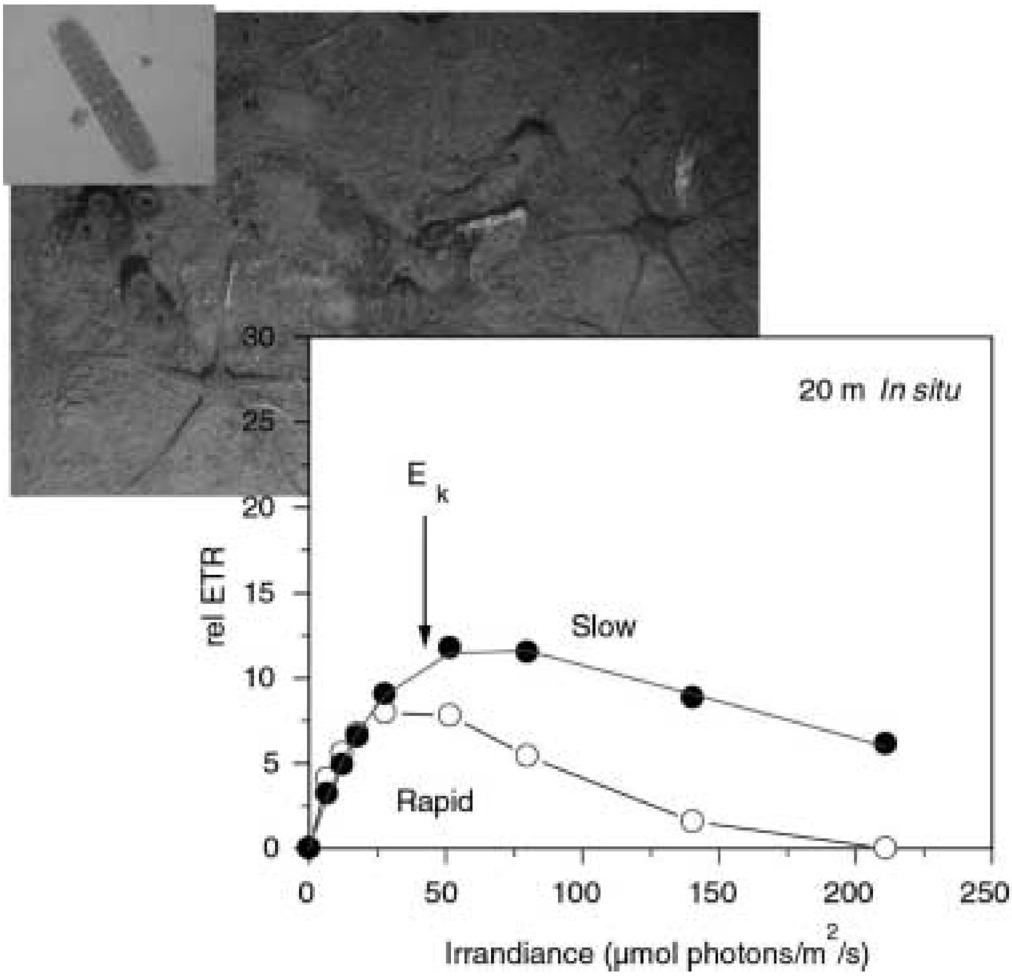


Fig. 5.16. The photo shows the distribution of algae at 20 m (max distribution) with microscopic photo of diatom inserted in one corner. The graph in situ production-irradiance curves for the same depth. E_k represent the irradiance where photosynthesis begins to saturate. Rapid light curve shows how algae are adapted to in situ light, and slow curve represents the adaptational response to higher light intensities.

The flux rates were determined on sediment from different water depths (5, 10, 20, 30 & 40 m) exposed to various light intensities (0-250 µmol photons/m^2/s) to investigate the response of the sediment community to varying light intensities.

In conclusion, this investigation will be used to evaluate benthic microalgal distribution and primary production and compare their production with that of other primary producers (e.g. phytoplankton, sea ice algae, coralline algae, and benthic macrophytes) in the area. This will increase our understanding of their relative importance to total primary production in Young Sund and in the numerous similar fjord ecosystems along the coast of Greenland. In addition, the investigation will contribute to an increased understanding of the regulation of benthic microalgal production as a function of light and nutrients at different water depths, sea ice and snow conditions which is a pre-requisite to an overall understanding of their geographical distribution and production in the Arctic region.

Growth in Arctic and temperate populations of *Laminaria saccharina*

Dorte Krause-Jensen, Peter Bondo Christensen, Jens Borum and Morten Foldager Pedersen

L. saccharina has a broad distribution range from north-temperate to Arctic areas, and we compared growth strategy of the Arctic *L. saccharina* in Young Sound with that of a temperate population in Århus Bay, Denmark.

Light and photosynthesis

The Arctic and temperate sites differ with respect to several physico-chemical features of which the light period is the most obvious. The Arctic site is ice-covered and in darkness for about 10 months per year while it is exposed to light during both day and night for 2 summer months. In contrast, the temperate site has a daily light-dark cycle throughout the year.

Photosynthesis of *L. saccharina* saturates at about 50-100 µmol photons/m^2/s, and at the Arctic site, light intensities are often above this level, and therefore not available for photosynthesis. At the temperate site, a larger fraction of the light can be exploited.

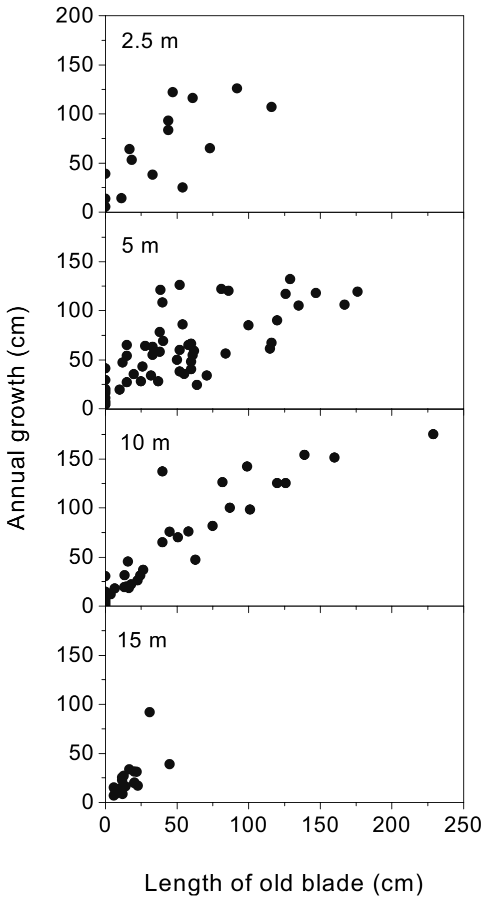


Fig. 5.17. Annual growth of the blade of Laminaria at different water depths in relation to the length of the old blade.

Morphology and growth

L. saccharina is composed of a perennial haptera and stipe, and a blade which is renewed every year. The growth zone is situated at the transition between stipe and blade, and the new blade thus appears between the stipe and the base of the old blade. Secondary growth takes place in the stipe and creates annual growth rings.

We measured length growth by puncturing a pair of holes at the base of the new blade, and measuring the distance from the base to the holes at time intervals. In Arctic *L. saccharina*, the old blade remained attached with 2 or 3 blades being visible and separated by a distinct narrow zone between the leaves of different age. We found that the length of the new blade in mid-August corresponded exactly to annual length growth, and this finding allowed us to estimate annual growth rates of all individuals collected in mid august.

Annual growth rates

In the depth range 2.5-10 m, Arctic algae were on average 135 cm long (when excluding the juveniles) and grew about 65 cm per year corresponding to a turn over rate of the blade of almost 2 years. The longest individuals were up to 4 m and grew up to 175 cm per year. Growth rates and blade lengths were much reduced at 15 m depth, and at 20 m *L. saccharina* was generally absent.

Annual length growth increased as a function of the length of the old blade, indicating that the new blade benefited from the production of the old blade (Fig. 5.17). Lengths of the old and new blade as well as stipe length were related to the number of growth rings in the stipe. Blade length and growth rates were largest for intermediate age groups while the length of the perennial stipe increased with the age of the alga.

Temperate *L. saccharina* was generally shorter (90 cm on average) but had larger annual growth rates (140 cm on average) than in Arctic individuals. Consequently, the turn over rate of the blade was much shorter (6 months) in temperate than in Arctic individuals. Also, temperate *L. saccharina* was generally younger (up to 3 growth rings) than Arctic individuals (up to 6 growth rings).

Growth in winter and summer

Arctic algae grew fastest from late June to mid-August (0,6 cm per day), and 40% of annual length growth took place during this period. From mid-August to the following June, the remaining 60% of the length growth occurred, and this length growth under ice-cover makes the new blade ready to efficiently intercept the irradiance once the ice breaks.

During summer, the algae grew not only longer but also thicker. The specific blade biomass thus increased from June to August, and at least 60% of the growth in biomass, i.e. the “real growth”, occurred during this period.

At the temperate site, length-growth was fastest in spring (1 cm per day), and was reduced to a minimum in late summer. Although length growth decreased during summer, the blades gained biomass by becoming thicker, and biomass growth reached a maximum in mid-summer. In early winter, the new blade was initiated, and during winter and spring a new long and thin blade was produced partly by recycling of old blade material.

Conclusion

In conclusion, *L. saccharina* copes remarkably well with the adverse conditions of the Arctic. Longer life span allows the Arctic algae to grow larger than temperate individuals in spite of lower growth rates.

Mineralization in the sediment after sedimentation of organic material

Jens Würgler Hansen

Global warming is expected to result in increased marine primary production in the Arctic. This is mainly a consequence of increased light availability due to a decrease in area extent and thickness of the ice. Part of the CAMP project is to investigate how the Arctic sediment responds to increases in marine primary production.

The effect of increased marine primary production on sediment biogeochemical processes was also investigated in 1999. In 1999 the study was carried out in June, where the sediment is depleted in substrate as very little organic material that has been supplied during the previous 9 months of ice cover. This year the study was carried out in August, where the sediment had recently received a large input of organic material from the sedimentation following the bloom in primary production and the river runoff after the melting of snow and ice from mid June to mid July.

Benthic metabolism

The dynamics of sediment metabolism after sedimentation of faecal pellets and various species of algae were studied in a temperature-controlled laboratory experiment. During two weeks of incubation, the sediment-water fluxes of oxygen, carbon dioxide and nutrients were determined at regular intervals. Furthermore, the microscale distribution of oxygen at the sediment surface was measured at the beginning and at the end of the incubation using microelectrodes.

The preliminary results support the findings from last year, that the Young Sund sediment responds much more slowly to the addition of organic material than has been observed in temperate sediments. Furthermore, the overall sediment metabolism was not affected differently when the organic material was added as diatoms, green algae or faecal pellets produced by mussels. These observations indicate that although the Arctic benthic community may metabolize as rapidly as do communities from warmer waters, the low temperature has an inhibitory effect on the dynamic response to rapid pertubations.

During the 10 months of ice cover in Young Sund, primary production and thereby the supply of organic material to the sediment is very low. Therefore, the benthic metabolism is mainly fuelled from the sedimentation of organic material during the short open-water period. To study the long-term effect of the benthic sediment to this pulse supply of organic material, a number of sediment cores were brought back to Denmark and the incubation was continued in a thermostated container. The experiment is still running and will provide information on how the benthic metabolism reacts to the long period of low substrate availability during ice cover.

Benthic organisms in Young Sound: Level of adaptation and role in carbon cycling

Mikael K. Sejr, Jens Kjerulf Petersen and Mikkel Sand

Previous work on the composition of benthic animals in Young Sound has revealed a high abundance of bivalves, especially the large species *Hiatella arctica* and *Mya truncata* which are a dominant food source for the walruses in the area. Little is known, however, of how the low temperature and variable food levels influence physiological processes such as filtration and respiration of these bivalves. The object of this summer's work was to quantify biomass of dominant bivalves, especially *H. arctica* along depth transects in the outer part of Young Sound and to supplement earlier studies on benthic composition with underwater photography. Furthermore, the filtration of *M. truncata* was studied in order to assess its adaptation to temperature and food availability

Growth, biomass and production of the mussel *Hiatella arctica*

Abundance and composition of the benthic fauna, particularly the bivalve *Hiatella arctica*, were investigated along several depth transects in the outer part of Young Sound.

H. arctica was a dominant species of the benthos within the studied areas especially at depths around 30 m. In August 1998, 50 individuals of *H. arctica* were measured, tagged and released at 36 m in order to obtain estimates of bivalve growth under *in situ* conditions to supplement growth rates estimated from shell analysis. Although the recapture rate was relatively high (85%) shell growth was less than the detection limit of 0.5 mm and could therefore not be estimated. The lack of measurable growth during the 2-year period, however, agrees well with preliminary results from shell analysis that revealed ages of up to 105 years. Based on the available data on growth and abundance, estimates of production and production/biomass ratios can be calculated for this species. Together with the available data on primary production and sedimentation it will be possible to estimate the role of *H. arctica* in the total carbon mineralization in the outer part of Young Sound.

Detailed knowledge is available on how bivalves take up and assimilate food and convert it into growth in temperate areas whereas little is known of how polar temperatures and food regimes influence energy utilisation of macrobenthic organisms. In order to understand how the long period of low food availability during winter affect *H. arctica* filtration, assimilation, respiration and excretion were studied at different food levels in the laboratory. Thus it will be possible to test a hypothesis often put forward, that benthos of polar areas has high growth efficiencies because of low temperatures and variable food availability. Preliminary investigations on effects of food level on filtration rates were carried out this summer and showed that filtration rates are dependent on food concentrations (Fig. 5.18). At low algae concentrations, corresponding to <2 μg chl. *a*/l, filtration rates are lower than at optimal concentrations of approx. 4 μg chl. *a*/l. With further increasing food concentrations, filtration rates decrease correspondingly to a constant food uptake rate. A similar functional response has been observed in other mussels, also from temperate regions.

Filtration as a function of temperature in *Mya truncata*

Mya truncata demonstrated a high level of adaptation as filtration rates at *in situ* temperature generally matched rates from boreal regions. Increasing filtration rates were found as a function of temperatures up to about 8°C after which rates decreased (Fig. 5.19). Similarly, last years studies showed that the filtration rates of *Hiatella arctica* also increased up to approx. 8°C in an Arctic population, whereas filtration rates increased from 5 to 22°C in a Scandinavian population. This suggests that the adaptation to cold temperatures in bivalve filtration rates have occurred at the expense of lacking plasticity towards temperature changes. In order to fully understand the level of adaptation of the Arctic population, similar measurements of the effect of temperature on filtration rates in *M. truncata* are currently taking place on individuals from southern Sweden.

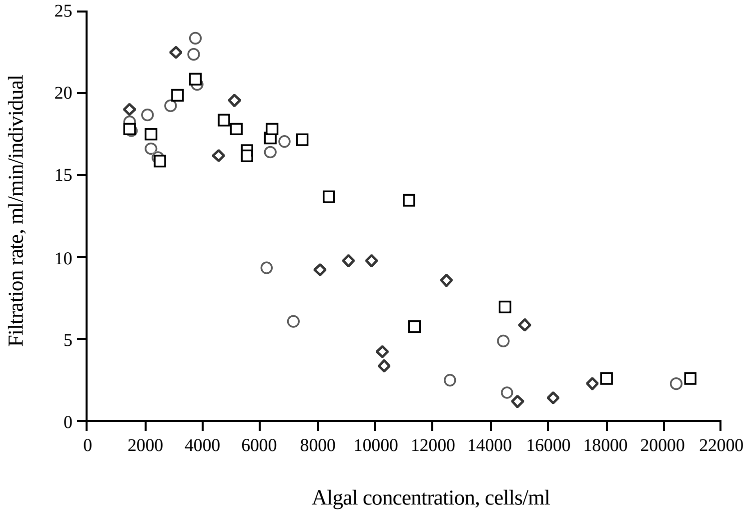


Fig. 5.18. Filtration rate in Hiatella arctica as a function of concentration of Rhodomonas baltica cells.

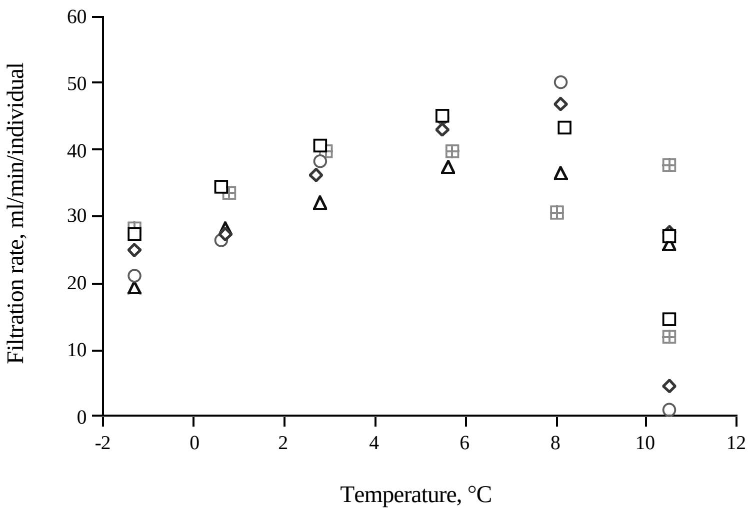


Fig. 5.19. Filtration rate in 5 specimens of Mya truncata as a function of temperature.

Arctic char

Ole Fristed Kunnerup

During summer, a large number of anadromous Arctic char (*Salvelinus alpinus L.*) migrate via Zackenbergelven from Store Sø into the marine environment of Young Sund to forage on the abundance of food available here. Arctic char is the worlds most northern living Salmoniidae and frequently appears as the only freshwater species in Greenland. Chars spend most of their life in freshwater, either in lakes or in rivers. Stocks that have access to marine environments migrate each summer, and tend to grow faster and have higher fecundity than landlocked stocks without access. In the Zackenberg area both migratory (anadromous) and landlocked stocks of Arctic char are found. In order to estimate the direct and indirect influence of anadromous Arctic char on production in Young Sund a basic knowledge of the char population is needed.

A pilot project launched in 1997 (Meltofte & Rasch, 1998) provided important knowledge of char migration strategies in Young Sund and furthermore information on size distribution and diet. This years campaign was designed to add further to this knowledge and to gather information on the population size, growth, the importance of different types of prey through the season, and other basic population related topics. This years field season covered July and the first half of August. Anadromous chars were caught both in the fjord and in the river Zackenberg. In the fjord the chars were caught throughout the season using a beach seine, gillnets and rod and tackle. Each year the Sirius patrol launches a fishing campaign, and in close cooperation with the fishing members of the patrol, the amount of chars available for investigation increased dramatically during a weekend. All fishing in the fjord took place from the shoreline near the old trapping station.

From mid-July a fish trap was mounted in the river, 500 m upstream from the Zackenberg research station. The fish trap caught a proportion of the fish moving up river and thus provided information on the number of anadromous char, together with information on migration patterns correlated with water level, time in season, and temperature. A total of 522 fish was caught during the season, 239 in the fjord and 283 in the fish trap migrating upstream.

This years results show that char in their marine environment prey upon snails, crustaceans and fish fry as the most important food items. Combined with data from 1997 this draws a picture of char as being a generalist feeder, preying on whichever food is in abundance. The fullness of the stomachs collected during the season indicates that in the early summer, prey is reduced in number, but already in mid-July food is in high abundance.

In order to estimate growth parameters of the population, a number of otoliths (earstones) were collected from a representative subsample. The otoliths are paired calcified structures used for balance and/or hearing in all teleost fishes. Otoliths contain information on the age of the fish, like year rings in trees. Based on these otoliths an age to length relationship can be established leading to a growth estimate of the population. The age reading is still in process, but in earlier investigations anadromous char ranged from 6 to 20 years of age. Data from the fish trap have not yet been analysed, but will undoubtedly help in establishing an overall picture of the nature of char migration in the area and will provide valuable information on the population size of migrating chars.

Studies of walrus energetics and behaviour

Mario Acquarone, Erik W. Born and David Griffiths

The goal of this study, linked to the CAMP study, is to determine the role of walruses as predators in the arctic marine ecosystem. During the 2000 field season, the second in this three-year project, from 27 July until 28 August, we concentrated our effort on measuring the walrus water metabolism and daily activity. Because of the general absence of walruses at the Sandøen haul-out in 1999 we concentrated our efforts at the Lille Snenæs site (Fig. 5.20) on the northern coast of Dove Bay where previous studies have indicated a high and reliable presence of walruses through the open-water season (Born and Knutsen 1992, 1997). However, we also inspected Sandøen both at the beginning and at the end of the field season. On Sandøen we positioned an automatic weather station and time lapse camera to monitor walrus activity on the haul-out beach and successfully recovered the satellite tag positioned on the tusk of an animal in 1999.

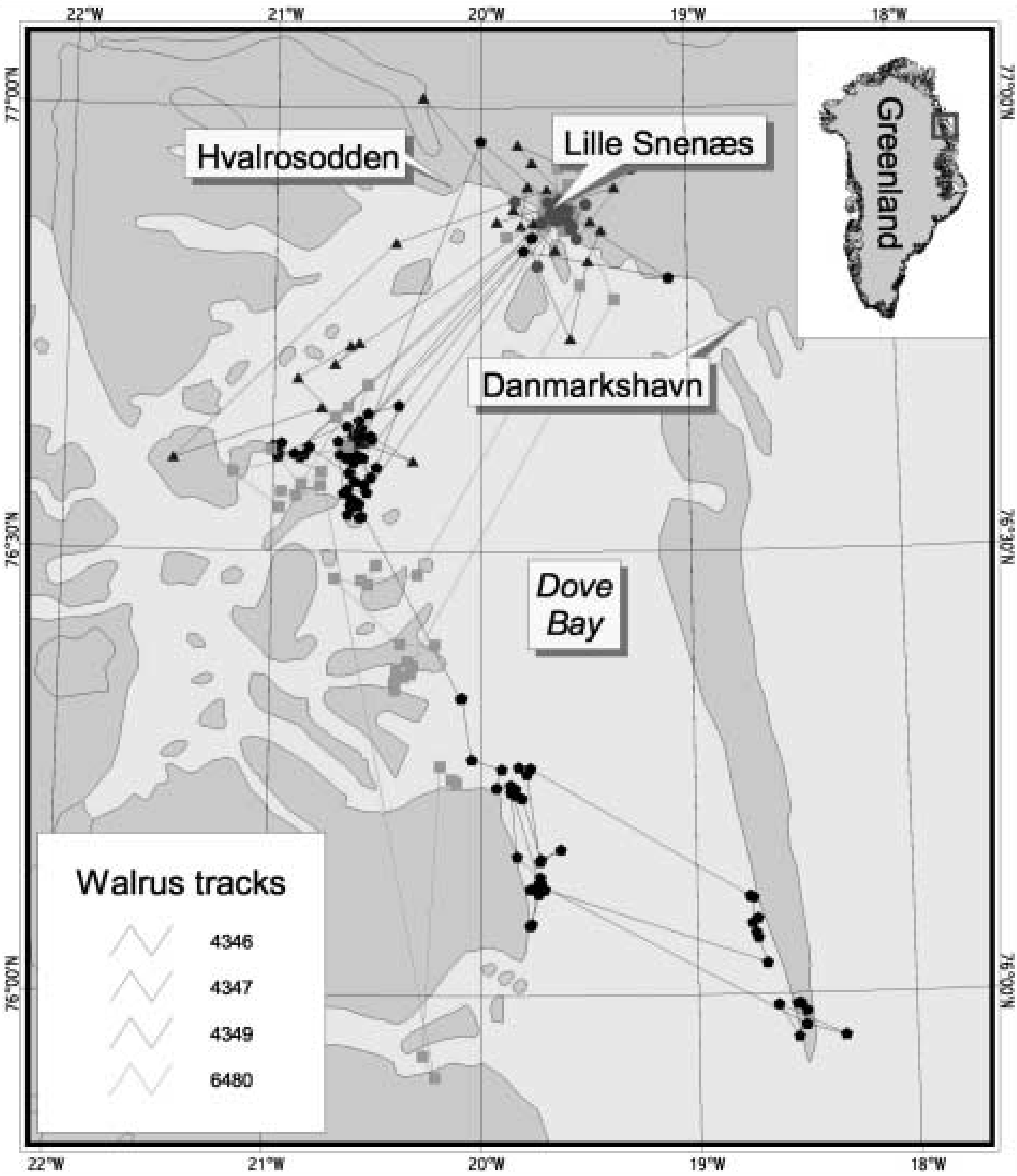


Fig. 5.20. The movement of 4 walruses equipped with satellite-linked dive recorders at Lille Snenæs in summer 2000 (Relocations of the least precise category have also been included and may give the false impression that the animals were located relatively far inland at certain sites)

Observations at Sandøen

For the third year in a row an automatic camera was set up to monitor activity at the haul-out site on the south-eastern tip of Sandøen through the open-water season. The instrument was programmed to take pictures at 00, 06, 12, and 18 hours local time from July 27 until August 27. A preliminary analysis of the pictures shows a continuous use of the haul-out throughout the period by a greater number than at any time in 1999.

Throughout the entire period other researchers related to the CAMP project and a team of film photographers operated in the area. They reported the observation of a maximum of 22 animals on the beach. Furthermore, a walrus from 1999 still bearing a satellite tag attached to one of its tusks was observed both in the waters around Daneborg and on the haul-out at Sandøen. August 27 we successfully immobilised this individual and substituted the old instrument with a new one. On that occasion we observed 18 walruses on the beach.

An automatic weather station monitored wind speed, wind direction and air temperature in the vicinity of the haul-out during the entire period.

Observations at Lille Snenæs

The Lille Snenæs haul-out was monitored each hour during 24hr cycles both visually and photographically from 3 August until 23 August. A preliminary analysis of the data gathered shows that the haul-out was occupied during 17 of the 21 monitoring days. The maximum number of animals present on the beach at any time was 15. There was no particular tendency in the number of animals that hauled out during the season, which indicates that our activity did not influence the utilisation of the site by the walruses. On days where no animals were observed on the beach, compact pack ice had accumulated along the shore suggesting that they chose to escape before they were trapped. A similar situation was observed in 1989.

A weather station similar to the one used on Sandøen was established at this site too.

Immobilisation and instrumentation

During the 23 days of our field season we performed 21 immobilisations. It was possible to keep the animals immobilised long enough to inject deuterium-enriched water and sample blood from the epidural vein at regular time intervals for up to 6 hours in 18 of the immobilisations. On only 2 occasions the animals awoke quickly from the immobilisation and escaped to sea where they exhibited a normal, rapid swimming behaviour. All of the immobilised animals later returned to the beach and showed no visible sign of long-term effects from the treatment.

During immobilisation we measured the animals and, when possible, weighed them. At the same time we equipped them with a satellite linked dive recorder (SDR), a time depth recorder (TDR) and flipper tags. Upon later recapture we sampled blood and downloaded data from the TDR's. A total of 7 animals were equipped with a SDR attached to one of the tusks and 6 of these were also provided with a TDR on the other tusk. At the end of October the satellite position data received showed that 4 of the instrumented animals have transmitted high quality position data and that they mainly utilised the northern and western part of Dove Bay (Fig. 5.20).

The TDR's have given us a large amount of detailed depth, temperature and light intensity data (more than 55 sampling days) which will be analysed later. As an example, a diagram that shows dive data for one animal for a period of half an hour is presented in Fig. 5.21.

Water metabolism

The final aim of this study is to measure the energy requirements of free ranging walruses and for this purpose it is essential to determine the water metabolism of the walruses (total body water and body water turnover). Deuterium enriched water was administered to a total of 7 ani-

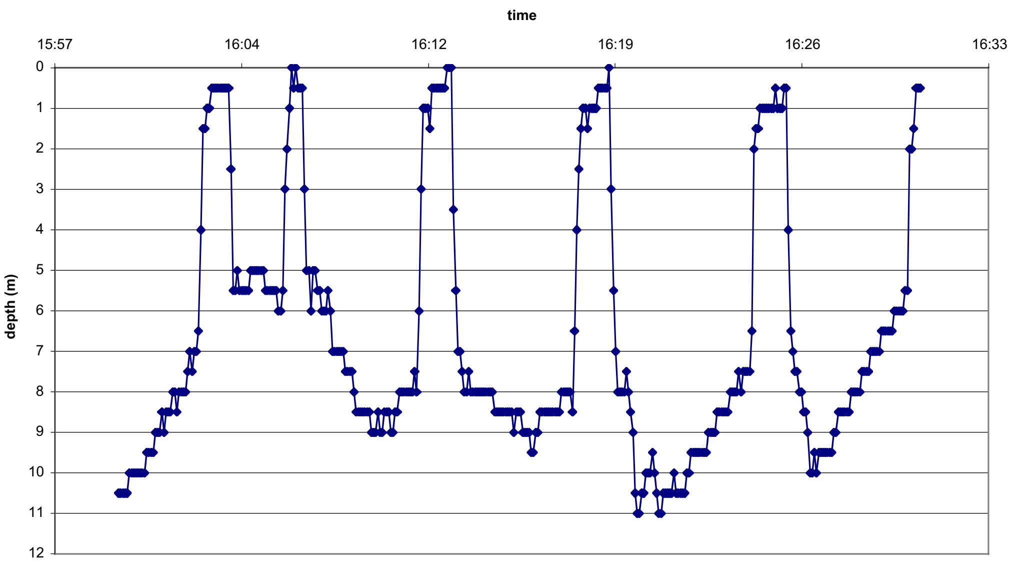


Fig. 5.21. Detailed dive information for walrus 4345 on 18 August 2000 between 16:00 and 16:30.

mals immediately after a first blood sampling, to determine background plasma levels of deuterium. Four animals were subsequently sampled for blood at regular intervals for a maximum of 6 hours to determine deuterium equilibration times and total body water. In four other cases it was possible to recapture the animals and take further blood samples to determine body water turnover rates.

From these data it will be possible to determine the exact dosage of double labelled water to be injected in the animals in 2001 to measure their energy expenditure during the open water season.

Walrus photos and film

Göran Ehlmé and Allan Falk

The previous year's photography and film documentation of walrus behaviour in Young Sund and nearby areas was continued this year. Photo and film record of walruses was performed to document their resting, diving and feeding behaviour. The project will support the scientific observations and produce photo material for public broadcastings of animal behaviour in polar regions.

Walruses are thought to be dangerous, and we are the first to dive with them and to film their feeding behaviour.

We have spent much time to get confident with the animals and they with us. This year was the 4th in a row where we have been filming walruses in Young Sund. The animals appeared not to be hostile in the surface when the diver was swimming toward them and sometimes they even turned around and gently approached the diver. However, at the bottom in bad visibility the walruses often saw the diver at a very short distance, which scared them and made them escape.

An average number of 12-13 walruses hauled out on Sandøen this year. Furthermore, some new young animals had joined the group. Their main feeding area was still from the airstrip north west of Sandøen to the old dump east of Daneborg. Furthermore, we observed some feeding just off the coast in the area between Daneborg and Zackenberg and in the area around the Basaltøen. The feeding depth was from 5 meters to 30 meters with an average of 10-11 meters.

Future studies

Søren Rysgaard

This year was the last field campaign of the CAMP project that will end in April 2001. The plan is now to work up all data and present the results through publications. When all specific studies have been published we will attempt to integrate all measurements in a summarizing publication. The publication status can be followed on the internet at location: www.dmu.dk/LakeandEstuarineEcology/camp.

Several new aspects have arisen from the CAMP project and hopefully we will be able to continue our work next year based on the proposals submitted in 2000.

5.10 A collection of *Nysius groenlandicus*

Morten Frej Bøyesen

200 individuals of the Greenlandic heteropteran *Nysius groenlandicus* were collected during the summer 2000 at Zackenberg in order to establish an experimental laboratory model for the study of temperature adaptations in Arctic insects including *N. groenlandicus* from Zackenberg and Qeqertarsuaq/Godhavn. The study will include various life history traits (clutch size, size and weight) in single female lines reared in different temperature regimes, thus simulating the long-term human induced changes in the climate.

6 Disturbance in the study area

Hans Meltofte

Surface activities in the study area

The number of 'person-days' (one person in one day) spent in the terrain in the main research zone 1 was among the lowest so far (Table 6.1). Activities in the low impact study area (1b) remained very low, whereas activities in the protection zone for moulting and breeding geese (1c) was higher than in previous years. These activities were both by boat along the coast and on foot with dogs on land. The area around the peninsula was totally devoid of moulting geese when checked on 21 July, six days after the most intensive disturbance had taken place. Almost 200 partly flying geese had returned by 29-30 July (see under Other observations in section 4.3).

Only four ATV trips were made on the 'road' north of the climate station in July and August, and none of them passed Tørvedammen. The remaining trips were down to the coast at the present delta of Zackenbergelven.

Aircraft activities in the study area

The number of fixed-wing aircraft take-off and landings in 2000 (Table 6.2) was about the same as in 1998 and 1999. No helicopter operations were performed this year.

Discharges

As in previous years, combustible waste (paper etc.) was burned at the station, while plastics, cans, bottles etc. were flown out of the area. Solid but biologically degradable toilet and kitchen waste was poured through a grinding mill into Zackenbergelven in August, including an amount left over from 1999. During storage of the waste in June, July and August, a total amount of about 500 g 'Vera-fluesafe' was added as a killing agent against fly maggots. The active chemical is cyromazine (N-cyclopropyl-1,3,5-treazine-2,4,6-triamine) in a concentration of 2%. A similar amount was used in 1999. The total amount of untreated wastewater and solid waste let into Zackenbergelven from the toilets, kitchen, showers, sinks and laundry machines equalled about 1000 'person-days'.

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 30 May-1 September 2000. Visits by boat in the goose protection zone (1c) count one each.

Research zone	May	June	July	Aug.	Sept.	Total
1		133	260	333		726
1b		1	19	11		31
1c (20.6-10.8)			11	3		14
2			10	4		14
ATV-trips		1	6	2		9

Manipulative research projects

In Tørvekæret, 26 plots of 1 x 1 m were shaded during the period 3 July – 19 August (see section 5.1).

Take of organisms

A total of 239 arctic char *Salvelinus alpinus* were caught during July-August off the old trapping station together with 283 in river Zackenbergelven close to the research station. The size range was 14-66 cm with an average around 45 cm. Almost all fish caught at the coast were killed, while those from the river were released alive (see section 5.9). A total of 76,000 arthropods were collected by BioBasis (see section 4.2). 200 live Greenlandic seed bugs *Nysius groenlandicus* were collected for physiological studies (section 5.10) and three individuals of collared lemming *Dicrostonyx groenlandicus* were brought home for exhibition at the Natural History Museum, Aarhus. 30 tube samples of fen vegetation, each 5 cm in diameter and about 6 cm deep, were taken in Gadekæret and 18 in Sydkærene during June and July, together with 12 similar samples of sediment in the old delta of Zackenbergelven during July and August for invertebrate analysis (see section 5.5). All leaves of *Dryas* and *Vaccinium* were harvested regularly from 40 10x10 cm plots on the first terrace just south of the station, and all leaves from 40 male and 40 female individuals of *Salix arctica* were harvested in the area. Between 5 July and 1 September daily samples of *Dryas*, *Salix* and *Poa actica* were randomly collected in close vicinity of the station as food for the four live trapped lemmings (see section 5.7). 15 soil samples, 9.5 cm in diameter and about 50 cm deep, were taken in July-August on the *Cassiope* heath near the climate station (six samples at UTM 8,264,739 m N, 513,371 m E), on *Dryas* heath south of the runway (three samples at UTM 8,264,100 m N, 513,000 m E) and in Rylekærene (six samples at UTM 8,266,185 m N, 513,444 m E). At each of these sites, a further five samples, 20 cm in diameter, of all above-ground-vegetation were harvested in August (see section 5.2). About 50 samples of lichens were taken from different parts of the valley.

Type of aircraft	May	June	July	Aug.	Sept.	Total
Fixed-wing	2	8	14	27	1	52
Helicopter						0

Table 6.2. Number of flights with fixed-winged aircraft and helicopters, respectively, over the study area in Zackenbergdalen 30 May-1 September 2000. Each ground visit of an aircraft is considered two flights.

7 Zackenberg-Daneborg Publications 1993-2000

This is an accumulated bibliography of the literature generated by research at the Zackenberg-Daneborg Research Station from the early start in 1993 until 2000.

Scientific papers

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8 Personnel and visitors

Research

Zackenberg

Christian Bay, Ph.D., National Environmental Research Institute, Denmark (BioBasis, vascular plants, 27 July-14 August)

Thomas B. Berg, Ph.D. student, National Environmental Research Institute, Denmark (BioBasis, lemming ecology, 30 June-1 September)

Kirsten E. Caning, Danish Polar Center (BioBasis, general information, 27 July-8 August)

Henrik Gammelager, graduate student, University of Aarhus (Biobasis, vscular plants, 27 July-14 August)

Birgit Hagedorn, Institute of Geochemistry, University of Göttingen, Alfred Wegener Institut (water chemistry, 26 August-1 September)

Birger Ulf Hansen, Institute of Geography, University of Copenhagen (hyperspectral analysis, BioBasis, 28 July-8 August)

Eric Steen Hansen, M.Sc., Botanical Museum, University of Copenhagen and National Environmental Research Institute, Denmark (BioBasis, lichens, 27 July-8 August)

Anna Joabsson, Department of Plant Ecology, University of Lund (trace gas exchange, 30 June-26 August)

Andy Van Kerckvoorde, Laboratory of Polar Biology, University of Antwerpen (testate amoebae ecology, 27 July-8 August)

Ole Fristed Kunnerup, University of Aarhus (marine ecology, 30 June-14 August)

Dorthe Prip Lahrmann, M.Sc., National Environmental Research Institute, Denmark (BioBasis, wader ecology, 3 June-1 September)

Joke Lennaers, Laboratory of Polar Biology, University of Antwerpen (testate amoebae ecology, 27 July-8 August)

Hans Meltofte, D.Sc., National Environmental Research Institute, Denmark (BioBasis Manager, 3 June-4 August)

Claus Nordstrøm, Ph.D., Institute of Geography, University of Copenhagen (BioBasis, 3 June-19 June)

Jonathan N.K. Petersen, ASIAQ, Greenland Field Investigations (ClimateBasis, 14 August-26 August)

Charlotte Sigsgaard, graduate student, Institute of Geography, University of Copenhagen (Geobasis, nivation, pedology, 3 June-1 September)

Gabrielle Stockman, Danish Polar Center (BioBasis, general information, 27 July-8 August)

Lena Ström, Department of Plant Ecology, University of Lund (trace gas exchange, 8 August-26 August)

Mikkel Tamstorf, Ph.D. student, National Environmental Research Institute, Denmark (hyperspectral analysis, BioBasis, 28 July-8 August)

Lars Thomsen, ASIAQ, Greenland Field Investigations (ClimateBasis, 14 August-26 August)

Koen Trappeniers, Laboratory of Polar Biology, University of Antwerpen (testate amoebae ecology, 27 July-8 August)

Daneborg

Mario Acquarone, Ph.D. student, National Environmental Research Institute (marine ecology, 27 July and 26-30 August)

Erik W. Born, Ph.D., National Environmental Research Institute, Greenland Institute of Natural Resources, Greenland (marine ecology, 27 July and 26-30 August)

Peter Bondo Christensen, Ph.D., National Environmental Research Institute (marine ecology, 27 July-16 August)

Göran Ehlmé, photographer, Water Proof Diving AB, Sweden (marine ecology, 27 July-16 August)

Allan Falk, photographer, Stalia 6619, 47496 Nösund, Sverige (marine ecology, 27 July-16 August)

Egon R. Frandsen, technician, National Environmental Research Institute (marine ecology, 27 July-16 August)

Ronni Nøhr Glud, Ph.D., The Marine Biological Laboratory, University of Copenhagen (marine ecology, 27 July-16 August)

David Griffiths, veterinary, Norwegian College of Veterinary Medicine & Department of Animal Science and Animal Health, Royal Veterinary and Agricultural University (marine ecology, 27 July and 26-30 August)

Jens Würgler Hansen, Ph.D., National Environmental Research Institute (marine ecology, 27 July-16 August)

Jens Kjerulf Petersen, Ph.D., National Environmental Research Institute (marine ecology, 27 July-16 August)
Dorte Krause-Jensen, Ph.D., National Environmental Research Institute (marine ecology, 27 July-8 August)
Michael Kühl, Ph.D., The Marine Biological Laboratory, University of Copenhagen (marine ecology, 2-16 August)
Jens Larsen, technician, National Environmental Research Institute (marine ecology, 27 July-16 August)
Søren Rysgaard, Ph.D., National Environmental Research Institute (marine ecology, 27 July-16 August)
Mikkel K. Sand, Cand. scient, Institute for Biological Sciences, University of Aarhus (marine ecology, 27 July-16 August)
Frank Wenzhöfer, Max Planck Institute for Marine Microbiology, Bremen, Germany (marine ecology, 27 July-16 August)

Logistics

Zackenberg

Karina Bernlow, Cook, Danish Polar Center (30 June-1 September)
Aka Lynge, Logistics Manager, Danish Polar Center (29 May-1 September)
Henrik Philipsen, Logistician, Danish Polar Center (29 May-1 September)

Others

Zackenberg

Jens Gregersen, Artist (visit, 19 June-30 June)
Lars Moseholm, National Environmental Protection Agency, Denmark (visit, 8 August-14 August)
Hans Pedersen, Radio Denmark (visit, 8 August-14 August)
Leif Skov, Aage V. Jensens Fonde (visit, 8 August-14 August)
Niels Skov, Aage V. Jensens Fonde (visit, 8 August-14 August)
Øystein Slettemark, Greenland Home Rule (visit, 8 August-14 August)
Frank Sonne, National Environmental Protection Agency, Denmark (visit, 8 August-14 August)

Further contributors

Morten Frej Bøyesen, graduate student, Zoological Institute, University of Copenhagen
Kirsten Christoffersen, Ph.D., Freshwater Biological Laboratory, University of Copenhagen (BioBasis)
Erik Jeppesen, D.Sc., National Environmental Research Institute, Denmark (BioBasis).
Henrik Søgaard, Ph.D., Institute of Geography, University of Copenhagen (BioBasis)

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Erratum

Corrections to the 5th ZERO Annual Report, 1999 are given in bold.

P. 9
1st column, line 26:
… landings was **26** in 1999, **16** in connection …

P. 14
Fig. 3.4. **Variation in wind speed (m/s) and wind direction 1999. Parameters are measured 7.5 meters above terrain.**

P. 33
2nd column, line 3:
… probability test: **p<0.05** for both sanderling …

P. 34
1st column, line 15:
… (Table **4.21**) …
2nd column, line 8:
… Table **4.21** …

P. 35
1st column, line 29:
… At least a further four pairs **without goslings** stayed at Lomsø …

P. 39
2nd column, line 41:
… (Fig. **4.1**) …

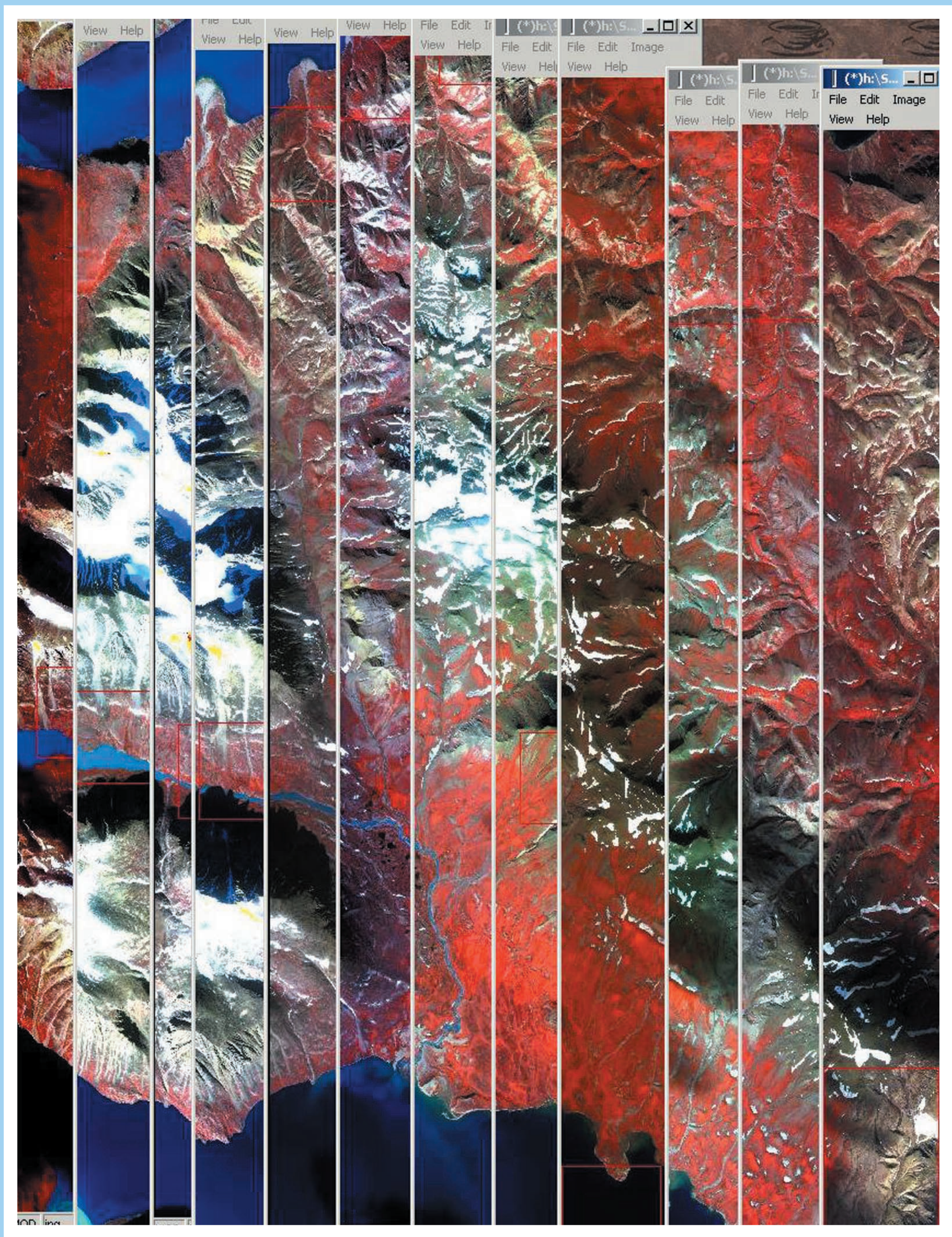
P. 40
2nd column, line 28:
… (Table **4.28**) …
2nd column, line 31:
… (Table **4.29**) …

P. 41
1st column, line 1:
… Table **4.30** …
1st column, line 12:
… (Table **4.30**) …
1st column, line 25:
… (Table **4.30**) …
1st column, line 35:
… Table **4.35** …
1st column, line 39:
… (Table **4.39**) …

P. 42
2nd column, line 19:
… Table **4.31** …
2nd column, line 39:
… Table **4.39** …

P. 43
2nd column, line 37:
… Fig. **4.2** …

P. 45
1st column, line 23:
… and **4.1 (**in Langemandssø …



Zackenbergdalen was scanned by a hyperspectral scanner on 7 August 2000. Each strip shows three spectral bands from the nearinfrared, red and green spectra in red, green, blue, respectively. Vegetation is therefore shown in red colours, barrens in grey and snow in white. The Zackenberg station is located in the mid-lower part of the image.