The 1993 Northeast Water Expedition
Scientific cruise report of RV "Polarstern" Arctic cruises ARK IX/2 and 3, USCG "Polar Sea" cruise NEWP and the NEWLand expedition

Die Nordostwasser-Polynja-Expedition 1993
Wissenschaftlicher Fahrtbericht über die „Polarstern" Reisen ARK IX/2 und 3, die USCG „Polar Sea" Reise NEWP und die NEWLand Expedition

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with contributions of the participants

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Cruises ARK IX/2 and 3

Bremerhaven - Tromsø
May 16 to June 24, 1993

Tromsø - Tromsø
June 26 to August 4, 1993

The North East Water polynya (Greenland Sea)

1 INTRODUCTION

1.1 Summary

The expeditions ARK IX/2 and 3 of RV "Polarstern" to the Northeast Water Polynya (NEW) off Greenland was part of the main field phase of the International Arctic Polynya Programme (IAPP) under the umbrella of the Arctic Ocean Sciences Board (AOSB). The other components were the USCG ice breaker "Polar Sea" and the NEWland program. While "Polar Sea" continued to measure core parameters and time series stations after the departure of Polarstern, the NEWland scientists worked continuously on the shore side between May and August. The major goal of the programme was a detailed study of the generation mechanisms of the polynya and its ecosystem and the effect of the polynya on the adjacent land ecosystem. Physical, biological, chemical and geological programmes were performed at sea to obtain a complete data set from this area. Observations of ice coverage, ice conditions and drift completed the study; on shore, in addition an archeological project was included.

1.2 Itinerary

The NEW cruise started in the evening of May 16. At 22.00 hours Polarstern left Bremerhaven with 44 scientists and 44 crew members. In Bremerhaven the ship was equiped with a new navigation system. For testing and instructing 10 scientists and engineers joined the cruise. In Tromsø they disembarked and in exchange 21 scientists boarded the ship and completed the team. The ship left Tromsø on May 21 at 20.30 in northerly direction towards the North East Water Greenland polynya (NEW).

The first station was performed on May 22 to catch organisms for preliminary experiments in the Atlantic water. At a station in the central Greenland Gyre on May 23 the equipment was tested. The polynya project started on May 25 with a transect across the East Greenland Current . Polarstern had to break through heavy ice, until we finally arrived in the NEW area on May 26. The polynya consisted mainly of a long lead along the Norske Øer Ice Barrier, where extensive station work and helicopter sampling programmes started. On May 27 Polarstern was near the NEWland station Eskimonæs. A first meeting was arranged by helicopter with the two Swedish scientists. Fuel and equipment for the Greenland Geological Survey was deposited by helicopter. Two Polish scientists disembarked here to perform an ecological survey of the coastal

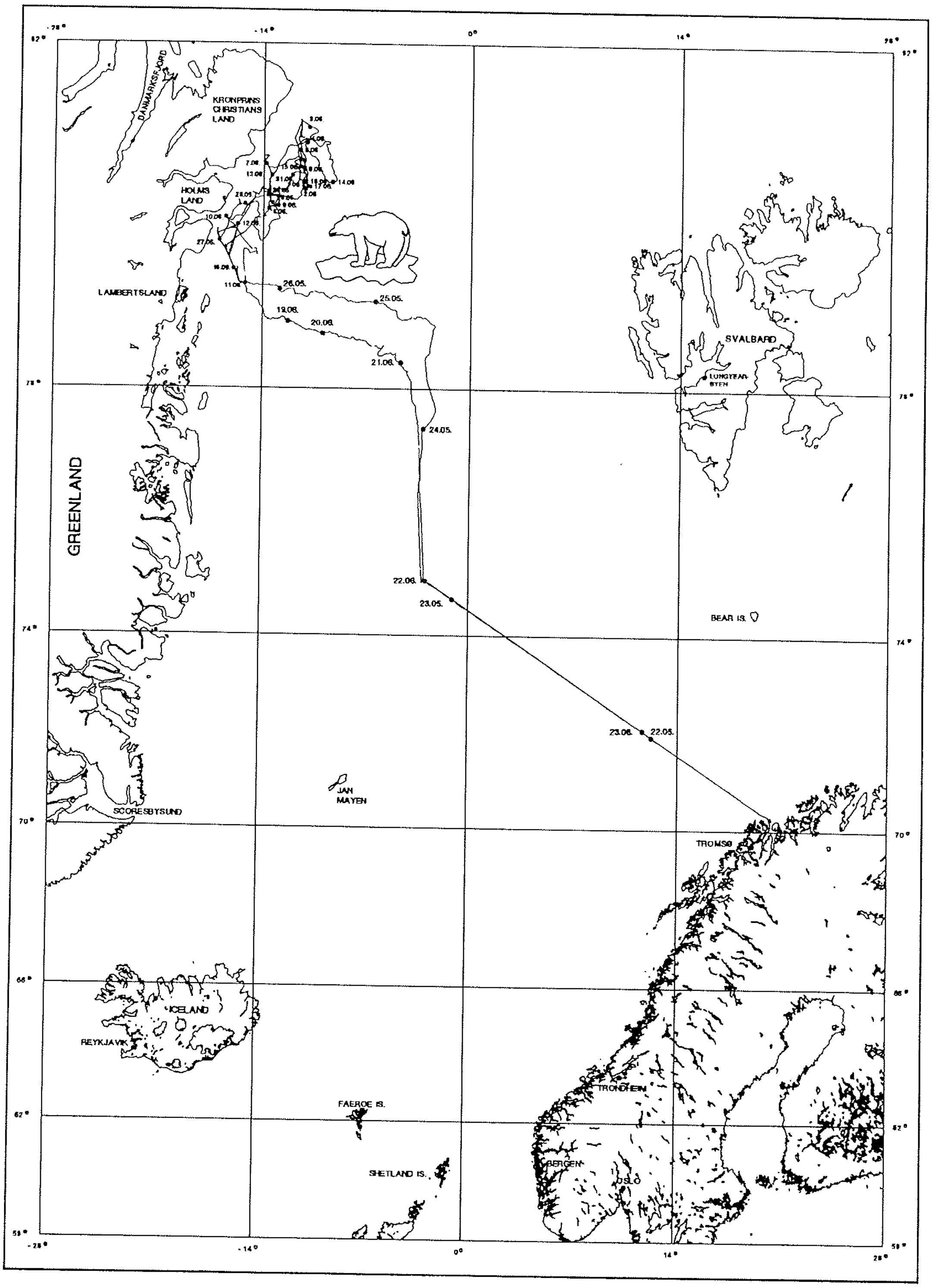

Fig. 1.1. Cruise track of ARK IX/2.

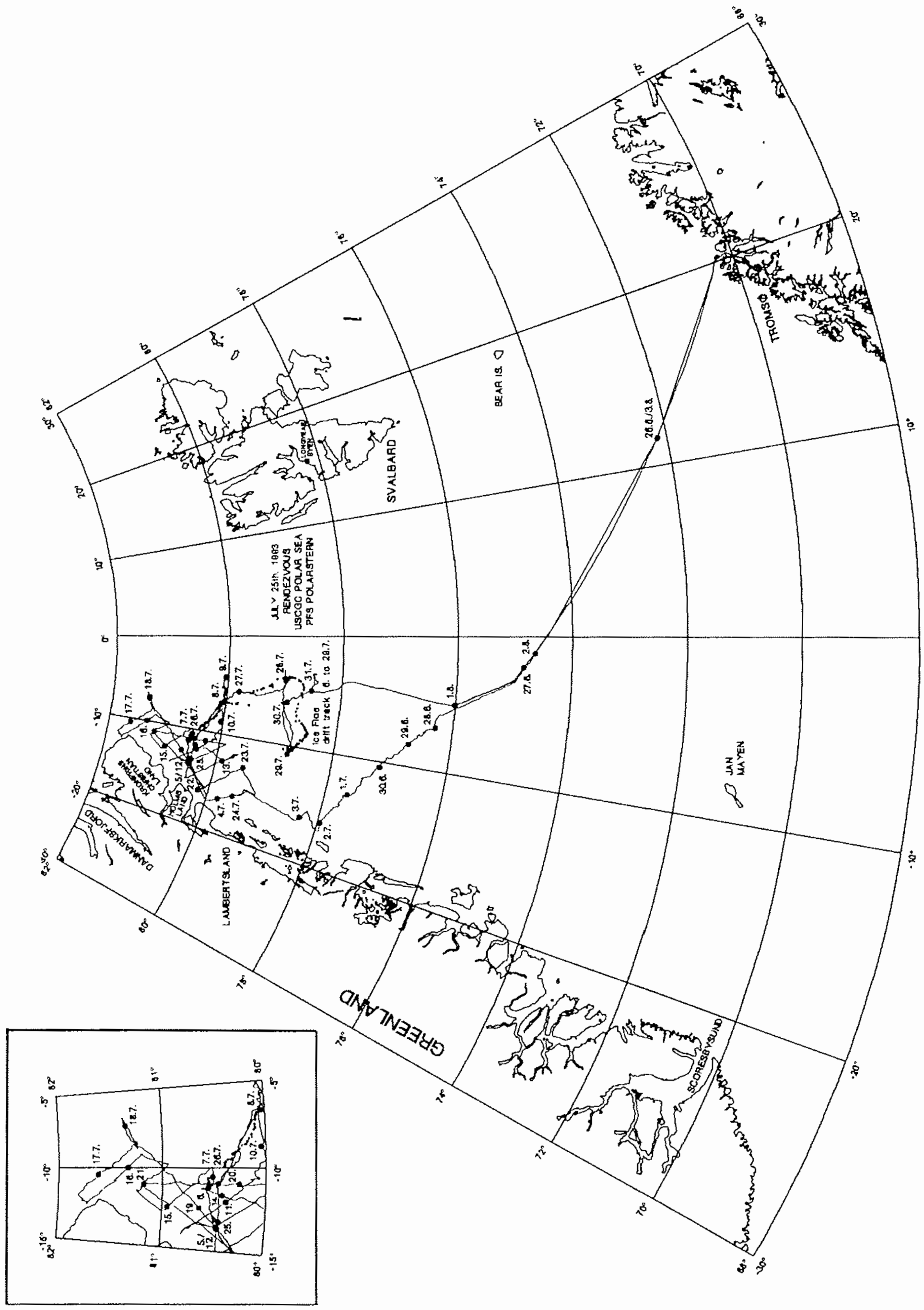

Fig. 1.2. Cruise track of ARK IX/3.

system from shore. The first ice camp was performed on a large ice floe. On May 31 the station work was completed in the southern polynya and Polarstern seeked a way through heavy ice toward the northern part near Ob Bank, which in the meanwhile has become ice-free. After time-consuming ramming and waiting we finally succeeded to reach this area and on June 3 again a close grid of stations was performed. The southern polynya has nearly closed up in the meantime.

After intensive station work the next 24 hour ice camp started on June 8. All equipment was transported by helicopter to the ice floe. Thereafter the work continued in the southern part of the NEW near Norske Øer on June 10 where the lead had opened again, but to a much larger extend previously. Several stations were repeated to study the seasonal development. On June 13 Polarstern steamed again to the northern polynya. As the ice had slightly opened in northeastern direction we were able to perform some stations in this ice-covered region. A north-south transect was repeated and on June 15 the work was completed by the third ice camp, which lasted 36 hours. On June 17 the ice camp work ended. On our way southward the Polish colleagues and their equipment were retrieved by helicopter from Eskimonæs. Along the southern ice barrier again several stations were performed. We left the east Greenland Shelf with a transect across the East Greenland Current. In the morning of June 22 the last station in the marginal ice zone was completed, and on June 24 we arrived in time at Tromsø.

During the port call, crew and scientists were exchanged. On June 25 at 20.00 Polarstern departed with 57 scientists and 38 crew members from Tromsø for the second NEW leg. The test station from ARK IX/2 was revisited, and under calm weather conditions the ice edge was reached on June 28 at 76°20'N 7°W. This was the starting point for a hydro-biological transect covering the trough system on the shelf off NE Greenland, including Belgica Trough, Norske Trough and Westwind Trough. Especially in the western part of Belgica Trough we met heavy pack ice. The transect was interrrupted for the first visit of the time series station during this leg on July 30. During our absence from the NEW, strong melting had set in and the polynya had opened up considerably. Melt ponds were covering a large part of the ice, and the enormous ice algae assemblages observed during 9/2 were to a large extend washed off the ice and floated in the water. Under much easier ice conditions transects from the previous leg were repeated and could be extended further into the ice without considerable loss of time. However, the melting made the choice of ice floes appropriate for ice camps difficult. Therefore it was decided on July 7, to equip a multi year ice floe with current meters and sediment trap and use it as an ice island. During the 22 days before its recovery on July 29 it described an anticyclonic drift pattern. Other ice activities included investigations of ice types and thicknesses of the Norske Øer and Ob Bank Ice Barriers.

On June 29 north of Ob Bank a large part of the ice barrier broke off and drifted northward, leaving an area of open water behind. This gave us the opportunity for a transect along the ice barrier north of Ob Bank between July 16 and 17 to study the hydrographic and biological conditions upstream of the NEW. During this transect we reached the northernmost position of this cruise at 81°49'N

12°54'W. On the way back the transect was extended eastward across the shelf slope for the northernmost of 3 transects across the East Greenland shelf slope of the marine geological program.

During our presence in the NEW Polarstern and her helicopters served as an emergency back up for the ongoing programs on shore, the NEWLand project and the Danish Geological Survey. Radio contacts were maintained daily, which allowed a close coupling of the land and sea-based mammal and bird observations.

The US Coast Guard ice breaker Polar Sea with 20 scientists onboard entered the NEW on July 21 to continue the NEW project. A small group from Polarstern visited Polar Sea on July 23 for a first planning meeting. Both ships met on July 25 for a meeting of scientists and crew. NEWLand participants also joined this meeting, and for a few hours all three components of the NEW project were united. An intercalibration program was conducted with exchange of water samples and parallel biological and physical measurements at the position of the time series station.

Shortly after Polarstern concluded the cruise program with the recovery of moorings equipped with sediment traps, which were deployed in 1992 by Polar Sea, and headed towards the marginal ice zone. Here morings of a long term hydrographic program focusing on the East Greenland Current were recovered and redeployed. On July 31 we left the marginal ice zone under increasing winds for a last visit of the test station at 75°N 3°W. On August 4 the ship arrived at Tromsø at 09.00 in due time.

The expedition to the Northeast Water was only possible due to the cooperation of the Greenland National Park authorities and the Danish Polar Center, which we deeply acknowledge. We are grateful to the captains H. Jonas and E. Greve, their officers and crews for the willing assistance and great engagement which made the large sampling programme and the great success of the NEW polynya study possible.

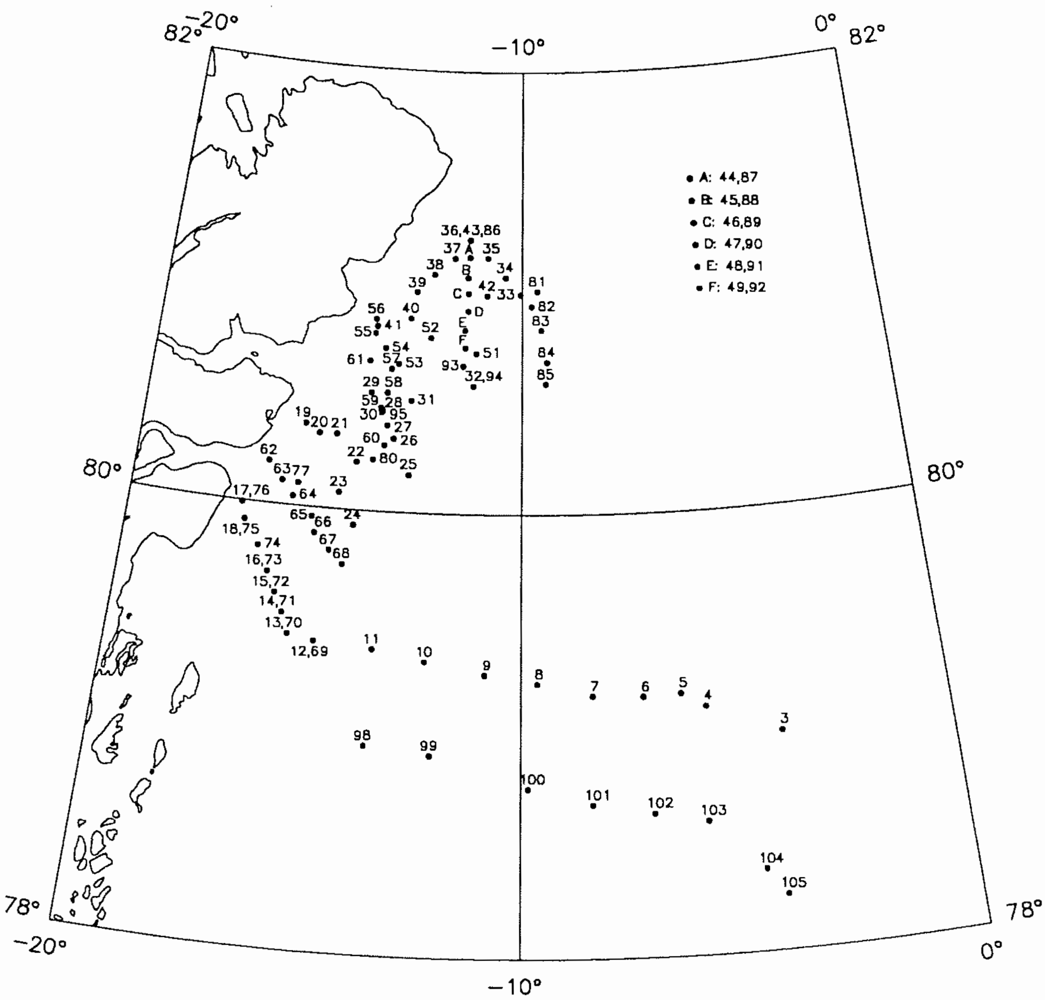

Fig. 1.3. Research area and stations during ARK IX/2.

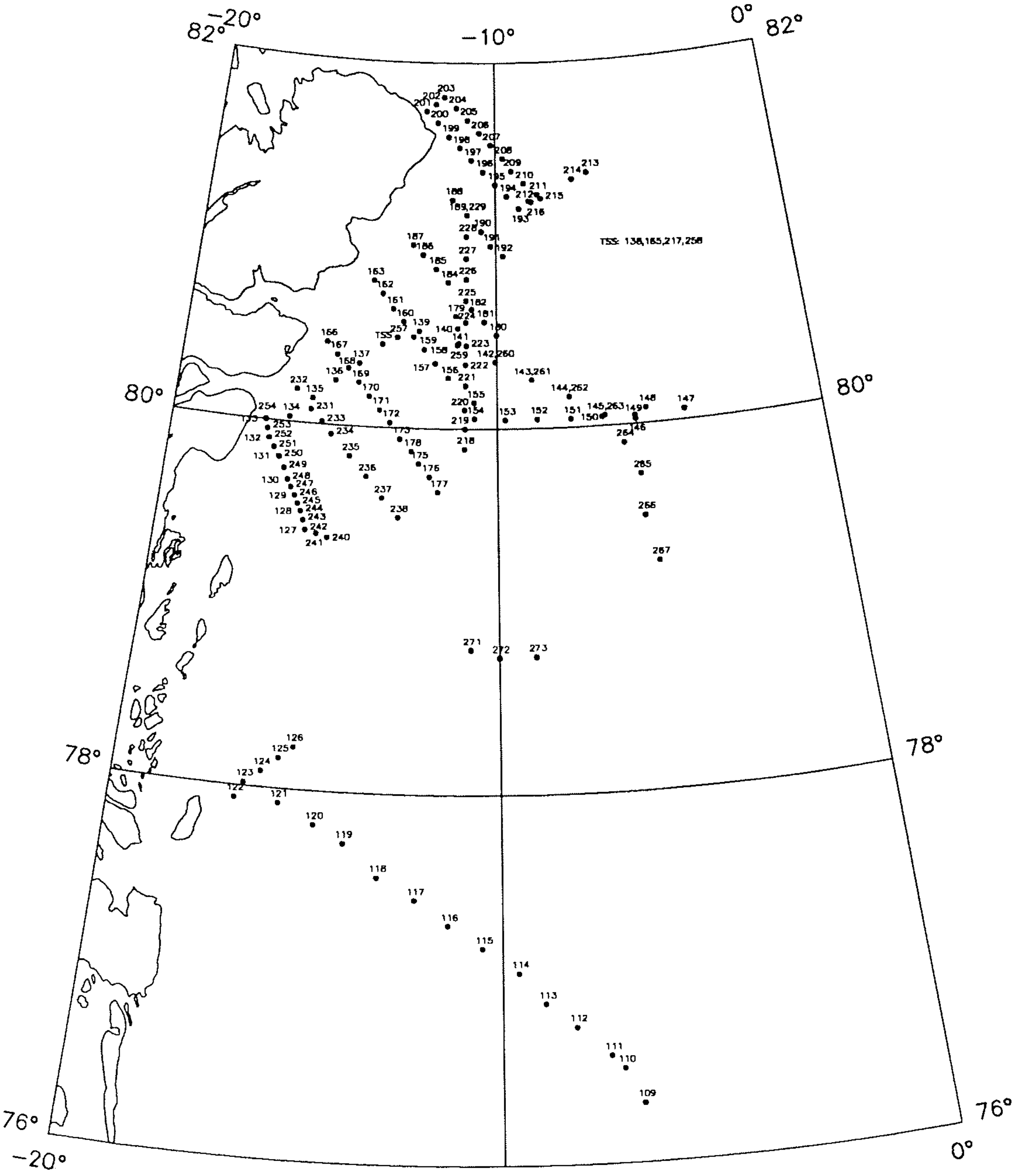

Fig. 1.4. Research area and stations during ARK IX/3.

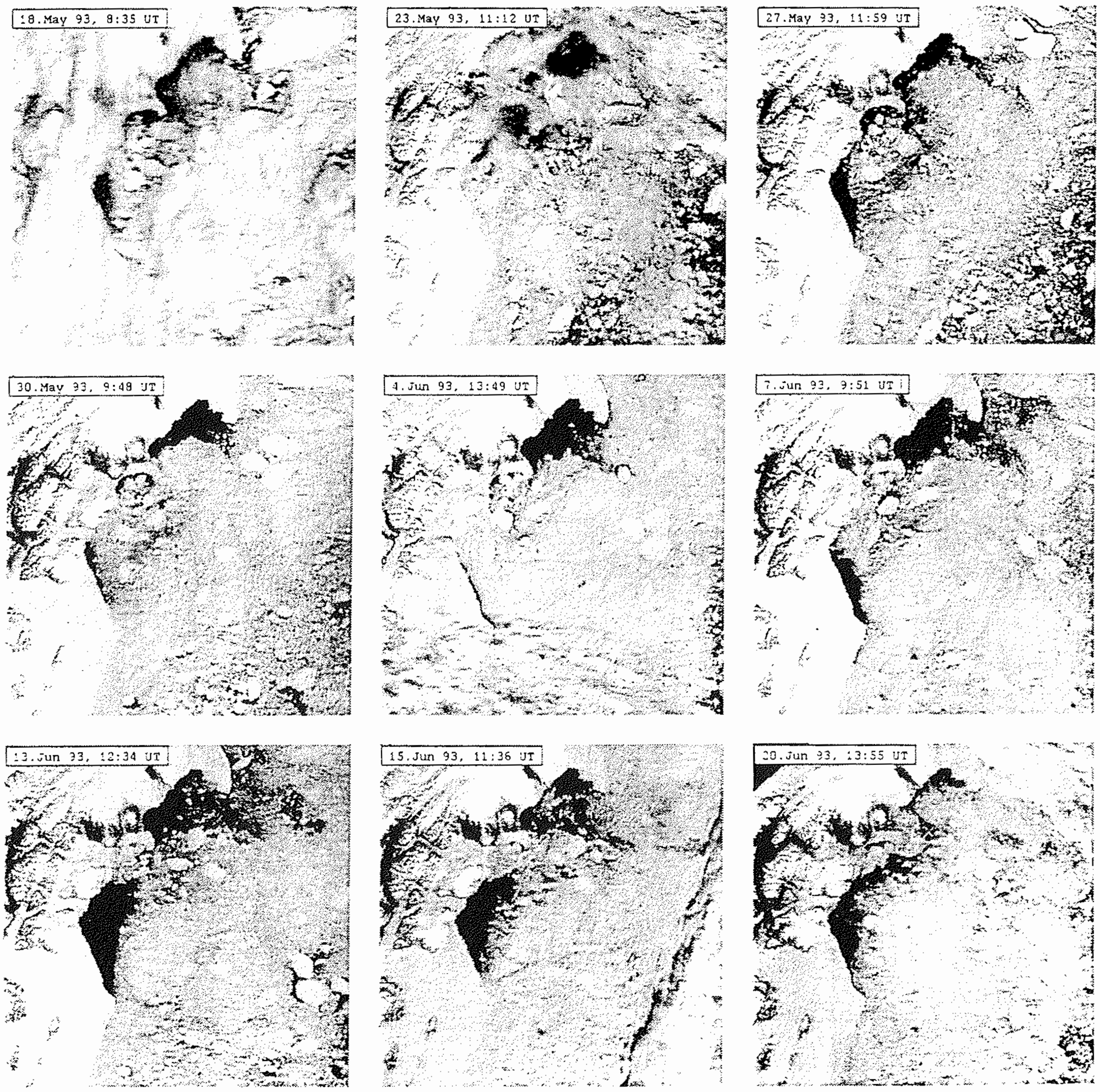

Fig. 1.5. Ice cover of the NEW during ARK IX/2 from NOAA-AVHRR images.

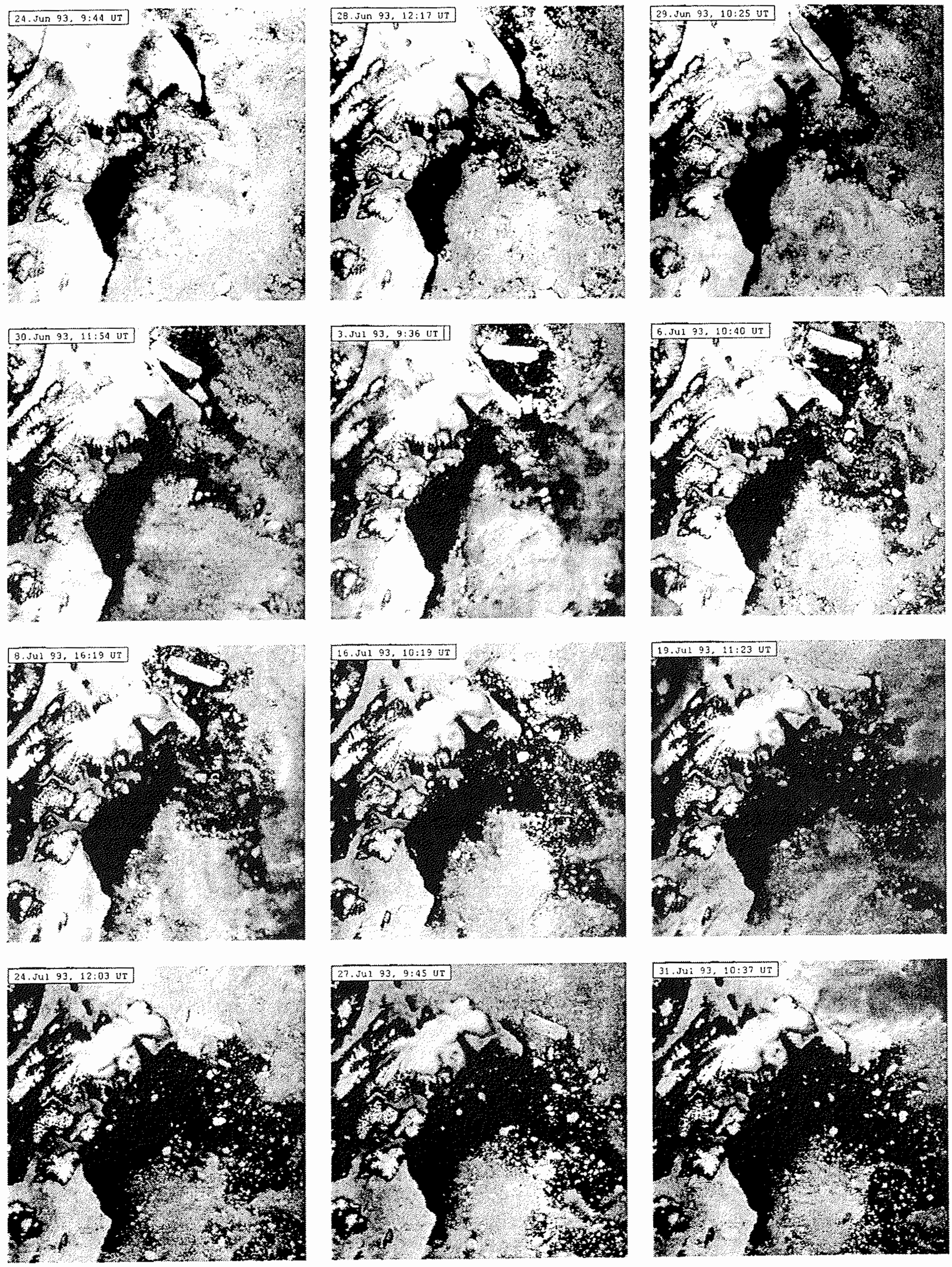

Fig. 1.6. Ice cover of the NEW during ARK IX/3 from NOAA-AVHRR images.

2 METEOROLOGY

2.1 Weather conditions

E. Röd, T. Bruns

ARK IX/2

Atmospheric pressure and wind: At the time when "Polarstern" entered the area of operation, an extended and strong Arctic high had settled down over the Greenland region. On May 29 it reached its highest intensity with 1040 hPa and began to decay and withdraw across the North pole. Till June 7 a period with pronounced lower pressure level (below 1020 hPa) followed. A depression coming from the northern Ural mountains crossed the Barents Sea and Svalbard, reached the North pole and could be identified in the satellite images as far as to the Newsiberian Islands. On June 7 a high near Franz-Josef-Land started moving east and reached the north-eastern Greenland Sea on June 9. This second anticyclonic phase culminated between June 10 and 12. For the rest of this cruise leg the Greenland high weakened steadily. On June 19 the pressure dropped to its lowest value of 1009 hPa due to a cyclone that moved from northern Canada towards the coast of western Greenland.

Corresponding to the season of early summer, no intense cyclogenetic processes could be observed. The lows that appeared were in general of small-scale-type and not sufficient for a dangerous tightening of pressure gradients. The wind was mainly determined by the outflow from the Arctic anticyclone. Subsequently, wind directions from north to northeast were prevailing. From June 4 to 11, however, the wind came always from south to Southwest, driven by a high pressure cell over the Norwegian Sea. Later on till leaving the Greenland shelf winds from the northeast quadrant dominated again.

Only on a few days the wind force exceeded 5 Bft. Just once, on June 14, for a short time NNE 7 Bft was observed. Winds with gale force did not occur at "Polarstern" at all, but sometimes near the coast according to pilot reports and bulletins of stations on land. It could be seen from the general pressure distribution that these winds, reaching locally 40 knots, were undoubtedly of catabatic character. It may be supposed that catabatic winds are important for the opening of the polynya.

Visibility and cloudiness: Longlasting fog, typical for the subpolar summer, was missing during this cruise. Fog persisted only several hours each time with a maximum duration of one day before dissolving or raising to form low stratus. Flight operations of the helicopters thus were sometimes delayed but not essentially obstructed. Much higher was the frequency of low stratus, which sometimes persisted for three or four days. Sunny periods with cloudless sky however were of equal length. The arctic stratus repeatedly released short and weak snowfall. Apart of this visibility below the cloud layer was excellent.

A well marked correlation was found between the occurence of fog or lower stratus respectively of sunny sky with the wind direction: wind with a component towards the coast mostly brought fog or stratus, on the other hand winds coming down from the inner ice frequently were associated with blue sky. It could also be seen that the low stratus only reached the coast with the inner glaciers and mountains being free of clouds, probably a consequence of catabatic effects.

Air temperature and moisture: Within the packice-belt the temperature remained below freezing point with only small variations. The lowest value was -8°C, the mean value about -4°C. The daily variation was very small, but still had some influence on the tendency of intensification or dissolution of fog. The relative humidity of the air was constantly extremly high, frequently near saturation. In spite of this the lack of a sufficient number of condensation nuclei in the polar air caused the good visibility that would have been impossible under different conditions. Due to rather low absolute humidity no helicopter-icing could be observed. Ships icing was insignificant even in supercooled fog.

ARK IX/3

When "Polarstern" departed from Tromsø in the evening of June 25, clear sky and weak northeasterly winds promised a calm cruise on the route to the Greenland Sea. In fact, a ridge over the North Sea developed to a high pressure cell southwest of Svalbard and remained stable til the end of the month. During the first days winds prevailed from easterly, later from changing directions, where Bft 3 was never exceeded. Unfortunately, low stratus covered "Polarstern" since she left the Tromsø Fjord. On June 27 south of Greenland a strong cyclogenesis took place, ending in an almost stationary low near Iceland. The corresponding occlusion moved very slowly northward and, along with simultaneous weakening of the Svalbard high, reached "Polarstern" on June 30 with light rain. Since June 28 the ship had steamed through heavy ice and now the low stratus alternated more frequently with fog.

In the first week of July the occlusion remained stationary over the southern Greenland Sea, while the high recovered and moved to northern Greenland. Later, a low moving to the Norwegian Sea steered reinforced the supply of humid air masses over the Greenland Sea. Therefore, the sky was mostly covered and foggy, while the wind force ranged between 2 and 4 to 5 from east to northeast. The fog seemed to disperse on July 2, when a group of scientists visited the ice by helicopter for the first time. During their work, a suddenly approaching fog bank covered them completely for one hour. However, just before an emergency rescue by crane was started, the conditions allowed for helicopter operation again.

On July 3 coastal shelf ice was encountered and "Polarstern" entered into a strip of open water, leading the way along the coast to the NEW polynya. On the following day the polynya was reached and the coast appeared as a light band under the dark stratus ceiling. Finally, in the afternoon the sky was clear. These conditions were still accompanied by northeasterly winds with 2 to 4 Bft and persisted in the polynya area till July 11 with short interrupts. The polynya could already be recognized on the satellite images long before the arrival of "Polarstern". This seemed to indicate that the warm open water had suppressed the formation and/or forced the dispersion of fog and low clouds. During ARK IX/2 the sun had been shining here for most of the time, heating the surface water up to 4°C.

On July 6 "Polarstern" headed eastward into the ice again in order to set up a 36-hour camp on a large ice floe. As expected, fog and stratus occasionally occurred over the colder surface. However, fog advection dominated over local generation. On July 9th the satellite image showed an overcast of low clouds over large areas north of 81°N. These clouds rapidly approached and stayed for one day with northerly winds between 4 and 5 Bft. On July 11 "Polarstern" returned to the open water with a short episode of fair weather. The fog came back on the other day, caused by the occlusion of a weakening low near Jan Mayen.

Until the end of July the stationary Greenland high and the ridge directed towards Svalbard were responsible for weak gradients over the operation area of "Polarstern". Therefore, the prediction of wind and associated parameters became more difficult. While the synoptic situation often indicated dry winds off the land, mostly southerly winds carried humid air masses into the area. On July 14 the 850-hPa-temperature increased to 9°C by 7 K with the arrival of a warmfront. However, over the cold surface and within a layer of dense fog a warming could not be observed. Correspondingly, the temperature sounding showed a strong surface inversion with a vertical gradient of 10 K/300 m. In the rear of the warm front the fair weather came back on the next day. In the meantime "Polarstern" had arrived at the "ice nose" at 81°N 12°30W. This characteristically shaped floe on the northern rim of the polynya, as well as the floe that broke off on June 29, could easily be identified on the satellite images, in order to locate cloud and fog patterns.

When "Polarstern" passed the Ob Bank ice barrier, on which an unmanned camp was installed, the northwind picked up to 5 Bft for a few hours, but it was calm in the evening. The northernmost position of this leg was reached at 81°37'N 10°27'W on July 17. A low over northern Scandinavia was now responsible for the advection of humid air, that locked the helicopters in the hangar for two days. Therefore, the clearing of the camp had to be put off til the evening of July 20. When finally the ceiling lifted to 2000 m, several rain showers were observed, but did not reach the ground. The showers were due to an unstable stratification between 850 and 750 hPa in front of an upper trough approaching from the west. When the trough crossed the Greenland Sea on July 21, the showers turned into rain falling from high straticumulus clouds.

In the following, high pressure influence recovered. Good flight conditions prevailed, interrupted by short fog or rain episodes. On August 1 a low developed over the Norwegian Sea. The low moved slowly northeastward and therefore touched the route of "Polarstern" heading towards Tromsø. On August 2 the wind increased to Bft 6 from northwest, changed to southeast 7 in the evening and to southwest 8 to 9 during the night. The wind began to decrease in the afternoon. Arriving in Tromsø in the morning of August 4 "Polarstern" was welcomed by sunshine and weak southerly winds. The distribution of wind speed and wind direction is shown in Fig. 2.1.

The high frequency of fog and low stratus observed during the expedition is typical for the Greenland Sea in summer. Fig. 2.2 shows frequency distributions of fog events (a) and combined fog and/or stratus events (b) north of 75°N. The shaded columns represent the total duration of events (number given above the

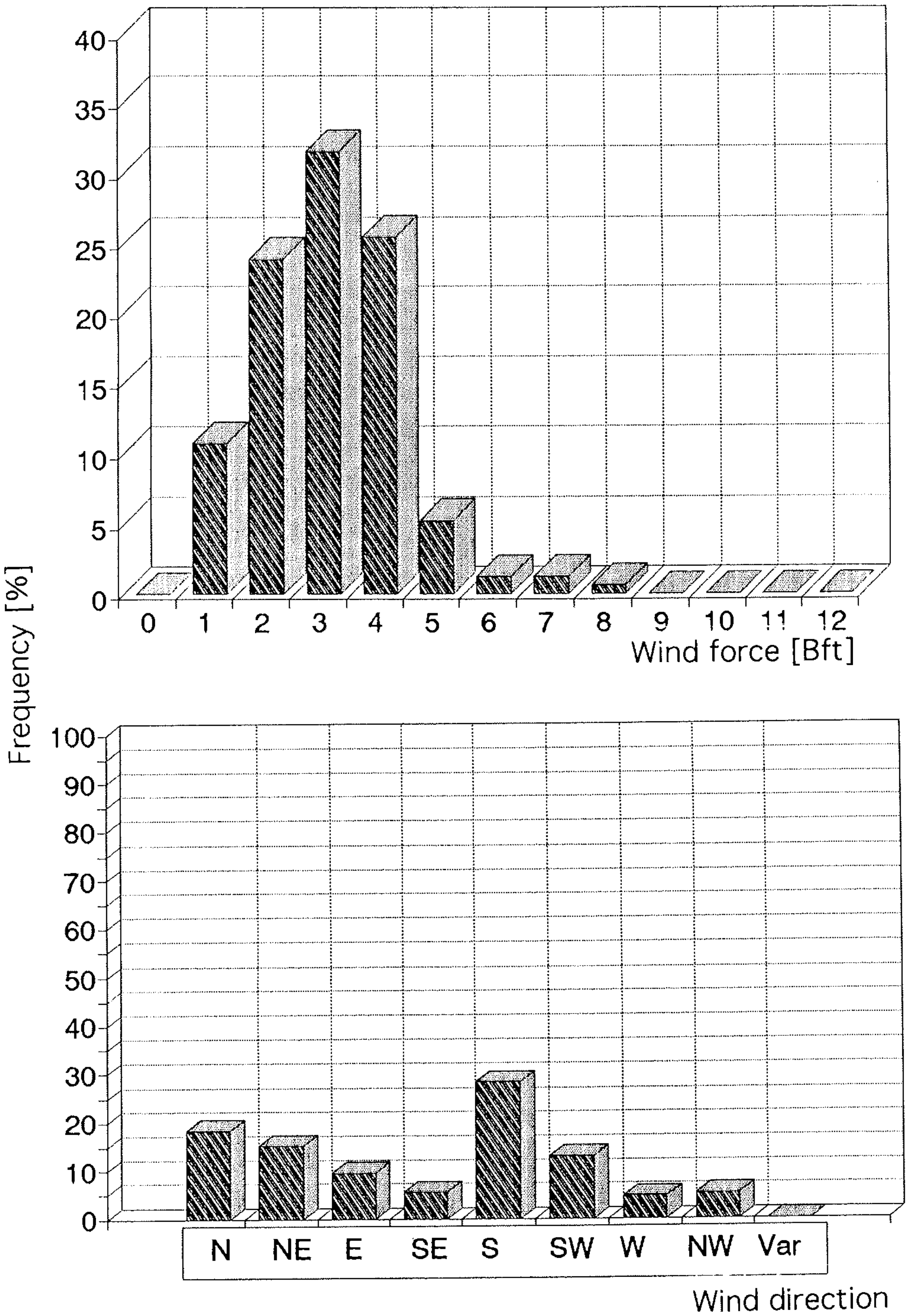

Fig. 2.1. Frequency of wind speed (a) and wind direction (b) during ARK IX/3.

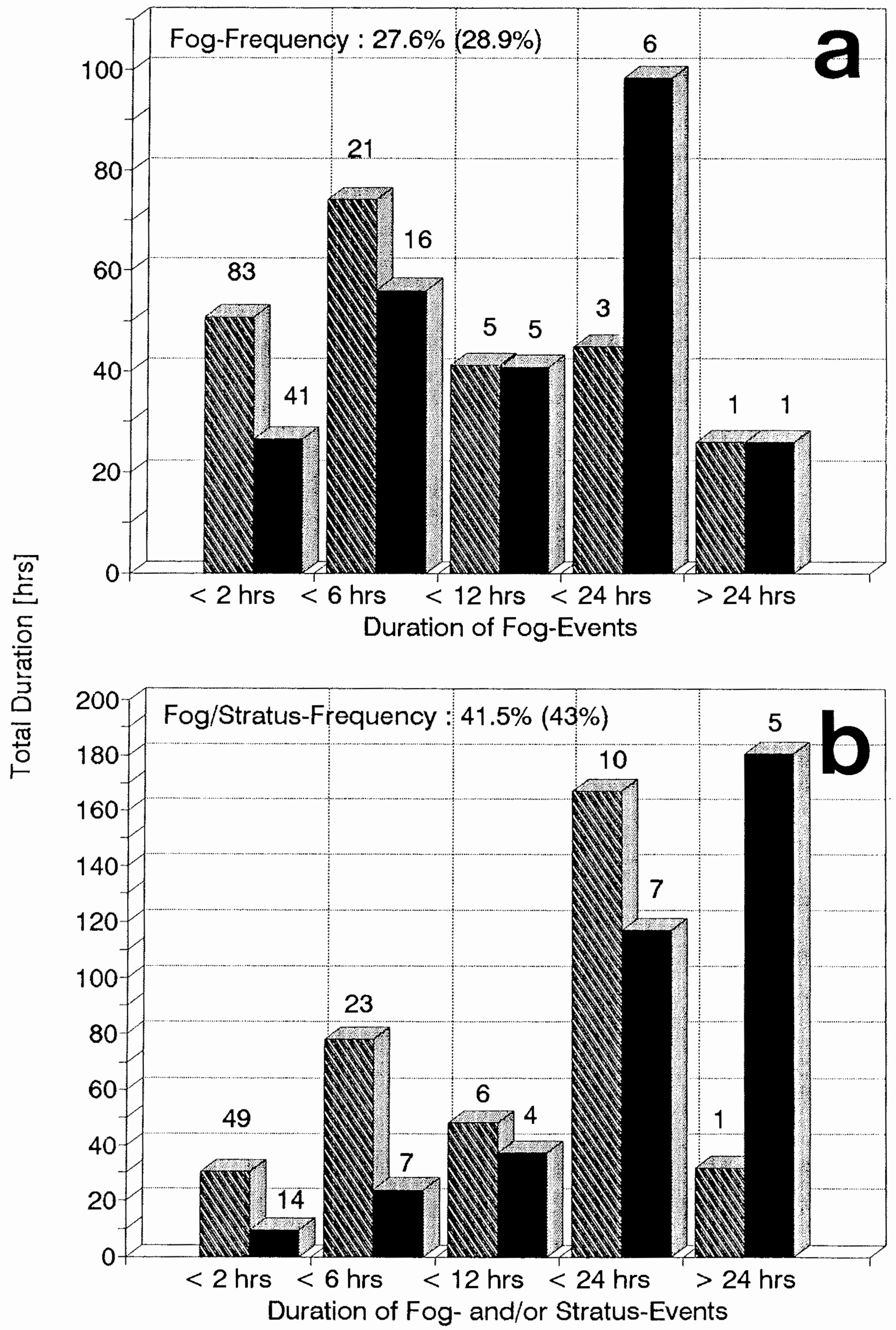

Fig. 2.2. Fog frequency (a) and fog/stratus statistics (b) during ARK IX/3.

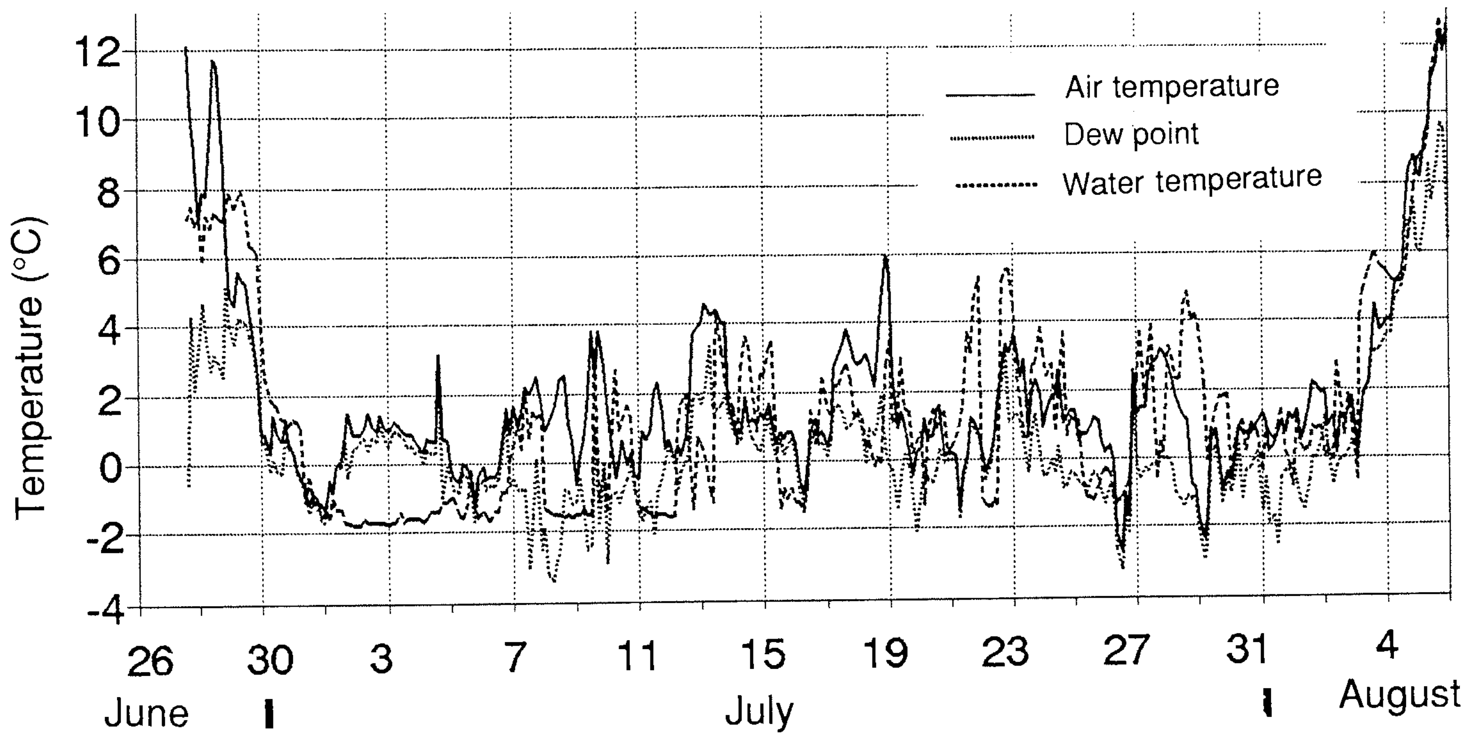

Fig. 2.3. Air temperature, dew point and water temperature during ARK IX/3.

columns) in each duratuion class. The black columns represent events including interrupts not longer than 30 minutes. Under this condition 6 events lasting longer than 12 hours account for more than 50% of all fog hours. Only once a duration of 24 hours was exceeded. In comparison to the fog statistic (a) the fog/stratus statistic (b) exhibits a shift to longer durations. Thus, very frequently low stratus was observed between two fog events. Including short interrupts 12 events account for about 90% of all fog/stratus hours. At least in 43% of the time "Polarstern" spent north of 75°N helicopter operation was impossible.

2.2 Weather Station

P. Galbraith, G. Ingram, C. Bélanger

An Aanderaa weather station was raised at height of 5 m at Eskimonæs, on the Greenland shore (80°26.276'N° 15°47.687'W), from May 25 to July 21. It sampled temperature, average wind speed and gust speed, wind direction, atmospheric pressure and solar radiation every 20 minutes. The data will be compared with the ship's data, and with the Danish Meterological Service's data from Henrik Krøyer Holme. Solar radiation data will be of use to photic zone biology as well as possible heat flux estimates. The wind stress will be estimated from quadratic wind stress formulae to compare ice camp drift tracks to predicted wind-induced ice drift.

2.3 Meteorological data and heat flux

W. Schneider

The POLDAT system of RV Polarstern recorded meteorological and hydrographic data in intervals of 5 seconds together with all relevant navigational information. 5 minute averages of POLDAT data are available for wind speed, wind direction, relative humidity, air pressure, air temperature, SST and global radiation together with the geographic location of the measurements, corrected ship speed and heading.

A three dimensional wind speed sensor (Kajio Denki) was employed on an extention of the ship´s bow, about 15 m abovd sea level. At stations the ship´s bow was manoevred into the wind to allow measurements free of ship induced turbulebnce. Unfortunately, during ARK IX/3 at least one of the sensors malfunctioned.

3 OCEANOGRAPHY

3.1 Ship-borne physical oceanography

G. Budeus, W. Schneider, J. Brunßen, M. Damm, R. Plugge

The work performed during the pilot study phase of the Northeast Water (NEW) in 1991 already allowed to derive a general concept of the generation and maintenance of the NEW. The main phase of the NEW study in 1993 is on one hand based on this concept, but on the other hand the 1993 field studies are used to further refine and revise the existing concept and to quantify some of its inherent processes.

The general concept includes essentially the effects of a northward coastal current (North East Greenland Coastal Current) and of a permanent fast ice feature, extending perpendicular to the coast (Norske Øer Ice Barrier, NØIB): The coastal current meets NØIB, and ice floes carried along are retained at the southern edge of it. The waters at somewhat greater depths, however, can continue to flow northwards underneath NØIB, since it bridges over Norske Trough and is grounded again at its eastern side. Ice import by the coastal current thus is inhibited by NØIB and, as at the same time ice export continues, an open water area, i.e. the NEW, establishes in its lee. The upper water layers of the NEW are also influenced by the combined effect of NØIB and coastal current. With the ice, melt waters of the upper tens of metres are retained south of NØIB, resulting in deeper PW emerging to the surface north of the barrier. This deeper PW is colder, namely at freezing temperature, and more saline than the summerly surface melt water layer observed elsewhere. In the NEW, the surface conditions are then modified by fresh water supply from the coast as well as from sea ice melting, both introducing enhanced vertical stability. This concept is depicted in Fig. 3.1.

Instrumentation and measurements

CTD: A Seabird 911+ system has been used for the CTD casts, with additional optical sensors for chlorophyll flourescence, backscattering, gelbstoff fluorescence (all three Dr. Haardt instruments), light intensity relative to the surface (LICOR with AWI interface) and transmission (Seatech instrument managed by SFB 313 Kiel). During both legs 257 CTD stations have been performed, extending to local bottom depth. On many stations additional casts have been necessary for water sampling. Four calibration checks have been performed in the central Greenland Sea (75°N 3°W) at about 3000 m depth on May 23, June 22 and 27, and August 2, since the NEW area is not suited to calibrate CTD sensors by comparative temperaure measurements and water sampling.

ADCP: An RDI 150 kHz ADCP has been used during the cruise. It worked for the first time in its new design which allows its operation in ice covered regions. A 81 mm thick acoustically transparent protection is placed in front of the transducer, and instrument and protection window can be exchanged during a cruise. Positioning of transducer and window has been chosen to minimize cross beam as well as single beam interference. An outline of the construction (manufactured by Lloyd Werft Bremerhaven) is shown in Fig. 3.2. There is little reduction in the range of the instrument by the protecting window, and bottom detection worked well in the entire NEW area including 500 m bottom depths in Belgica Trough. While breaking ice, measurements are not reliable, however, since ice and air bubbles are entrained under the ship's keel.

Ice work: Since NØIB seems to be a determining factor in the NEW's generation, some effort has been made to investigate the nature of this fast ice feature. Ice core drilling has been perfomed at 8 locations, coordinated with the needs of the remote sensing group and with substantial help of various persons. Where ice thickness was small enough to drill through, depths were measured mechanically. Locations and some results are listed in Table 1.

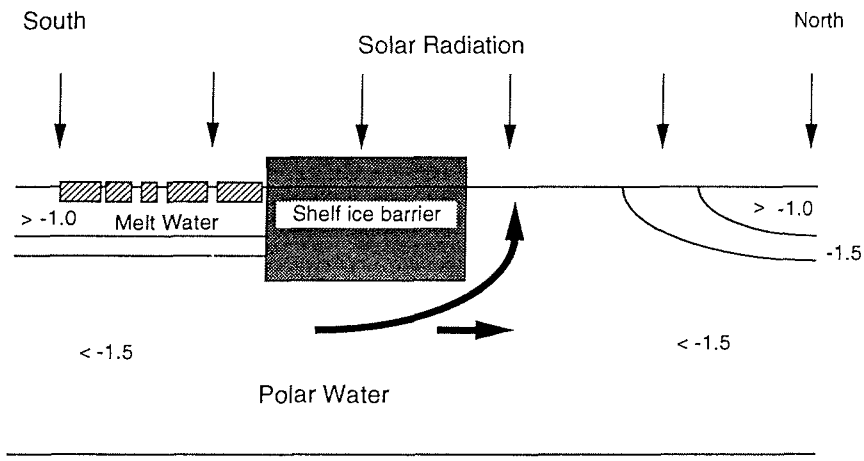

Fig. 3.1. Sketch to illustrate the effect of the ice barrier and the northward coastal flow (broad arrows) on the formation of the NEW (to the right of the barrier).

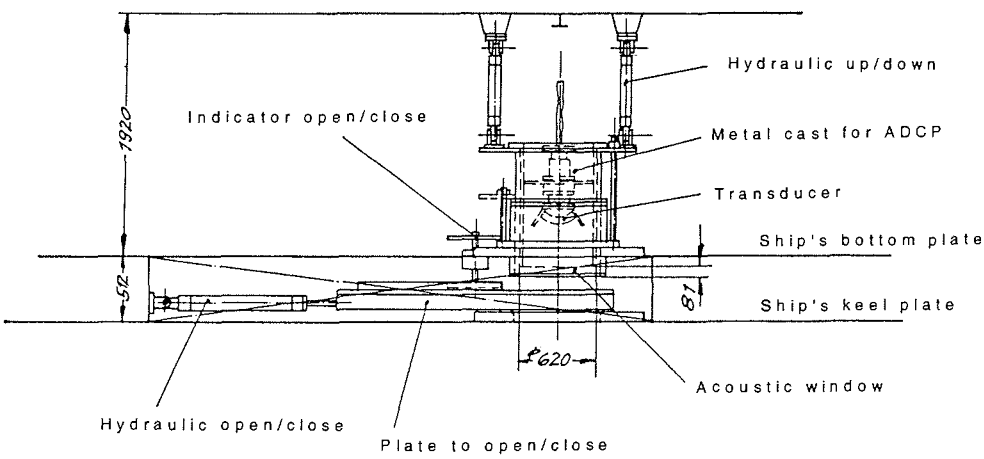

Fig. 3.2. Ice protected ADCP installation on RV Polarstern. The transmitter is protected by a 81 mm thick acoustically transparent window. For measurements the ADCP is lowered so that the acoustic window is inline with the ship's keel.

Table 3.1: Ice core drilling

Point	Date	Deg N	Deg W	Ice thick.	T(2m) /°C	Bottom/m
1	27.5.	79°19.83'	15°48.98'		-14	
2	27.5.	79°19.28'	15°53.30'			
3	27.5.	79°17.76'	16°47.39'			
3a	18.6.	79°24.00'	16°74.83'		-2.7	
4	13.6. 18.6.	79°12.00'	16°35.00'	2.3 m	-2	375
5	10.6.	79°20.86'	15°43.97'			
6a	18.6.	79°28.00'	17°48.00'	3 m	-2	>400
6b	18.6.	79°23.00'	18°00.00'	3.2 m	-2.8	400

Various: The AWI-COMED data aquisition unit was installed in the ship´s hydrographic well for on the way hydrographic measurements. The sensors resided at about 11 m depth about 0.5 m above the keel. The well and the sensors were protected against sea ice damage by a stell plate, slightly reducing the water exchange in the well. The sensors complement consisted of temperature sensor, conductivitiy meter and chlorophyll fluorometer. Together with navigational information 10 second averages of all three sensors were routinely recorded.

Preliminary results

Bathymetry: The bathymetry of the NEW area is determined by a trough system surrounding Belgica Bank: From south to north this is Belgica Trough, Norske Trough and Westwind Trough. Belgica Trough is about 500 m deep. Norske Trough in part is permanently ice covered; where it is open maximum depths on our cross sections range between 300 m and 400 m and show complex bathymetric structures. Hydrographic conditions suggest that trough depth below the ice covered parts is not below 250 m. Westwind Trough is about 300 m deep. At the eastern limit of NØIB bottom depths of less than 40 m have been observed.

Hydrography: There is immediate evidence of a roughly two layered vertical structure of water masses in the NEW. The upper layer is occupied by waters with a salinity below 33.0; surface temperatures range between freezing point and several degrees C later in summer. Thickness of this layer is 80 to 140 m. Vertical stability in the euphotic zone is determined by melt water from land runoff and sea ice. These two sources can be recognized in Fig. 3.3 where the lack of surface melt water in the lee of NØIB is also evident. Below the upper layer, temperatures rise and salinities increase, introducing a strong vertical density gradient. The waters filling the troughs are relatively warm (0 to 1°C) and salty (34.8 to 34.9). Occasionally temperatures show an intermediate maximum and decrease again towards the bottom (most stations in Belgica Trough, some in Norske Trough). The close neighbourhood of the Return Atlantic Waters (RAW) suggest that the trough waters are influenced by these, but trough waters in some respect show differences to the RAW. Various other water masses, still to be identified with respect to their origin, occur in the area. The general circulation seems to follow the suggested aniticyclonic circle in the northern NEW. The

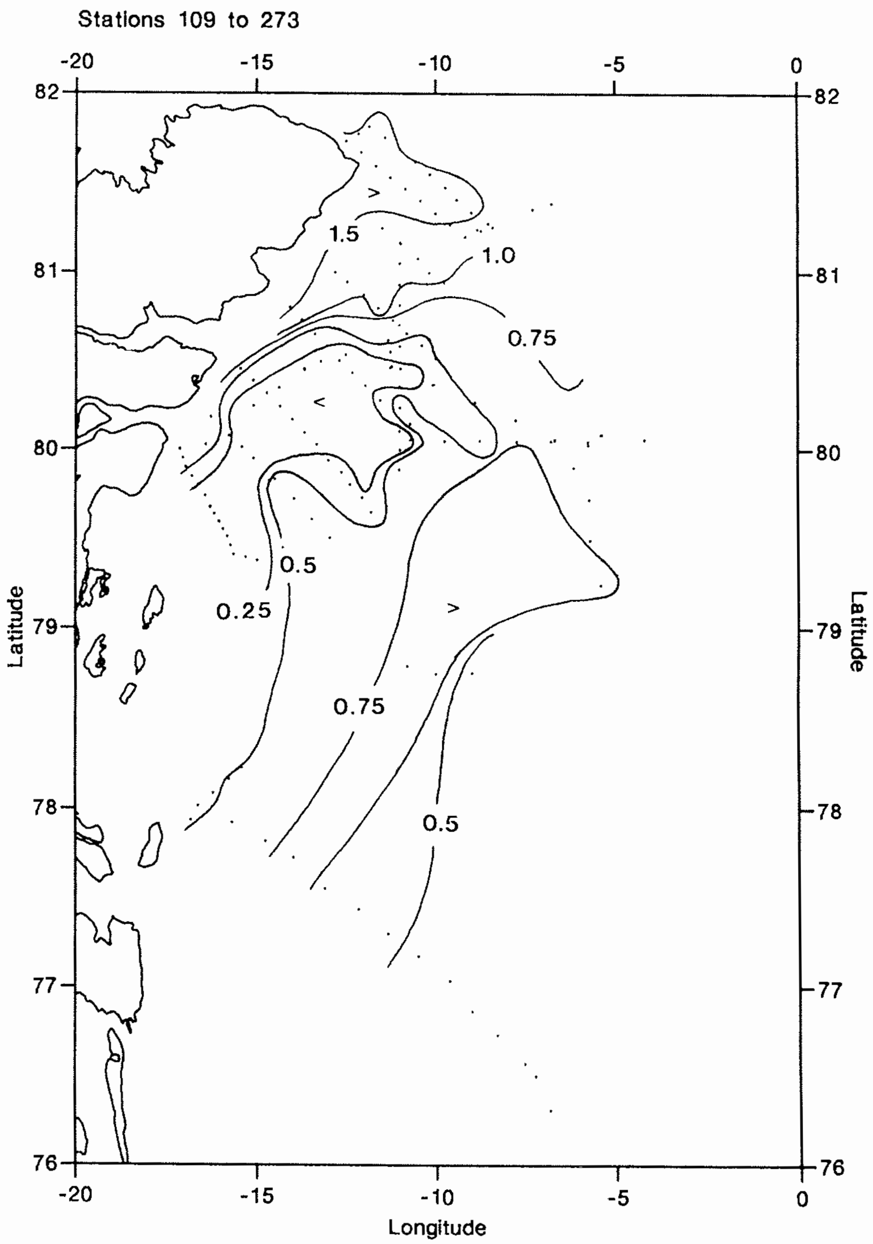

Fig. 3.3. Fresh water content of the upper 30 m of the water column, expressed as the height of pure water in metres. The water column is assumed to have S=32.5 before diluted by fresh water input.

northward coastal current is confirmed, speeds are estimated to above 10 cm/s. Tidal movements are of the same order.

Norske Øer Ice Barrier: NØIB is substantially smaller in 1993 than in the years before. Its eastern limit extended to about 13°W in 1991 and 1992, but only to 15°W in 1993. Thus interannual variability in size is considerable. There is a singular ice hill at 79°20'N 15°50'W that rises to about 120 feet above sea level and has a diameter of several kilometres. Ice temperatures there (point 1) suggest that the ice is grounded at this location. Sediments on the hill are indicative for an origination of this particular ice feature from a glacier.

3.2 Ice camps

P. Galbraith, C. Bélanger, K. Shirasawa

The goals were to determine the upper layer T-S and velocity profiles under the ice, away from the mixing effects of the ship and over complete tidal cycles. These data will be used along with under-ice turbulence data (Shirasawa, Aota and Takatsuka) and CTD/ADCP profiles taken from the ship (Budeus and Schneider) to provide an accurate picture of conditions influencing algae, nutrients and other biological variables. We will also look for the possible formation of a thin melt water layer on the underside of the ice.

Materials and methods

The physical variables were measured close to the sea water and ice interface by deploying moorings anchored to the sea ice during the period of the icecamps. Also, another small hole was drilled through the ice for CTD profiling.

An extra current meter and a T-S recorder were available for deployment because another of our project (ARGOS-tracked floe) failed to be realised during ARK IX/2. This increased our data acquisition during the first half of the cruise. Moored equipment were two Inter Ocean Systems S4 current meters, an Aanderaa vector-averaging RCM-7 current meter, an Aanderaa RCM-4 T-S recorder (no current meter sensors), two Aanderaa T-S sensors (conductivity / temperature sensors model 3211) and a 25-meter Aanderaa thermistor chain (the bottom-most sensor failed to function). The sampling depths and sampling intervals are shown in Table 3.2.

Table 3.2: Summary of mooring instruments and depths.

Depth (m)	Thermistors	T-S Recorders	Current Meters
0.5	T	T, S	
1.0		T, S,	U, V (RCM-7)
2.0		T, S (RCM-4)	
3.0	T	T, S, U, V (S4)	
5.0		T, S	
5.5	T		
8.0	T		
10.5	T		
13.0	T		
15.5	T		
18.0	T		
20.0		T, S, U, V (S4)	
20.5	T		
23.0	T		

Positions were usually logged at 5-minute interval using a Trimble Navigation Basic Plus GPS receiver.

Hydrographic profiles were done with a Guildline CTD model 8770 and a Sea-Bird CTD model Seacat SBE 19-03 used as a backup. Both of these were deployed using a battery-powered electric winch. Battery power was maintained using a battery charger and a generator. Some profiles were taken to the bottom during each ice camp, and profiles down to 50 m (ice camp 1) or 150 m (ice camps 2 and 3) were taken at 30-minute interval whenever possible. Additionally, the 50-150 m depth span was sampled for one hour at 10 minute intervals to check for high frequency internal waves in the pycnocline.

Stations (ARK IX/2): Three ice camps were done during ARK IX/2. While the first was shorter, two of the moorings were deployed a few hours earlier by helicopter when heavy equipment was transported to the site. The sampling time span of each instrument is shown in Table 3.3.

Table 3.3: Summary of mooring sampling times. Dates are as indicated in the first column unless otherwise noted.

Ice Camp	S4	RCM-7	RCM-4	T-C	T Chain
1 Start (30/05)	20:00 (29th)	04:40	04:00	03:38	19:35 (29th)
End (30/05)	14:15	13:45	13:45	14:35	13:25
Duration	16h15	09h05	09h45	10h57	17h55
2 Start (08/06)	14:30	15:35	15:05	14:45	14:00
End (09/06)	11:45	11:30	11:00	11:24	11:10
Duration	21h15	19h55	19h55	20h39	21h10
3 Start (16/06)	00:25	01:00	01:45	01:06	01:35
End (17/06)	08:25	08:15	08:05	07:37	07:45
Duration	32h00	31h15	30h20	30h31	30h10

CTD casts were done typically at every half-hour during ice camps, usually down to the pycnocline (except during ice camp 1, where they were only down to 50 m). They are meant to see possible high frequency variability, such as internal waves, or possible rare events such as fresh or salty intrusions. A one-hour series of casts taken between 50 and 150 m every 10 minutes may show any highest possible frequencies of isopycnal motions within the pycnocline. A few casts were taken 10 to 15 m away from the bottom (however, the seabird CTD used in ice camps 1 and 2 only has a 200 m pressure sensor such that only T-S are sampled below that depth). The numbers of CTD casts taken at each ice camp of ARK IX/2 are summerized in Table 3.4.

Table 3.4: Summary of the number of CTD casts during ice camps.

Ice Camp	0 to 60 m	0 to 150 m	0 to Bottom	50 to 150 m	Total
1	16	0	2	0	18
2	2	17	5	0	24
3	0	37	8	6	51

The GPS system was used to record positions for the longest periods possible. The time series of 11h22min, 22h18min and 33h during the three ice camps showed ice drift from the combined effects of mean circulation, tides, wind and inertial oscillations. Ice drift is also used to compute absolute current velocities under the ice.

Stations (ARK IX/3): The first-year ice had deteriorated by the beginning of ARK IX/3, severely limiting our ability to deploy all equipement for 25-hour sampling periods. It was therefore decided to deploy most moorings on a thicker and older drifting ice floe along with the sediment trap project described later (Bauerfeind and Galbraith). A strong easterly drift out of the polynya prevented the visit of the floe before recovery.

The T-S and thermistor moorings described in Table 3.1 were deployed July 6 and were recovered July 29. The RCM-7 current meter was also deployed during this period, but at a 20 m depth. The S4 current meters were only deployed during the initial occupation of the ice floe. A GPS positioning system was deployed, logging every 999 s, but its memory limited data acquisition to the first 8 days.

A few CTD casts were taken during the initial occupation of the floe, and one cast was taken at the recovery. This was due in part to equipment failure, but also because efforts were concentrated towards making a 1.2-m diameter hole in 2.65 m of ice to deploy the sediment trap.

Other projects included two fast-ice moorings with S4 current meters. The first was on the Ob Bank ice barrier at 81° 20.69' N 10° 59.64' W in 49 m of water, from July 21 14:45 to July 20 17:40. The two current meters were at 3.5 m and 27.5 m depth and a Seabird Seacat CTD was moored at 23 m. Unfortunately, the CTD battery pack failed after some hours. A second fast-ice mooring was deployed at 79° 28.95' N 16° 44.91' W with S4 current meters at 5.5 m and 25.5 m in depth. Mooring times are from July 23 11:40 to July 24 21:15.

CTD transects were done within the Ob Bank and Norske Øer ice barriers using natural melt holes. 10 CTD casts were done on the Ob Bank barrier, and only 5 were done on the Norske Øer barrier.

Preliminary results

The tides most probably represent the greatest source of variance of the currents. Ice camps 2 and 3 are sufficiently long to see some of these effects. Although the drift track shows clockwise rotation, the strong accelerations observed rule out inertial oscillations as a possible explanation. The period for successive oscillations is also uneven; if the motion is due to tides then the unsteady period must be explained.

The hourly-averaged structure of the currents below the ice have been calculated for ice camp 2. Results show strong shear, which could promote mixing, and an as-yet unexplained rotation of the currents with depth.

3.3 ARGOS-tracked ice floe

P. Galbraith, E. Bauerfeind, S. Pesant

The goals were to describe the near surface temperature and current beneath a drifting icefloe within the polynya during both legs 2 and 3 of cruise ARK IX. An attempt will be made to estimate the effects of internal stress on ice drift from measurements of wind at Eskimonæs and estimates of current stress on the underside of the ice floe from the current meter mooring.

Materials and methods

It was proposed to deploy an ARGOS-transmitting buoy on a floe along with a moored sediment trap (Bauerfeind and Haupt) and a mooring of an Aanderaa RCM-4 T-S recorder and of an RCM-7 current meter (both used in ice camps). Unfortunately, it has not been possible to conduct this experiment in ARK IX/2 because the ARGOS buoy was stolen just prior to the cruise, and a backup buoy failed to function. The experiment was conducted in ARK IX/3 from July 6 to July 29 on a drifting ice floe approximately 2.6 to 3.2 m thick. Other moorings were deployed on the ice floe as described earlier. The drift of ice camp 4 is shown in Fig. 3.4.

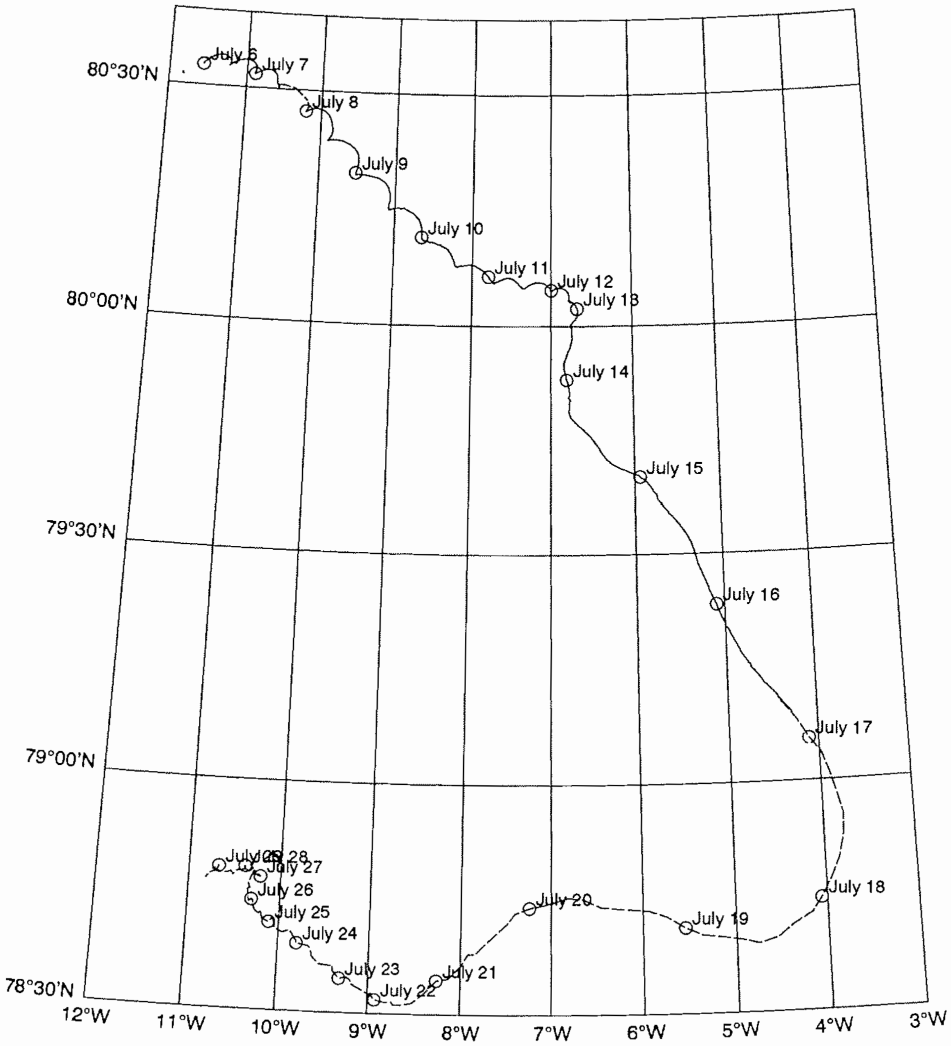

Fig. 3.4. Drift of ice camp 4 during ARK IX/3 from GPS (solid line) and ARGOS data (dashed line).

3.4 Comparative studies of atmospheric and oceanic boundary layers through sea ice layer and in the polynya

M. Aota, K. Shirasawa, T. Takatsuka, P. Galbraith

The goal was to determine the upper layer T-S profiles and 3-dimensional current velocities under sea ice. Turbulence parameters such as momentum, heat and salt fluxes will be measured in the upper layer.

Method

Turbulence data sets in the manners of (1) profiles in the upper layer and (2) time series for tidal periods are to provide an accurate picture of conditions influencing algae, nutrients and other biological variables near the ice-water interface, and also to look for the possible formation of a thin melt water layer on the underside of the ice. In addition, the momentum, heat and salt fluxes under the ice will be measured in various ice conditions to parameterize those fluxes by bulk momentum, heat and salt transfer coefficients.

Field Experiments: A four-days long time series record was obtained to investigate variations in momentum, heat and salt fluxes during the period from 21:45 on 16 to 19:30 on July 20. A summary of the experiment for this Project is given in Table 3.5 and an example of the time series of temperature, conductivity and currents is shown in Fig.3.5. Data analysis is to be done by computer in Japan after the cruises.

Table 3.5: Summary of under-ice boundary layer measurements during ARK IX/3

Ice camp No.	Latitude Longitude	Period Day/Mon	Start-End	Ice thickness cm	Depth m	Method
1	80 26.058N 13 37.496W	30/05	08:34- 13:40	56	0.10- 3.93	Profile; M, HSF
2	80 17.043N 13 38.965W	08/06	16:50- 20:28	55	0.15- 3.95	Profile; HSF
		08/06 09/06	20:45- 09:30	55	0.95	Time series; M, HSF
		09/06	00:07- 10:49	52	0.00- 3.47	Water temperature profile
3	80 34.761N 11 04.989W	16/06 17/06	04:00- 05:15	58	1	Time series; M, HSF
		17/06	05:30- 06:05	58	2.02- 4.02	Time series; M, HSF
		16/06 17/06	03:46- 06:21	58	0.00- 3.80	Water temperature profile
4	81 20.69 N 10 29.64 W	16/07 20/07	21:45- 19:30	173	0.50	Time series; M, HSF

Recording start : 16-Jul-93 21:45:00.
finish : 17-Jul-93 23:59:50.

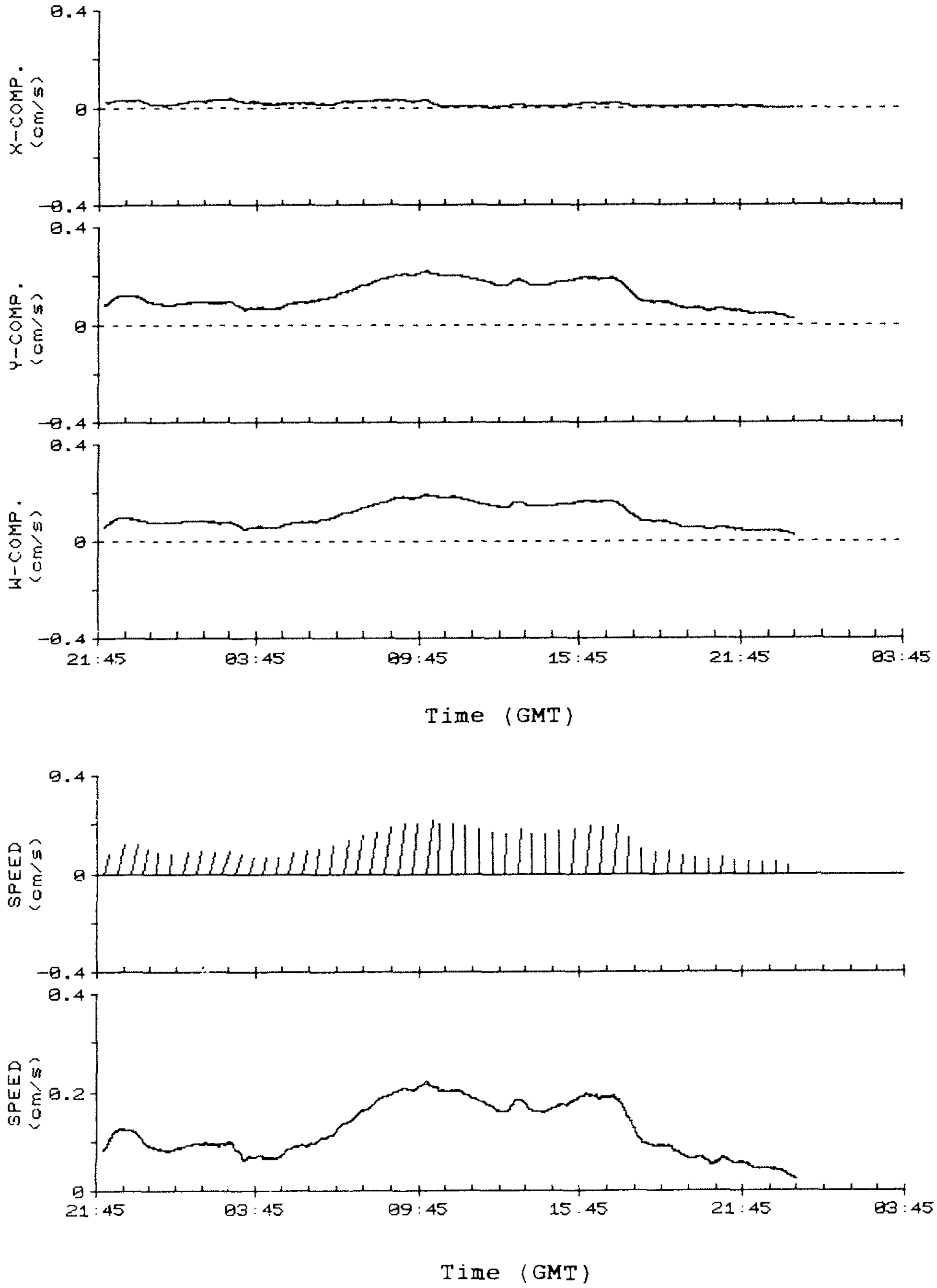

Fig.3.5: Example of the time series of current measurements from moorings during ice camps

3.5 Relationship between the crystallographic structure of sea ice and biological/chemical components of sea ice
M. Aota, T. Takatsuka, W. Schneider

The goals were
- to determine the crystallographical structure, brine volume and salinity distribution of the ice core samples and to compare them with the biological structures.
- to distinguish between sea ice and glacier ice by the crystallographical observation and salinity measurements.

Method

Ice cores collected at several stations are analysed to determine the ice strucure, the salinity and the brine ratio to the ice at each section of the 5-10 cm in length of the ice core. The biological variables in the ice core will be measured by the Canadian microplankton team. Ice cores were collected from the several stations. A part of analysis to determine the salinity of molten ice cores and the observation of the crystallographical structure has been done on the "Polarstern", but the accurate analyses for the ice structure and the brine ratio to the ice will be done in Japan.

3.6 Current meter moorings
C. Darnell

The transport of freshwater from the Arctic Ocean through Fram Strait represents a major contribution to the fresh water budget of the Greenland Sea. Because the stability of the water column in that sea area is determined to a large extent by the salinity of the sea water, the freshwater flux has the potential to control the convective overturning and in consequence deep water formation. As deep water formation is subject to significant interannual variability, it is planned to measure the freshwater transport through Fram Strait in a three years programme with moored instruments to investigate the relation between the two processes.

Work at sea: The freshwater flux occurs through ice and water transport. Therefore the moored arrays are equipped with current meters and conductivity, temperature and pressure recorders to measure the salt water transport and with upward looking sonars for the ice transport. Four arrays were recovered in the area between 79°N 6° 20'W 79°N 3°12'W and three were deployed.

4 REMOTE SENSING
R. O. Ramseier, A. Bochert, S. El Naggar, C. Garrity, S. Geiger, T. König, U. Lahmann

The main purpose of the remote sensing program was to support the NEW objectives by providing ice information to the participants as well as to investigate specific problems affecting a better understanding of remotely sensed data using a compatible family of sensors. The main objectives were:

- to support the NEW program with strategic ice information for planning purposes using passive satellite sensors,
- to support the NEW program with helicopter remote sensing flights by using the line scan camera and infrared line scanner,
- to provide ice information in support of RV "Polarstern" using AVHRR and SSM/I ice products and if needed line scan data.

Along with the main objectives there were a number of sub-objectives. They were:
- the study of the melt-puddle regime during the entire NEW period using all available remote sensing data,
- the study of ERS-1 synthetic aperture radar (SAR) and scatterometer signatures of the different ice types and characteristics by use of ice information gathered specifically with the line scanners, ship-board passive microwave radiometer, and measurements made by surface probes as well as visual observations, and
- the integration (fusion) of satellite data originating from active and passive sensors.

Methods

Special Sensor Microwave/Imager (SSM/I): The SSM/I sensor is part of an operational United States Defence Meteorological Satellite Program (DMSP). The first SSM/I became operational in July 1987. Currently there are two orbiting satellites providing day and night and all weather coverage of the cryogenic areas of the world at least four times daily. The data is received by the U.S. Navy's Fleet Numerical Oceanographic Office (FNOC) in Monterey, California, the Atmospheric Environment Service's (AES), and Canadian Meteorological Centre (CMC) in Dorval, Quebec, where the sensor counts are converted into brightness temperatures. The AES Research and Development Division, located in Stittsville, Ontario pulls the data via telephone lines from either FNOC or CMC and converts the brightness temperatures into ice products using suitable algorithms. A typical product of June 9, as received on the ship, is shown in Fig. 4.1. The figure shows total ice concentration values in percent for each grid point spaced 25x25 km2 apart. The actual field of view resembles an ellipse with dimensions of approximately 30x38 km^2 at a frequency of 37 GHz (0.81 cm wave length). The legend explains the meaning of the iso-contours.

In preparation for this experiment, collection of SSM/I data started on January 10, 1993 at two day intervals. The frequency was increased to once a day on March 24, 1993. Throughout the NEW experiment, SSM/I ice maps were provided to the RV "Polarstern" as long as the ship was within the INMARSAT receiving mask. Under favourable ship positions, such as the ship being on station and the antenna being unobstructed by the ships superstructure, ice maps were received as far north as 81°30'. The RV "Polarstern" received data either directly from the Ice Branch R&D office in Stittsville, Ontario or indirectly through the German Ice Service (Bundesamt für Seeschiffahrt und Hydrographie, BSH) in Hamburg where they were redrawn to a more simplified version for transmission by radio facsimile from Pinneberg. An example as received on the ship is shown in Fig. 4.2. Comparing Figs 4.1.and 4.2 shows that the maps, as far as the contours are concerned are identical.

NOAA-AVHRR: The NOAA satellite series is a series of weather satellites with orbital period of approximately 102 minutes, carrying an Advanced High Resolution

SENT BY:ENVIRONMENT CANADA/AES; 6- 9-93 ; 10:15 ; ICE F 6138313412 1120373;# 1

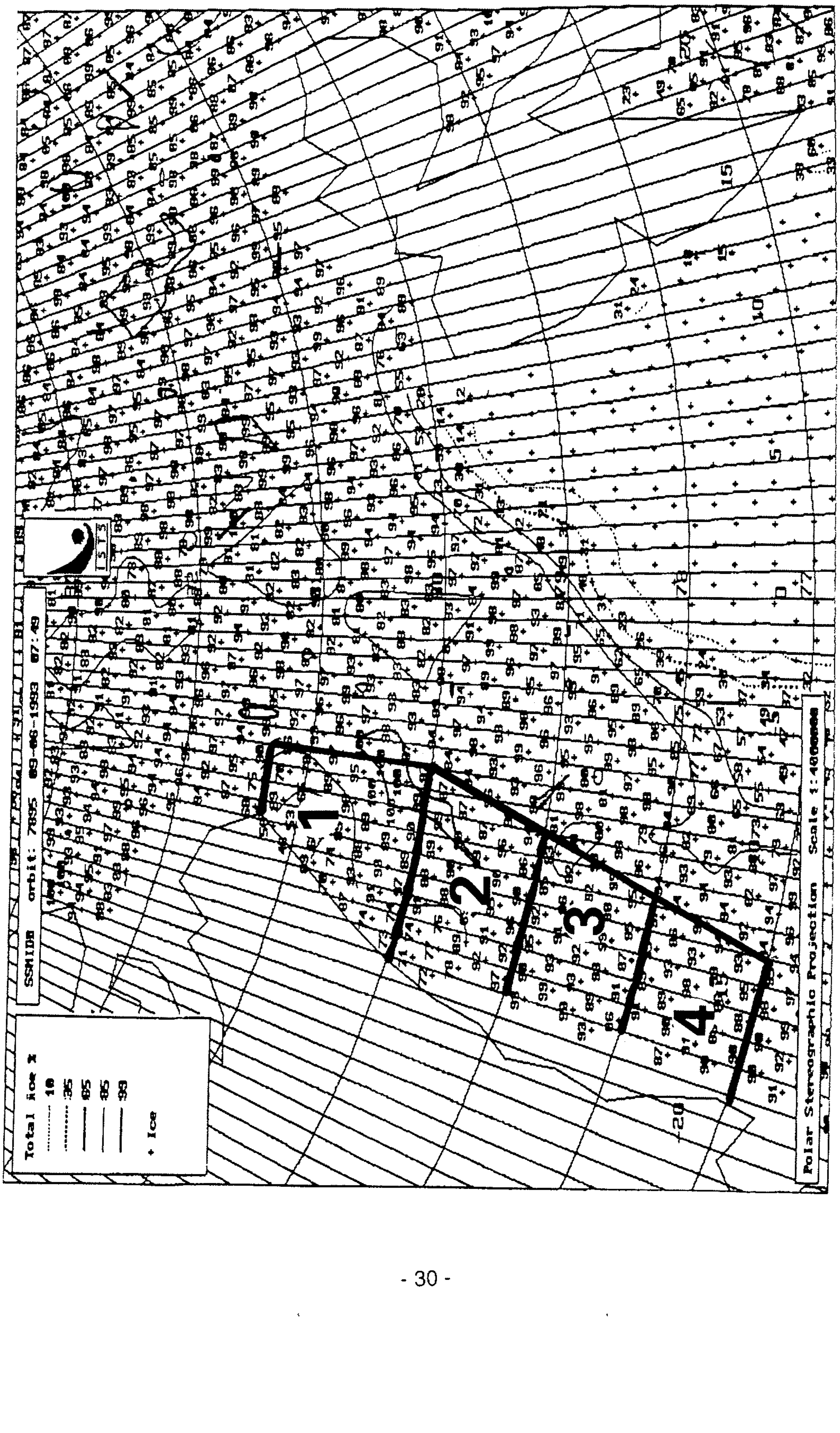

Fig. 4.1. SSM/I total ice concentration map using the AES algorithm. Map is as received by fax onboard the RV "Polarstern".

FEDERAL MARITIME AND HYDROGRAPHIC AGENCY
DDH3 DDK3 DDK6 9781
MARINE WEATHER SERVICE - HAMBURG

SPECIAL ICE CHARTS FOR POLARSTERN CRUISE ARK IX/3

TOTAL ICE CONCENTRATION CHART OF June 09, 1993
AES SSM/I data of orbit 7895, 07:49 UTC

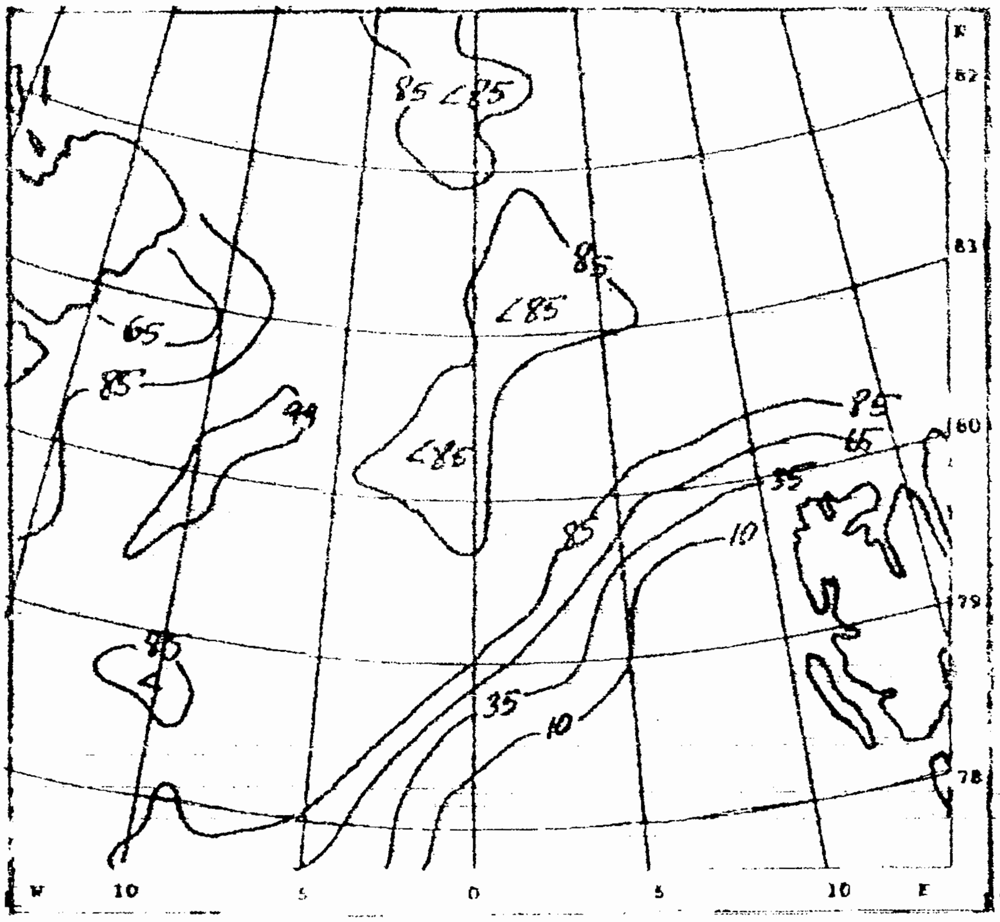

Fig. 4.2. Contoured ice map using the SSM/I total ice concentration map in Fig. 4.1. The simplicity of the map is better for sending to a ship using HF radio.

Radiometer (AVHRR), the TIROS Operational Vertical Sounder, the Data Collection Platform, different smaller instruments, SEM, SBUV, SAR; not all of these may be available on a single satellite.

The data are transmitted directly after collection in digital (HRPT) and analog (APT) form. The AVHRR is a 5 channel scanning instrument, covering a swath of 1500 km to both sides of the sub-satellite track (SST). Near SST, the geometric resolution is 1.1 km and the pixel spacing within one line is 800 m. The spectral ranges are: 580-700 nm, 700-1000 nm, 3.5-3.9 µm, 10.3-11.3 µm and 11.5-12.5 µm for channels 1-5, respectively. In near future, a 1.6 µm channel is to be added.

During the Polarstern cruises ARK IX/2 and IX/3, approximately 660 NOAA-HRPT overpasses were received and partly processed on board using the TERASCAN equipment and software. The data are dedicated to scientific application, as well as for providing basic information to aid setting up proper schedules and to find the most suitable way for the ship to travel through the ice. Each day, two or three overpasses were processed in near real time consisting of
- selection and extraction of the part of the raw data to be processed,
- establishing proper earth location transform by adjusting coastlines,
- calibration of all 5 AVHRR channels using the TERASCAN default schemes,
- correction of channels 1 and 2 for the sun illumination by dividing by the cosine of the sun zenith angle,
- computation of the difference of the sun corrected channel 1 and 2,
- computation of the difference of the blackbody-temperatures (BBTs) of channels 3 and 4 (T3.7 - T11), and 4 and 5 (T11 - T12) respectively,
- re-mapping of the products to three different kinds of maps: one Mercator map for the bridge, showing the region of navigational interest; one polar stereographic mapped overview, adjusted in size and region similar to the SSM/I ice concentration maps that were provided by fax, and one polar stereographic mapped closeup for the NEW polynya region,
- application of proper enhancement tables to the products,
- overlay of coastlines and latitude / longitude grid with spacingof 1° latitude and 5° longitude,
- overlay of ships position as a circle,
- overlay of ERS-1 SAR swaths
- printout of products
- writing raw and processed data to tape and maintaining files describing the tape contents
- saving some products to a special hard disk for further use in animation loop production. In addition, the data provided by the data collection system (DCS) was extracted and, if possible, the transmitter positions were calculated.

The following Mercator mapped products were provided to the bridge:
- channel 2, showing a "natural" view of the polynya region
- channel 1-2, showing, to some extent, the ice structure through transparent clouds
- BBT difference T3.7 - T11, showing snow, ice and water, dark, but fog and clouds (especially low and medium level) bright
- channel 4 (T11), showing high level clouds bright and giving some information on the ice/water temperature.

To have a natural view, one might use channel 1, sensitive in the green and red visible spectrum, or channel 2, which is a near infrared channel ranging from 700 to

1000 nm wavelength. Channel 1 is brighter over snow and ice, but Channel 2 was provided because it is less affected by atmospheric influences and, more important, shows more differences over different ice types.

The difference of channels 1 and 2 was known to show ice and snow structures through clouds as long as transparency permits, which works especially well over stratiform cloud layers. The radiation measured at 3.7 m wavelength is a composition of reflected sunlight and radiation emitted by the objects due to their temperature. At 11 m, there is no relevant solar radiation and thus only emitted radiation is detected. Therefore, the temperature difference T3.7 - T11 gets low over objects that are badly reflecting at 3.7 m and with nearly equal emissivity at 3.7 and 11 µm. Such objects are water, ice and snow. On the other hand, T3.7 -T11 gets high over objects that are good reflectors and therefore bad emitters at 3.7 m, but good emitters at 11 m wavelength. Over the ocean, this is only true for fog and clouds, especially those with water droplets in its top. This effect is the stronger, the higher the sun is illuminating the surface.

The procedures for image enhancement remained unchanged during both cruises in order to be able to directly compare the brightness of different images and to detect changes. For the operational processing scheme, a procedure was set-up which needed interaction at the first 2 steps, determination of processing region and coastline adjustment, as well as the printing step only. It needed approximately 1 hour between start of processing and the first copy of the products for the bridge and the science. The for archiving was very much dependent on the tape device and the tape driver software used and on the tape's degree of filling. Also, there was a high rate of repetitions of the to archive steps due to insufficient quality of the tape material used. This problem was solved for the second leg by the use of different tape material which was shipped to Tromsø.

At special dates, channel 4 was enhanced in order to show sea surface temperature patterns. Also, the Normalized Difference Vegetation Index (NDVI) was computed to show vegetation conditions over land as well as to answer the question, which darkening over fast ice was due to meltwater and which to rock. During the cruise, the satellites NOAA-9, -10, -11, and -12 were in operation. NOAA informed the users of the direct readout services that the AVHRR operation of NOAA-9 is to be discontinued on August 1, 1993. For inter-calibration purposes, a variety of overpasses of all satellites were received during the first leg (ARK IX/2). There are several sets of overpasses of all satellites that show parts of northern Greenland with less than 1/2 h time difference. During the second leg, mainly NOAA-11 and NOAA-9 were received. NOAA-11 is the only satellite carrying a nearly noise-free 3.7 m channel. Usable overpasses were available between approximately 7:00 and 15:30 UTC, whereas NOAA-9 gave reasonable coverage between 11:00 and 19:30 UTC. As many as 14 usable overpasses could be acquired per day. There were only few NOAA-10 overpasses taken because NOAA-10 lacks a 12 m channel, and it was observed that NOAA-12 had some problems with the scan motor causing inaccuracies in earth location. During the second leg, NOAA-9 overpasses covered the region of interest in a time distance of 40-60 minutes after and before two consecutive NOAA-11 overpasses, thus providing the best repetition rate.

A large number of high elevation overpasses was observed containing some or many unexpected missing lines before the satellite entered and after it left the region of interest. During the second leg an error in the antenna positioning software could be located. As no up-to-date source code was available, the error could not be fixed, but by changing configuration parameters, it was possible to reduce the number of missing lines considerably.

During the first leg and at the beginning and the end of the second leg, presentations of image animation sequences were held for all interested cruise participants. At the end of both legs, 9 and 12 images were selected and printed on a single sheet of paper showing the development of the polynya during the cruise. These images were provided to each member of the scientific crew.

Airborne Line Scanner systems: Two different line scanner systems were developed at the Alfred Wegener Institute for Polar and Marine Research to provide high-resolution digital images of flight paths. Both systems have already been flown on the "Polarheli" research helicopter, Messerschmidt Bölkow Blohm BO105 and the "Polar 2" research aircraft Dornier DO228. These line scanner systems are an improvement over the conventional airborne photogrammetry, with regard to the spectral properties as well as the availability of imaging data for computer processing. The major characteristics of an imaging remote sensing instrument are described in terms of spatial, spectral and radiometric resolution. Both line scanners provide images with a width of 512 pixels perpendicular to the flight track of the aircraft or helicopter and a length depending on the length of the flight. In practice the images are around 60,000 pixels long. The spatial resolution of the two dimensions of the images, perpendicular and along the flight track, are related to different features. Perpendicular to the flight track the resolution depends, beside the flight altitude, on the whole viewing angle of the line scanner, which is approximately 90° for both systems. Along the flight track the resolution is related to the rate at which the scan lines are recorded and the speed of the aircraft or helicopter. By choosing the flight altitude, speed and scan rate, the resolution can be determined. After data collection the values can be interpolated over the pixels of the digital image to represent any desired ground spacing.

Where the spatial resolution of both systems are the same, the spectral response is different. The Line Scan Camera (LSC) covers the visible range with an extension into the near infrared (400 nm to 1100 nm) of the electromagnetic spectrum to obtain reflectance information of the earth's surface. The Infrared Line Scanner (ILS) detects the thermal infrared radiation (8 µm to 12 µm) emitted from the surface, corresponding to its physical temperature. All pixels of the images are stored as byte values, that means, they are represented by a radiometric value between 0 and 255. For the ILS this results in a temperature resolution of 0.1 K in a 25 K range. The accuracy of the temperature measurement is ±1 K. The reflectance data from the LSC are uncalibrated. For satellite remote sensing the line scanner data are employed to update the ice algorithms during the melt season which use SSM/I data from several channels.

Data inventory: A complete overview of the data collected is available from the first author. It provides information on the data primarily received on the ship. One exception is the ERS-1 SAR data where we have indicated which frames we plan to order based on requirements for the validation of SAR imagery, coverage of the polynya area and its approach and departure legs by the ship. Inquiries concerning the data availability of individual SAR frames depicting an area of 100x100 km^2 should be directed to Dr. Ramseier, AES. Due to the extensive helicopter program the flight hours were recorded in order to keep track of the amount of fuel remaining. The DMSP-SSM/I data is available in form of ice maps showing total ice concentration as illustrated in Fig. 4.1. These maps are available on request from Dr. Ramseier, AES. The data was collected every day in Stittsville but sent to the ship only every other day. The NOAA-AVHRR data is available in form of images from Dr. König, DLR for the dates and times indicated in the Table.

During ARK IX/3 an additional LSC was used to detect melt-puddle size distribution. The pixel resolution was about 2x2 m^2 for an image width of 1000 m using a 56° optics. The LSC data provides limited coverage of some of the SAR frames as indicated in the table. Should there be any interest for portions of LSC imagery, requests should be directed to Mr. Bochert, and/or Dr. El Naggar, AWI. The ship-board passive microwave data as well as the surface measurements will be available in form of a data report from Dr. C. Garrity, Microwave Group-Ottawa River.

Preliminary results

Special Sensor Microwave/Imager: In order to obtain changes in total average ice concentrations, the area of interest, that is the total potential extent of the polynya, was sub-divided into four regions as shown in Fig. 4.3. Fig. 4.1 shows the four areas. Area 1, covering approximately 20000 km^2, shows the northern area of activity during this cruise. The southern area of activity is represented by Area 2 with approximately 19000 km^2 in extent. Permanent ice shelves of about 4000 km^2 are not included in the area calculations. Area 3 and 4 are located further south, but were not visited by the ship. Fig. 4.3 provides an overview of the average ice concentrations starting Feb 24, 1993 and ending June 17, 1993. The northern area was the most active one showing a low concentration of 75% at the beginning of this record. The average ice concentration for the entire period is 88% with a minimum of 75% and maximum of 96%. Area 2 had an average ice concentration of 93% with a minimum of 86% and a maximum of 97%. The standard deviation for Area 1 was 3.3% as compared to 2.2% for Area 2. Area 3 and 4 had the highest average ice concentration of 94% while the standard deviation of Area 4 was higher with 3% as compared to 1.9% for Area 3.

Of particular interest is to compare the development of the polynya for previous years as compared to this year. As mentioned in section 2.1 the SSM/I was launched in July 1987. There are only 11 days available for this month. The years 1988-1990 provide an average for the entire months of June and July. For the year 1991 only 10 days are available, while for 1992 no data is available at the present time. Table 4.1 gives the average ice concentrations as well as the standard deviations for all years and areas.

Table 4.1. Average ice concentrations of NEW Polynya 1987-1993

YEAR	PERIOD	AREA 1		AREA 2		AREA 3		AREA 4		TOTAL AREA	
		MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
1987	20 Jul - 31 Jul	49.9	8.0	51.2	3.6	78.2	8.2	57.5	12.0	59.2	5.3
1988	1 Jun - 31 Jul	75.3	7.0	82.6	8.2	90.4	5.9	91.8	6.1	85.3	5.5
1989	1 Jun - 31 Jul	65.2	6.9	80.7	8.5	88.1	5.3	84.2	5.9	79.6	5.6
1990	1 Jun - 31 Jul	40.2	14.7	72.9	7.5	86.0	7.4	69.3	14.9	67.1	10.5
1991	3 Jul - 30 Jul	34.2	8.2	45.2	6.5	63.0	8.3	46.0	8.4	46.7	6.7
1992	none										
1993	24 Feb - 17 Jun	87.8	3.3	92.8	2.1	93.7	1.8	93.7	3.0	92.0	1.6
1993	1 Jun - 30 Jul	55.3	21.8	80.5	8.2	85.6	6.3	87.2	5.1	77.4	9.1

Fig. 4.4 provides a graphical overview for all the years and areas. The trend in all four areas is the same. The year 1987 starts with a low concentration for Area 1 and 2 increasing significantly for 1988. However, one should keep in mind that the data record is small for 1987 and only for the end of July. By 1990 the ice concentration is again low in Area 1, while Area 2 the decrease is small. Again in 1991 there are only a few data points for the month of July showing a minimum. In 1993 the data set is large. Examining the data for June only the ice concentration average is about 84% which is higher than any of the previous years. Area 2 is significantly higher by about 10% as compared to previous years.

NOAA-AVHRR: The NOAA-AVHRR products were used by the bridge and the senior scientist for cruise planning, by the meteorologist to get knowledge of the fog extent and by the remote sensing group for flight planning. It gave a good general overview and reasonable ice information could be extracted for at least half of the region of interest nearly every day as in most cloudy conditions, the difference of channels 1 and 2 was still able to detect at least the differences between dark and bright surfaces below the clouds. Examples of the products provided quasi-operationally to the bridge and the scientists are shown in Figs 4.5a-c and 4.6 Fig. 4.5a shows channels 3.7 minus 11, thus the ice is difficult to locate due to the cloud cover. Fig. 4.5b shows the same area except for channel 2 only and the ERS-1 swaths are overlaid. The polynya area is evident, with thin cloud and/or fog appearing over the polynya. An SSM/I map covering the polynya area is shown in Fig. 4.5c for comparison to Fig. 4.5b. The SSM/I map indicates a lower ice concentration in the polynya area, whereas in the AVHRR map it appears to be open water. The resolution of the SSM/I sensor is coarse, thus there was some ice in the footprint. The AES SSM/I algorithm will include frazil ice and dark nilas in the total ice concentration. Fig. 4.6 is an AVHRR image 11 days later. It shows the ice clearly due to subtracting channel 2 from 1, even though there is low level cloud present using channel 2.

For the bridge, AVHRR was provided together with the SSM/I derived ice concentration maps and helped to avoid areas covered with heavy ice as far as possible. There was limited use for instantaneous navigational decisions, especially in the presence of fog and when the ship stopped in heavy ice. In the latter case, helicopters were used to find the optimum way.

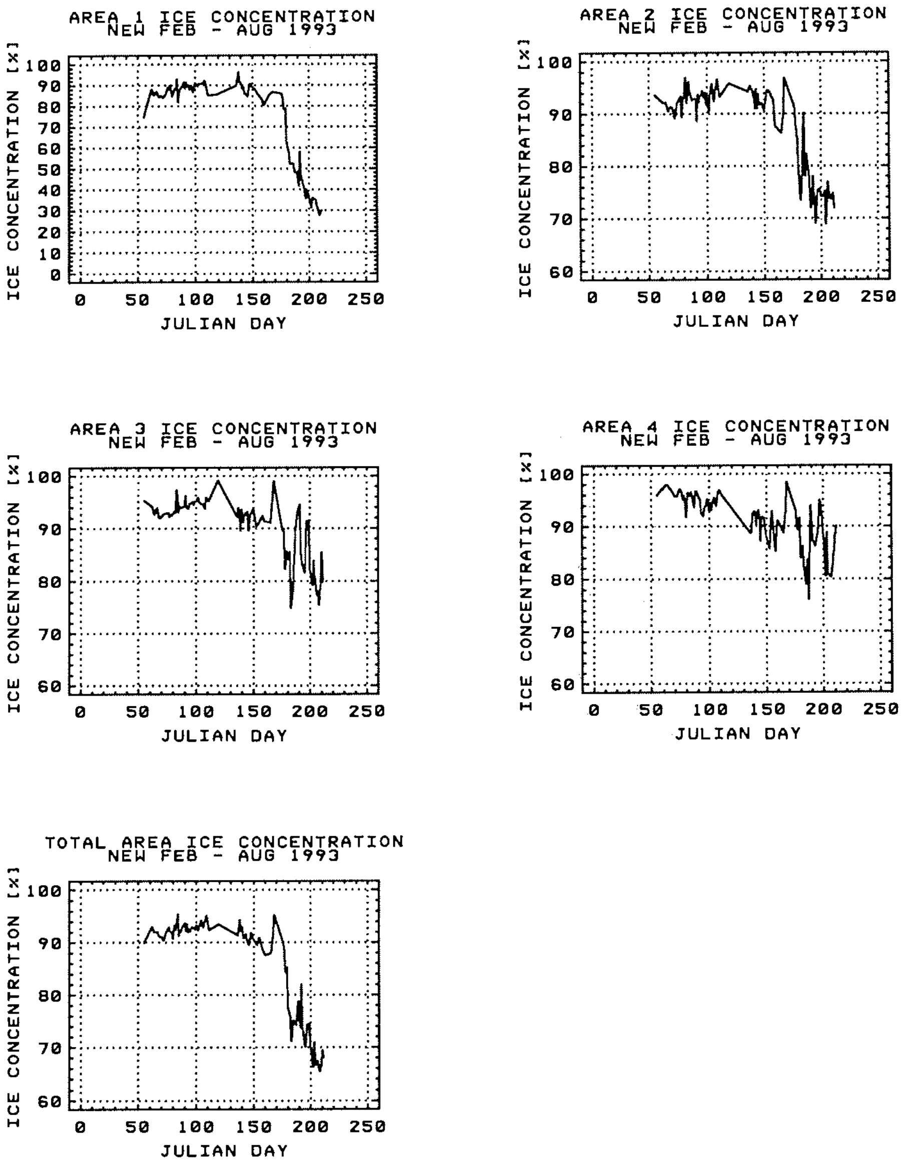

Fig. 4.3. Averaged total ice concentration as determined using the AES SSM/I algorithm for four areas as defined in Fig. 4.1. On the bottom left, an overall average for all four areas is shown.

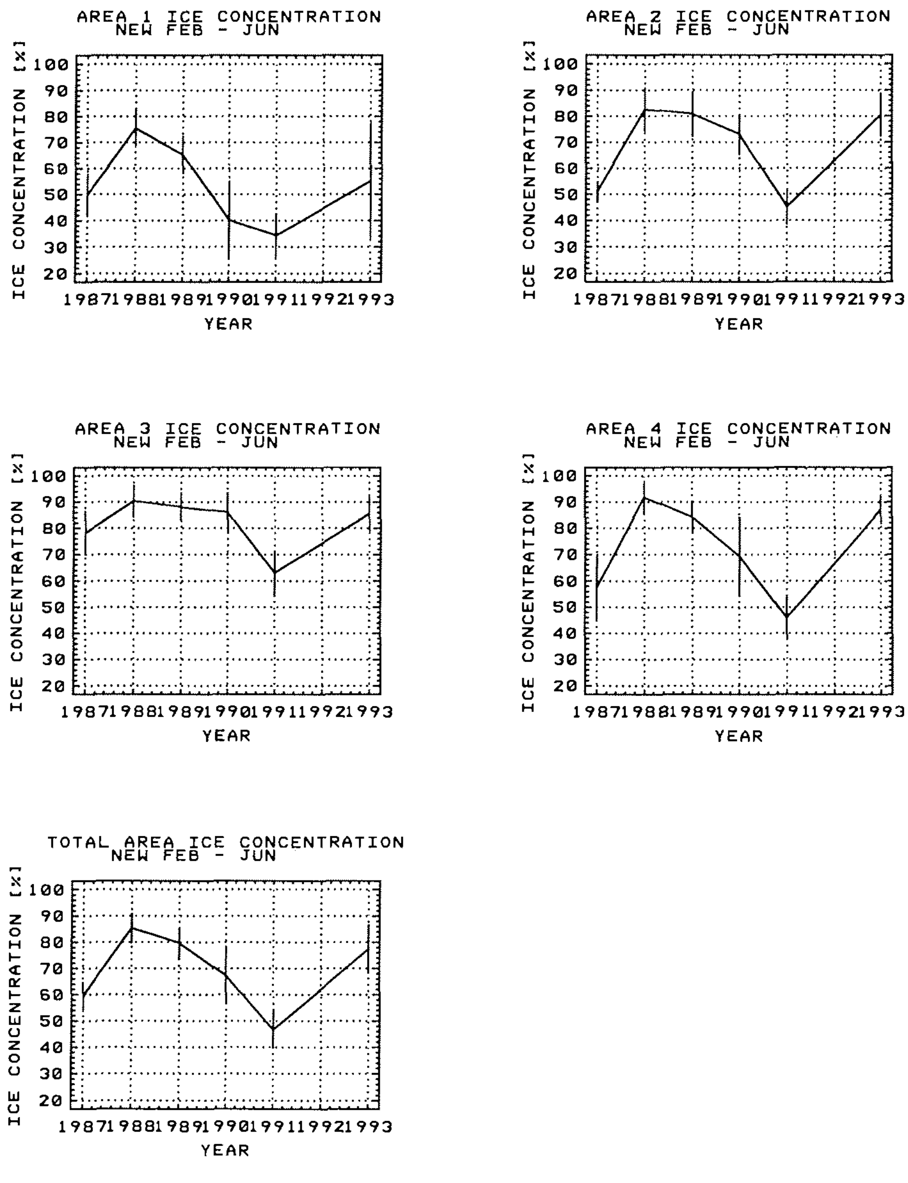

Fig. 4.4 An average total ice concentration from February 19 to June 19 for each area defined in Fig. 4.1. Comparing years 1987 to 1993, 1991 showed the lowest ice concentration.

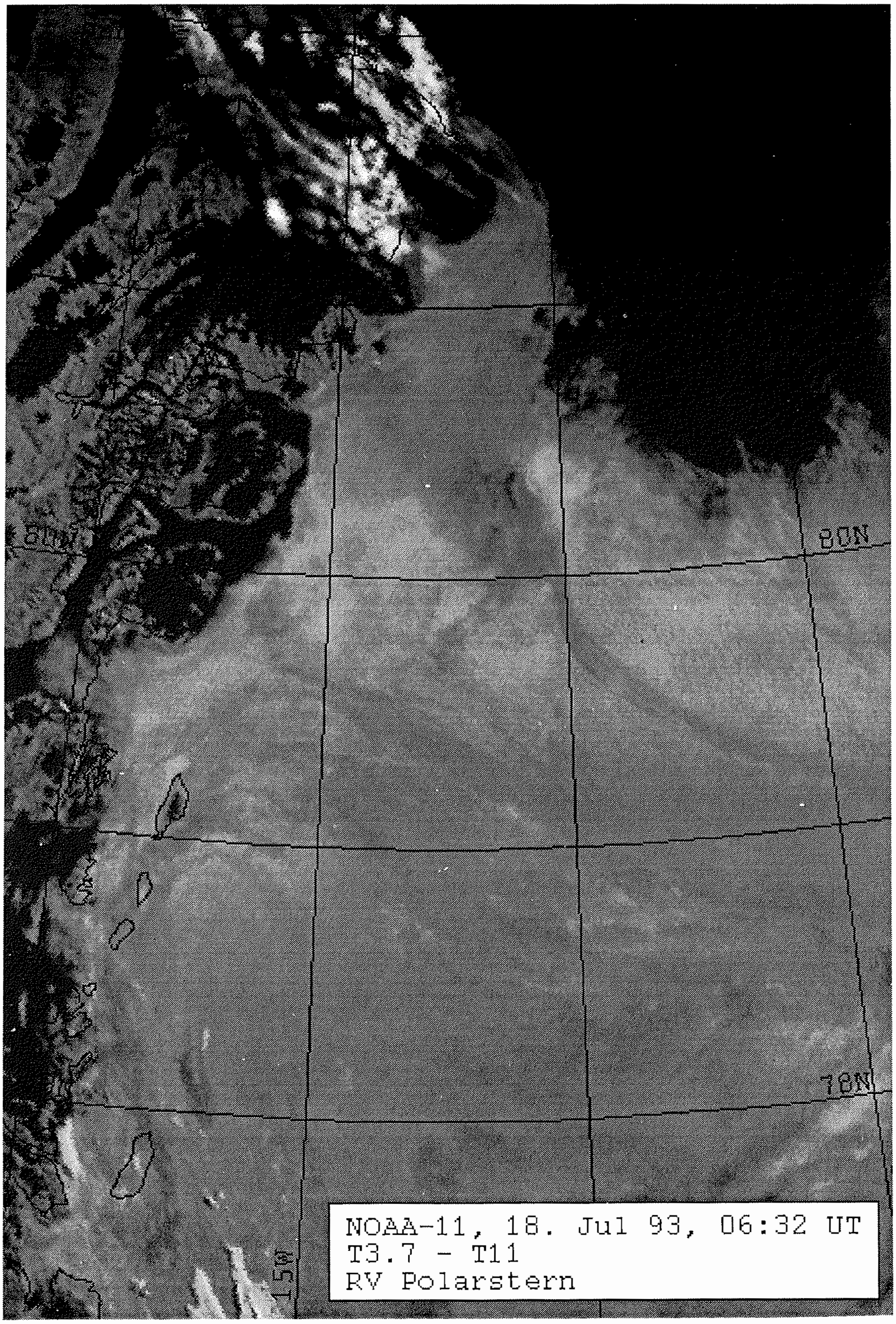

Fig. 4.5a. A AVHRR image using channels T3.7-T11 on July 18, 1993 at 06:32 UTC.

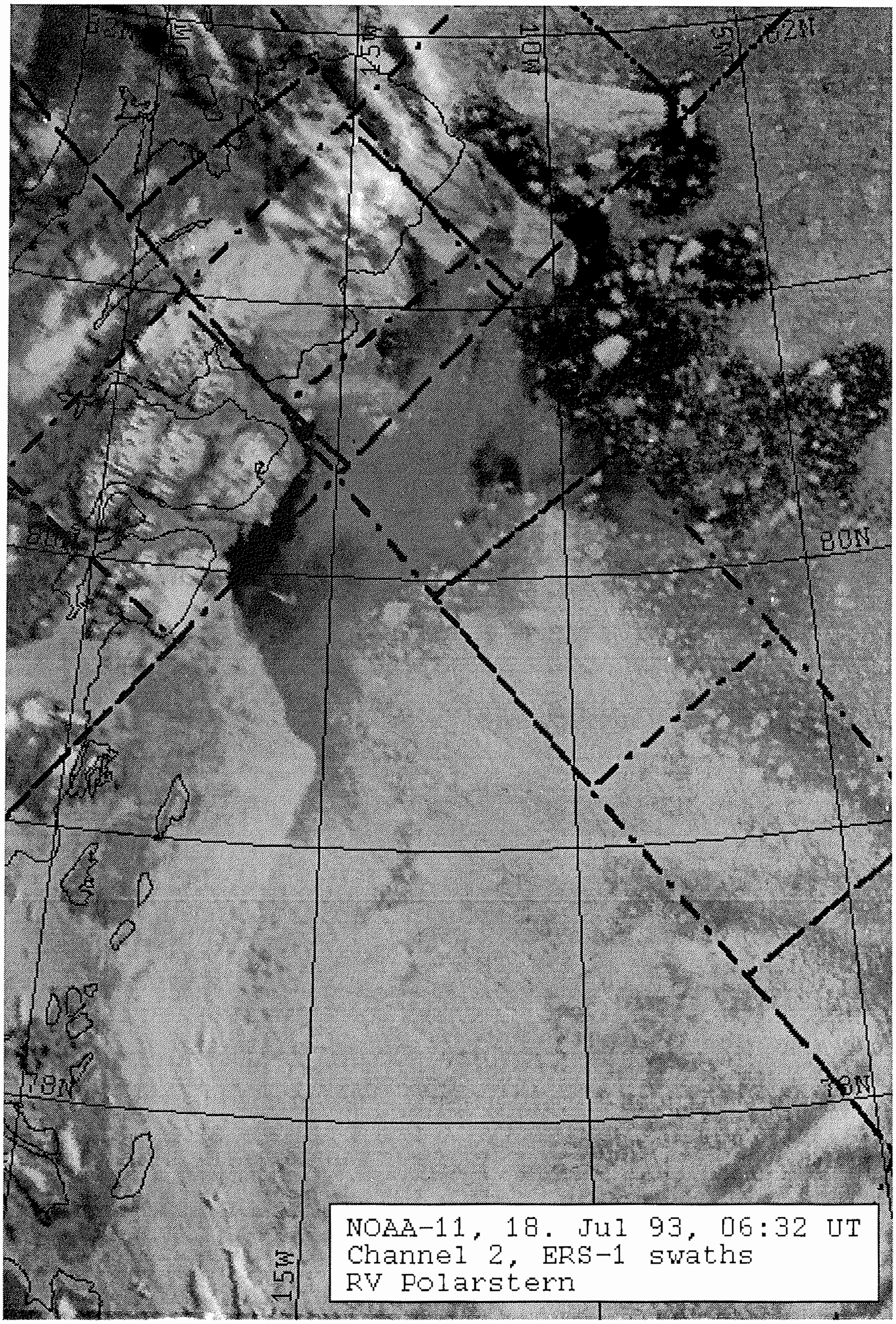

Fig. 4.5b. The same image area as in Fig. 4.5.a. except the image used channel 2. The ERS-1 SAR tracks for JULY 18, 1993 are overlaid.

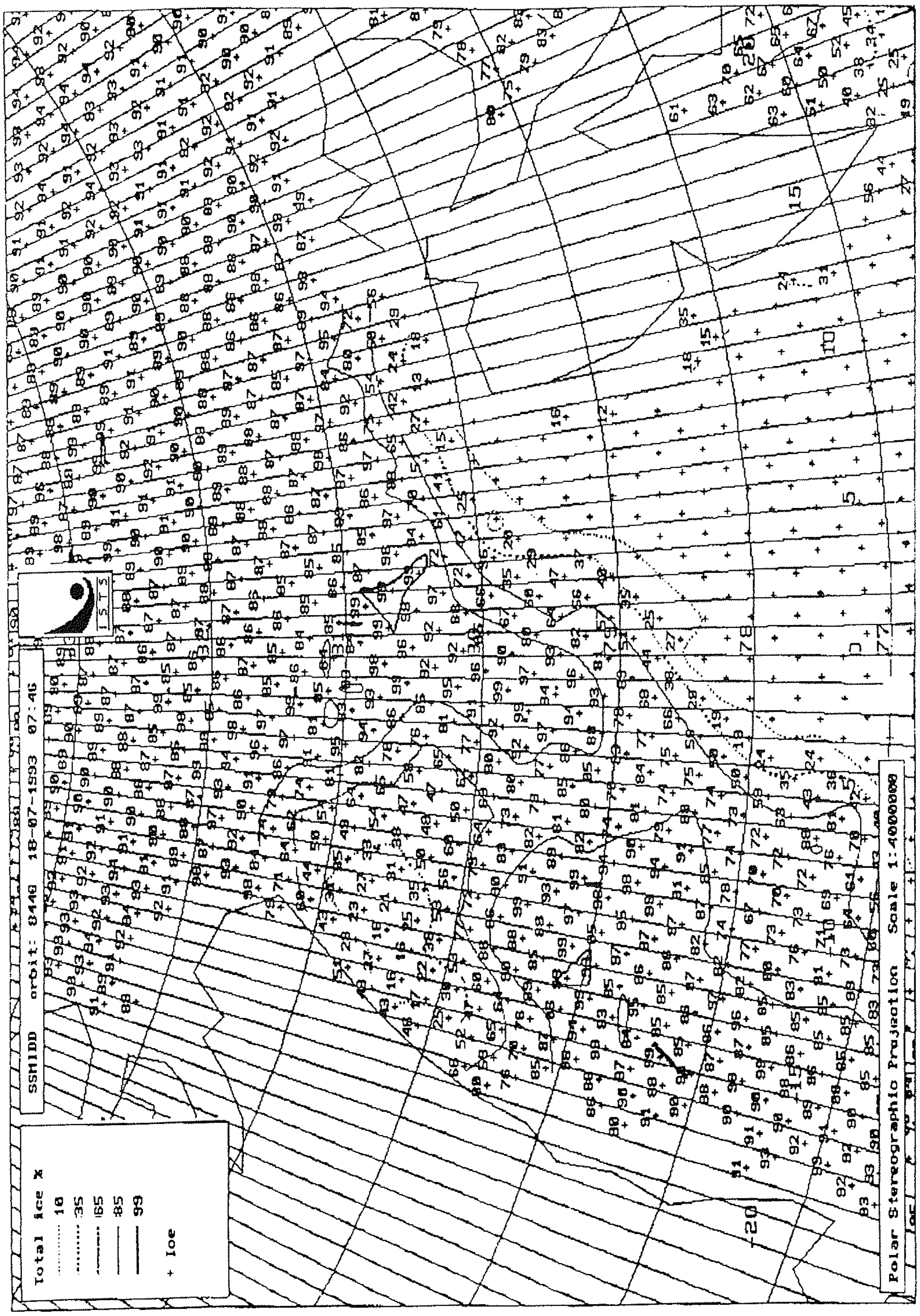

Fig. 4.5c. The total ice concentration in the polynya area is mapped using the AES SSM/I algorithm. The date is the same as in Figs 4.5a,b.

Fig. 4.6. An AVHRR image showing individual ice floes and the ice extent around the polynya. The clarity of the ice, even though there is a low level thin cloud cover, is a result of subtracting channel 1 minus 2.

The scientific community was informed about the opening of the whole NEW polynya as well as special events such as forming of two cracks in the southern ice tongue, the break off of the middle ice nose and, most spectacular, the break off of a huge piece of ice on June 29, 80 km in length and 18 km in width, from the northern edge of the northern ice nose. The inner polynya region was bound to the south by an ice tongue and to the north by an ice nose in the vicinity of the Ob bank. As compared to 1992, the southern fast ice edge was found up to 20 nm further to the south. A further feature is a small ice nose in the middle of the NEW polynya area connecting the shore with the Jan Kroyer islands. The northern ice nose extended more than 5 nm further to the east than in late May 1988.

During the whole cruise period, a clockwise rotating gyre over the Belgica bank with a diameter in the order of 100 km showed up in ice movements. At the start of the first cruise, the polynya was open between the northern and the middle ice nose and south of the middle ice nose. The latter closed during the time of our approach and the vicinity of the southern ice tongue opened instead. After reaching the temporary largest extent around May 29, the southern polynya closed again completely until May 31. Starting on June 5, the southern Polynya opened up again, increased steadily, joined the northern Polynya around June 22, which had closed to some extent until that date. Until June 29, a polynya formed north of the northern ice nose and a huge part of ice started to break off the northern edge of that nose, turned counterclockwise until it reached east-west direction (leaving an area of minor ice concentration and high east-west temperature gradient) and stayed with little movement until July 16, when the pack ice drifting in from the north started to force the big floe back to the ice nose pushing it to the south-east. The image sequence showed a strong water current shear to the east of the northern ice nose around July 3. Two pieces of ice that broke off together with the big floe came under the influence of a northerly and a southerly current respectively. Just at the east of the ice nose, the pieces got under pressure and the bigger one broke. Ice movement around the big floe is marked by two eddies, one turning counterclockwise at the south-west side and one rotating clockwise at the south-east side of the big floe. Also a number of smaller, fast rotating eddies is formed to the east of the northern ice nose.

Starting around June 28, a channel of less ice concentration was forming reaching from 80° 30' N, 13° W in south-east direction towards the ice edge. Within this channel, ice floes were moving in a fast and turbulent way. This channel was forming a wave pattern and was surrounded by eddies. The fate of single ice floes in that channel was quite random. Floes originally located next to each other were heading in totally different directions within 2 days. On July 30, some ice from the ice edge was transported more than 60 nm towards the north-west.

Another feature that was to be observed over the whole period was some oscillating ice movement to the south of the northern ice nose which might be due to tidal effects. Looking to consecutive overpasses, it was found that single floes moved at a speed of approximately 3 kn. The oscillation was observed mainly in the north-south direction, but occasionally also in the east-west direction. As the animation sequences consisted of approximately two overpasses per day, the movements observed seem to be somehow irregular and a detailed description will be due to further investigation with higher time resolution.

Small pieces of first year ice breaking off the southern ice tongue indicated a strong water current towards the north. The surface temperature shows a flame like pattern pointing towards the north. But in the vicinity of the shore, the ice movement had opposite direction and showed some counterclockwise rotational scheme. A first radiometric inter-comparison of the corresponding channels of the different NOAA-satellites showed considerable differences which need further investigation. Around June 21, the ice shows a considerable decrease in channel 2 brightness. As there were inconsistencies in calibration and no atmospheric correction was applied to the solar channels so far, no quantitative result can be given here.

ERS-1 data acquisition overview: As part of the Program for International Polar Oceans Research (PIPOR) ERS-1 SAR data acquisitions for the NEW area have been requested from the European Space Agency (ESA) by René O. Ramseier. An example of ERS-1 SAR coverage for June 10, 1993 is given in Fig. 4.7. Over a 35 day orbit cycle the area of interest is covered while each 35th day the coverage of the specific area is repeated.

Line Scanner flights: The line scanner flights during ARK IX/2 were carried out with both line scanners, the LSC and the ILS. Due to the weather condition it was possible to fly most of the days with an optimal flight altitude of 1.25 km. With a swath width of 2.5 km on the ground the spatial resolution is approximately 5 m. The SSM/I satellite data are available with a grid resolution of 25 km. To use the line scanner data to help up-date the AES sea ice algorithm, using SSM/I satellite data, will result in a big gap in regards to resolution and coverage by these two systems. With an optimal flight altitude the line scanner provides only 10% coverage of the SSM/I field of view. To close this gap, the ERS-1 SAR data provides a good transition. The SAR images have a spatial resolution of 12.5 m with a coverage of 100x100 km2.

During ARK IX/2 line scanner data were acquired on 14 helicopter flights. These flights provided partial SAR coverage of 19 SAR images. Together with the aircraft expedition REFLEX II the total becomes 29 SAR scenes. These flights were made at approximately the same time as the ERS-1 overpasses. Similarly, during ARK IX/3, 17 flights were carried out.

The data evaluation will begin with the interpretation of the line scanner data by creating detailed ice maps depicting several ice types. With this information understanding of the corresponding SAR images will be significantly improved and will enable the classification of the entire SAR image. Each SAR scene contains 16 SSM/I data points which can then be compared.

Evolution of a snow cover: A total of 116 snow pits were excavated, mainly on sea ice, for electrical and physical properties of different layers dictated by snow structure. The measurements made were grain size and shape, temperature, permittivity, density, salinity, total depth and thickness of each layer. Knowing the permittivity and density of a snow layer, the free water content was calculated using established empirical formulae. For a description of the measuring process and calculations the reader is referred to Garrity (1991).

The instruments used for remote sensing of sea ice during this experiment operated at short wavelengths making the upper ice and snow layer important when

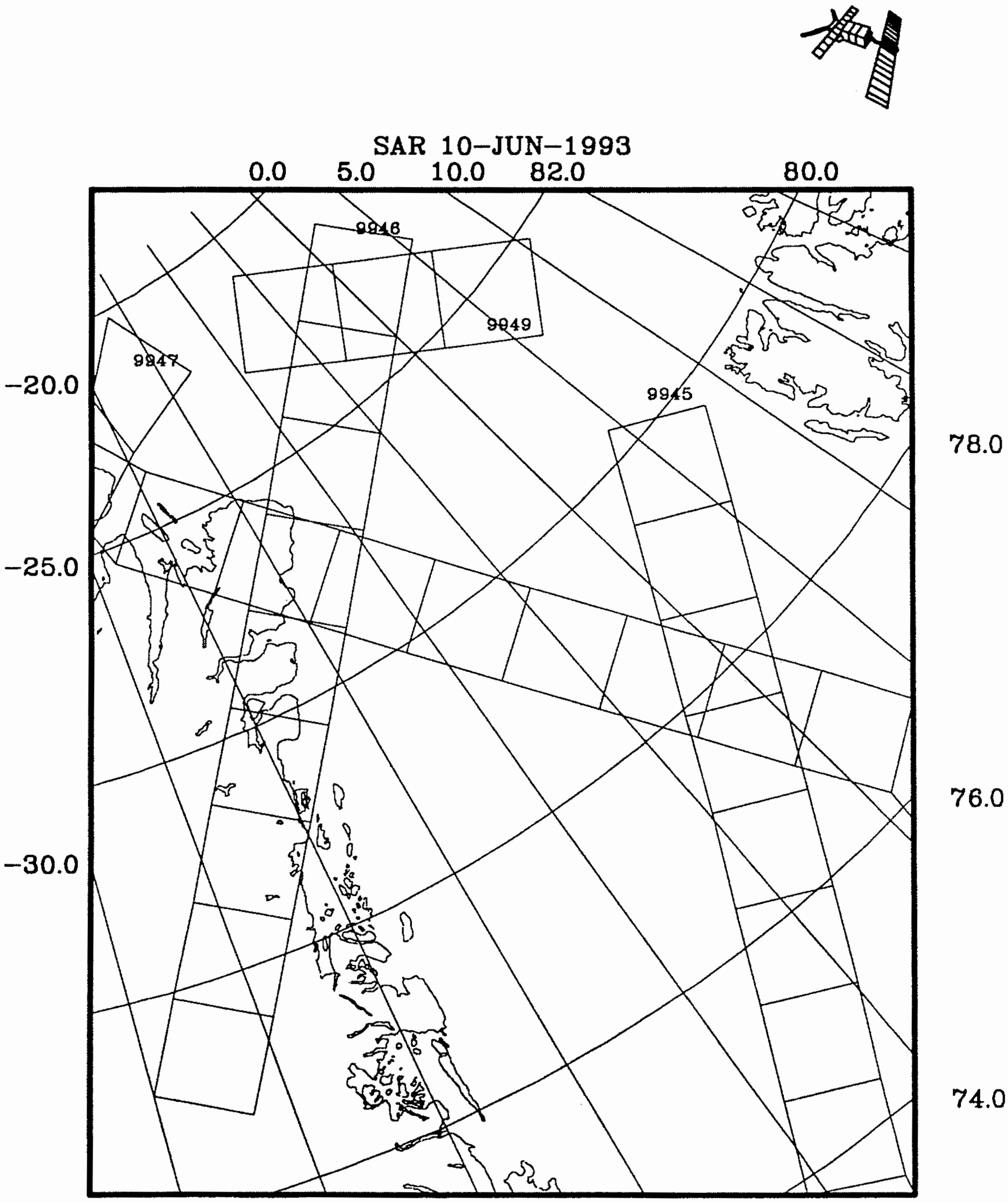

Fig. 4.7 An ERS-1 SAR over flights for June 10, 1993. Each box indicates a 100 x 100 km radar image.

interpreting the data. It is for this reason that the evolution of a snow cover during the melt-season is of interest to remote sensing of sea ice. The snow cover is also important for other disciplines due to the insulating properties and opaqueness of the snow. This section describes the evolution of the snow cover during the melt season for the Northeast Water Polynya experiment.

The first snow measurements were made on May 24. The snow cover was hard with a surface crust which had formed from previously high winds. Further in from the ice edge, on May 25, the snow cover had a new snow layer, followed by hard older snow. The beginning of depth hoar formation was the first visible sign of snow metamorphism due to increasing solar radiation. Depth hoar will form when there is a temperature gradient between the underside of a grain and the one just below it (Colbeck, 1973). The depth hoar was present on first year ice, and not on old ice (ice that has survived at least one summer's melt). It has been documented that the snow cover on old ice is often behind in the metamorphism process as compared to snow on first year ice due to the thicker snow cover on the older ice (Garrity, 1992). Evidence of an ice lens forming occurred on June 2 indicating the initial melt stages (Garrity, 1992). Due to moisture around the depth hoar crystals, they were freezing onto the dry first year ice surface. The lowered freezing point due to the presence of salt at the ice surface made this possible.

Any free water in a snow cover can migrate through less dense snow layers until stopped by a barrier, such as ice. On June 4 the snow cover had become harder compared to the previous days. It was evident by June 7 what was happening in the snow cover by an accumulation of water which turned into slush at the snow/ice interface on first year ice floes. The free water percolated through the snow cover, most likely by gravitational forces, until it hit the ice barrier. The slush layer was significant, reaching a thickness of 13 cm. The slush and accumulation of water in depressions on the ice surface marked the beginning of melt-puddle formation. The relatively thin snow cover found on first year ice combined with the dark ice surface caused melt-puddles to form at a quicker rate than for old ice. On June 7 there was no slush measured on old ice, but rather a continuation of the hard old snow with a centimetre layer of new snow common to first year ice on June 4. Old ice had a new snow layer, followed by layers of alternating old hard snow and loose "sugar" snow, and finally depth hoar at the snow/ice interface. The layering in a snow cover of this sort may be an indication of wether the ice is old or first year, however this statement is speculative.

On June 20, the snow free water content was distributed mainly to the middle of the snow depth profile. The porous sugar snow with mainly rounded grains was an excellent medium for the water to percolate downwards until being obstructed by a hard snow layer. The snow temperatures were just below zero. The impurities in the snow cover (including salts measured from 0 to 1.5 ppt) and absorption of 24 hours of solar radiation caused melting to occur.

During the beginning of cruise ARK IX/3 the upper snow cover was wet with rounded snow grains. This highly metamorphosed snow cover observed on June 29 is often called "corn" snow by alpine skiers. On July 4, prominent ice lenses were observed which indicated the beginning of significant melt where free water was able to percolate down through the snow cover and was stopped by a less permeable layer, thus collecting and refreezing due to the lower snow temperature towards the middle of the snow cover. Referring to Fig. 4.8 there is an increase in the average free water content for the snow covers measured near July 4, julian day 185. There is also a decrease in snow depth starting after day 185 (Fig. 4.9) as the snow melt water is transformed into a dense ice layer. The formation of ice lenses, as is for slush, are extremely important to remote sensing data from sensors such as the SSM/I. For example, a snow cover which has an ice lens present can reduce the microwave emission received in the horizontal channel as compared to emission from a homogeneous snow cover (Garrity, 1992). After the formation of ice lenses another dramatic change occurred in the snow cover. On July 22, a thin layer of slush, averaging 0.5 cm for a 3 cm total snow depth, formed at the snow/ice interface. The slush was not saline and was formed from snow melt. The presence of slush remained on most ice floes but became more variable in distribution. On July 5 there was slush observed on old ice, however the higher areas, called hummocks, were free of slush and the snow cover resembled new snow on top of fresh ice. This indicated that most of the snow melt occurred within the snow cover.

The snow cover on first year ice turned into a slush layer which had a surface crust of irregular snow grains frozen together. The slush was 4-6 cm thick. Just within a couple of days, the snow cover became drier similar to the beginning of cruise ARK IX/2. The free water in the snow found a way to the melt-puddles through drainage channels formed on the ice surface. The remaining ice floe was composed of melt-puddles and 3 cm clumps of snow grains attached to each other on the dry areas. The thicker snow on old ice was delayed in this drying stage and often had "corn" snow over slush.

On July 28 the shape of the snow grains were vertical and 2-3 cm long resembling candles. This medium was excellent for the final stages of drainage of water from the snow cover. Due to all the melt, the snow depth decreased significantly as compared to the situation in May (Fig. 4.9). The last ice floes visited were on July 31 where the candles were broken in appearance and irregular in shape. The formation of snow-ice started. Snow ice is ice formed on top of sea ice due to refreezing of snow grains, becoming an integral part of the ice cover. During this experiment, the snow cover progressed from "spring-like" characteristics to "summer-like" (Garrity, 1992). This should have a significant effect on remote sensing data from the SSM/I and ERS-1 SAR sensors, and also on the AVHRR images.

Evolution of melt-puddles: Melt-puddle concentration as a percentage of melt water covering the ice surface was visually estimated from helicopter flights. The Line Scan Camera measurements will give a reliable concentration and it will be interesting to compare these results with those from the visual. On May 29, melt-puddles started to form on thin first year (FY) ice and was observed as dark patches on the ice surface due to the presence of slush. By June 1, the slush was evident on medium and thick FY ice. On June 13 elongated melt-puddles covered about 3% of FY ice surfaces. Unfortunately, there were observations missing from June 13 to July 4 due to a crew and scientist change in Tromsø, Norway and bad flying weather. On July 4, there was a 40% and 5% melt-puddle concentration on FY and old ice (OI), respectively. The melt-puddle concentration varied significantly from 10%-80% on FY ice, with the highest value for thin FY ice, and 40% on OI. Old ice often had melt-pools, that is areas of melt on the ice surface covering a significant surface area of around 5%. There were drainage channels, in the shape of

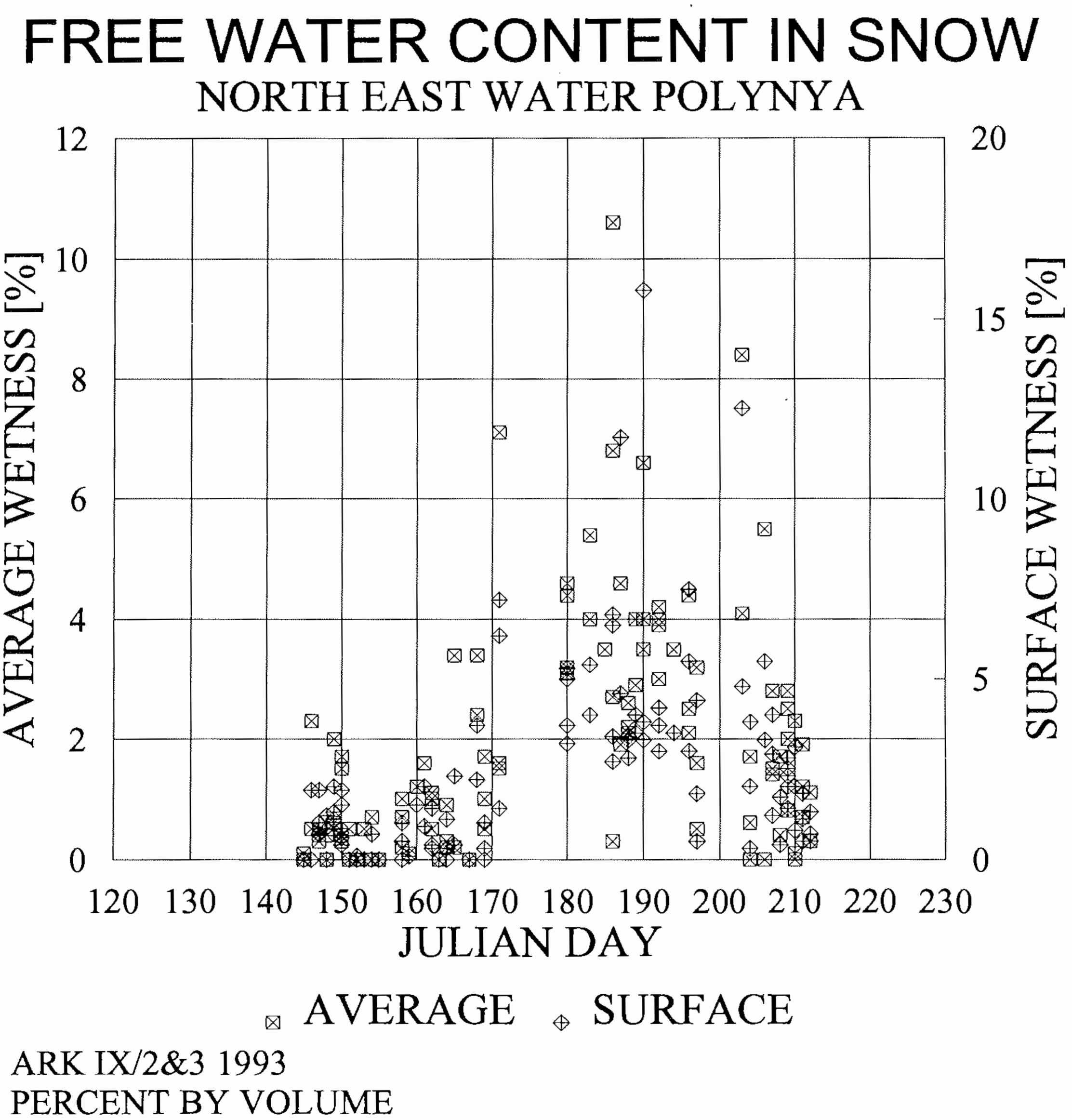

Fig. 4.8. The average free water content measured as a percent by volume in the snow cover and on the surface.

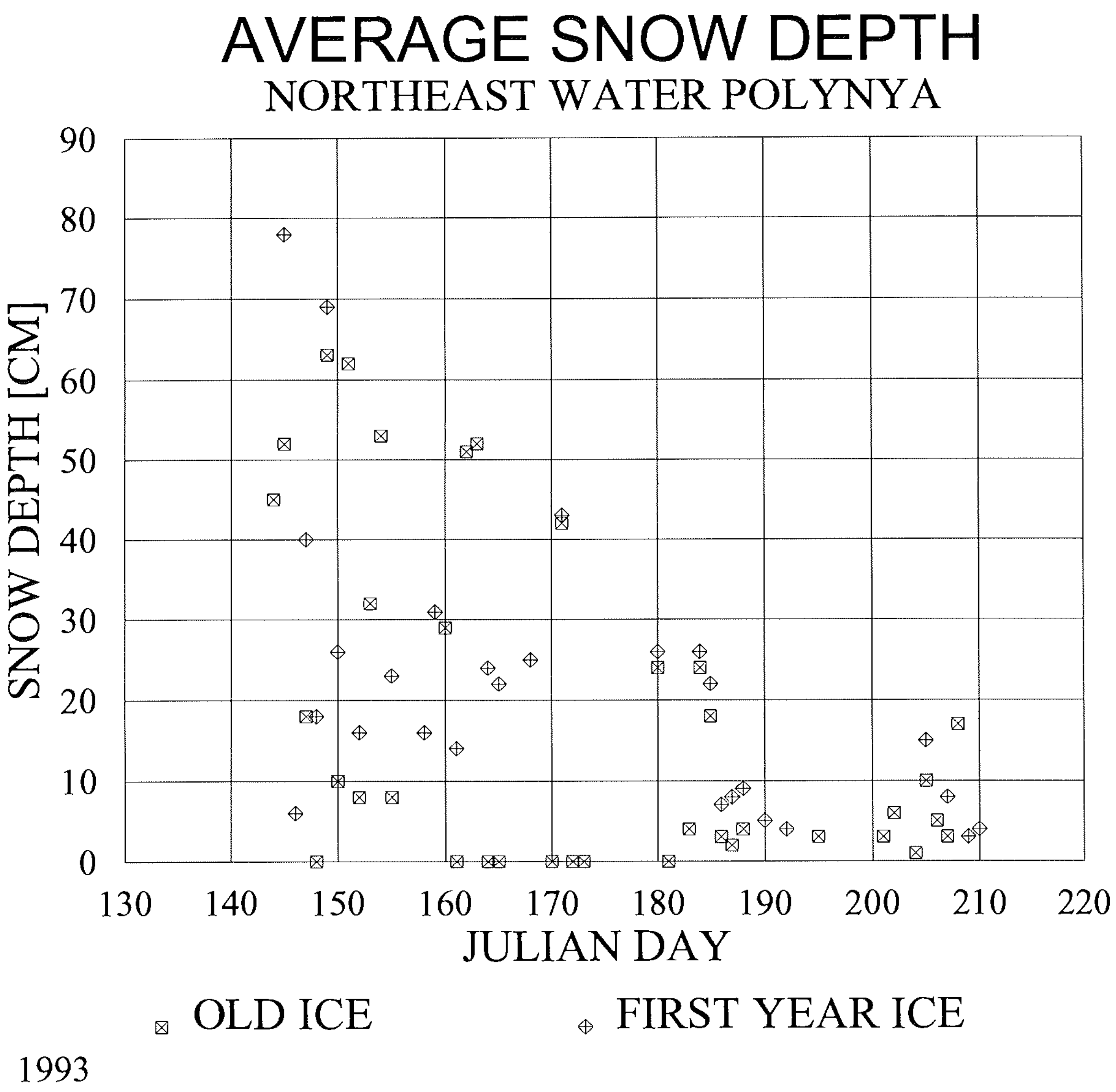

Fig. 4.9. Average snow depth measured on sea ice during ARK IX/2 and 3.

tadpoles, extending to the edge of OI floes. The melt-puddles were often blue in colour for multi-year ice and green for second year ice.

The grey to black melt-puddles on FY ranged from 60-80% on July 11. The black puddles were often thaw-holes. There was a slight increase in melt-puddle concentration on OI, ranging from 40%-50%. By July 15, it was evident that the melt-puddle concentration on FY ice was decreasing. The thin FY ice types were depleted and the melt-puddles on medium and thick FY ice ranged from 10-50%. The elongated melt-puddle shape was transforming into more of an irregular shape by July 18. The rounded shapes, common for the melt-puddles on OI, were transforming to irregular shapes by July 22 and decreasing in size. The irregular shapes were inter-connected by drainage channels. Freezing of the melt-puddles started on July 29. The freezing started from the rim of the melt-puddle. On OI the drainage from melt-puddles was significant. This became evident when visiting an ice floe with melt-puddles, once on July 7 and again on July 29. The melt-puddle decreased in size by 5 m in length, 8 m in width and on average 15 cm in depth (Cartens, this volume). On July 7 the melt-puddle covered the total depression on the OI with a hummocks surrounding it and by July 29 the melt-puddle edge was about 10 m from the surrounding hummock. This resulted in a flat area where the melt water used to cover. The ice surface appeared as porous ice somewhat resembling snow ice.

Figs 4.10a and b show the melt-puddle concentrations for FY and OI types from May to July. There are similar oscillations in melt-puddle concentration observed for thin, medium and thick FY ice, and these cycles are not synchronized. The cycles represent periods of melt accumulation followed by drainage of the melt to another depression on the ice surface using the drainage channel system. The percent of drainage channels was not estimated. The melt-puddle concentration maximum was high for thin FY ice (93%) whereas for OI, medium and thick FY ice the maximum was 45%. The evolution of the melt-puddle was observed from the initial stages to the final stages when the melt-puddles were completely frozen over on July 29.

Ship-based radiometric measurements: A 37 GHz dual polarized radiometer was mounted on the port side of the ship, about 17 m above the ice and water surface. The radiometer continuously measured the natural microwave emission at 37 GHz in units of Kelvin (brightness temperature), from snow, ice and water. A latitude and longitude was tagged to each brightness temperature measurement automatically by the PC-GPS system. Since different ice types will emit differing amounts of microwave energy mainly governed by the salinity of the ice, ice fractions can be determined from brightness temperature (TB). Every day, a "typical" TB for each ice type the ship crossed was recorded as a "tie" point to be used to calculate ice fractions. It is important to have a tie point during the spring and summer due to the evolution of the snow cover, thus a varying TB. If the snow cover has a free water content near 3%, first year ice will be radiometrically the same as old ice (Garrity, 1991).

Fig. 4.11 shows an example of the ship's track for June 29 and Fig. 4.12 the corresponding frequency plot of the horizontal and vertical TB. The low TB's, that is the first peak in the frequency plot, indicates the presence of open water. The low frequency values following the first peak indicates old ice and the second frequency

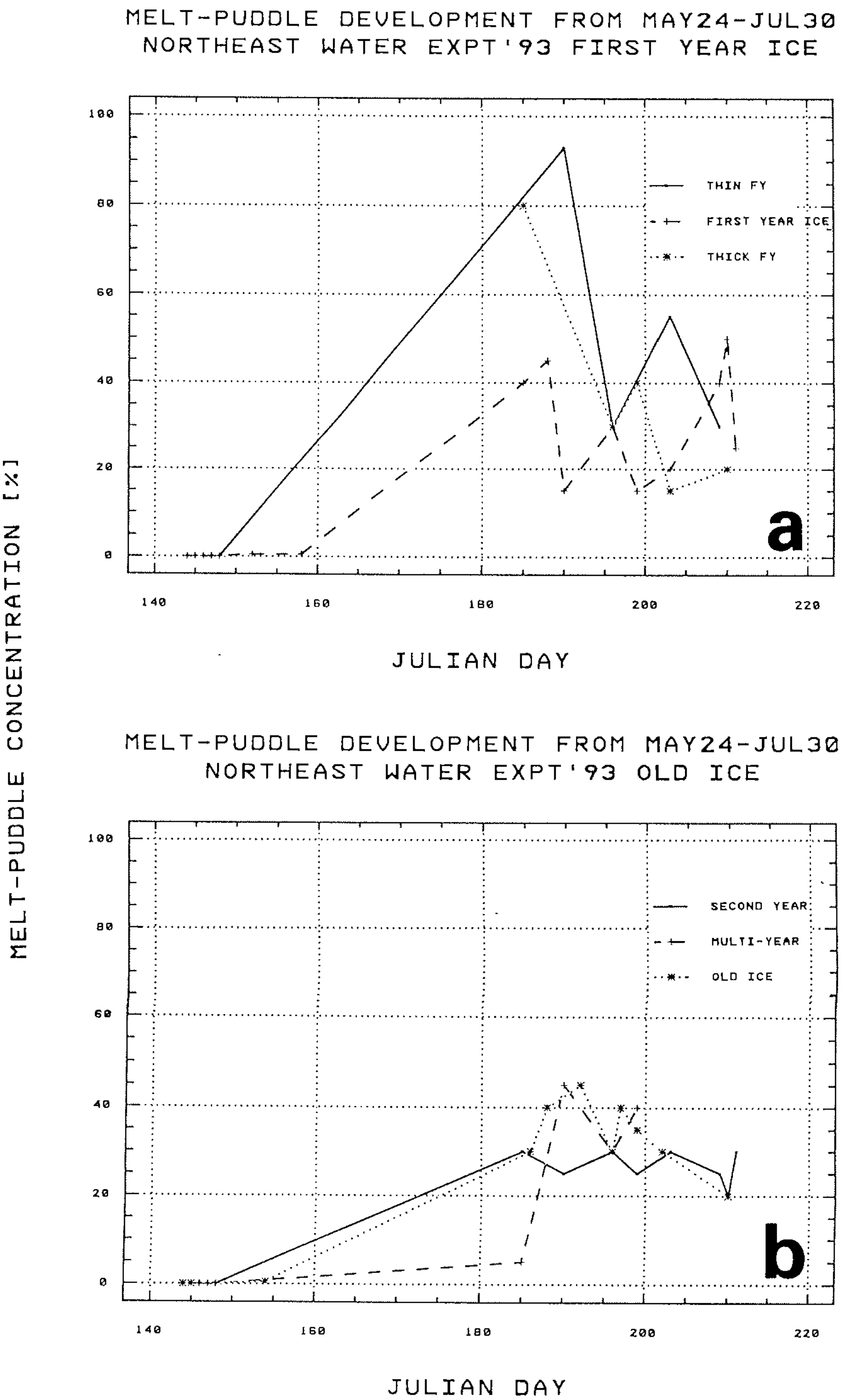

Fig. 4.10a. Melt-puddle development on first year ice types from May 24 - July 30, 1993.

Fig. 4.10b. Melt-puddle development on old ice from May 24 - July 30, 1993.

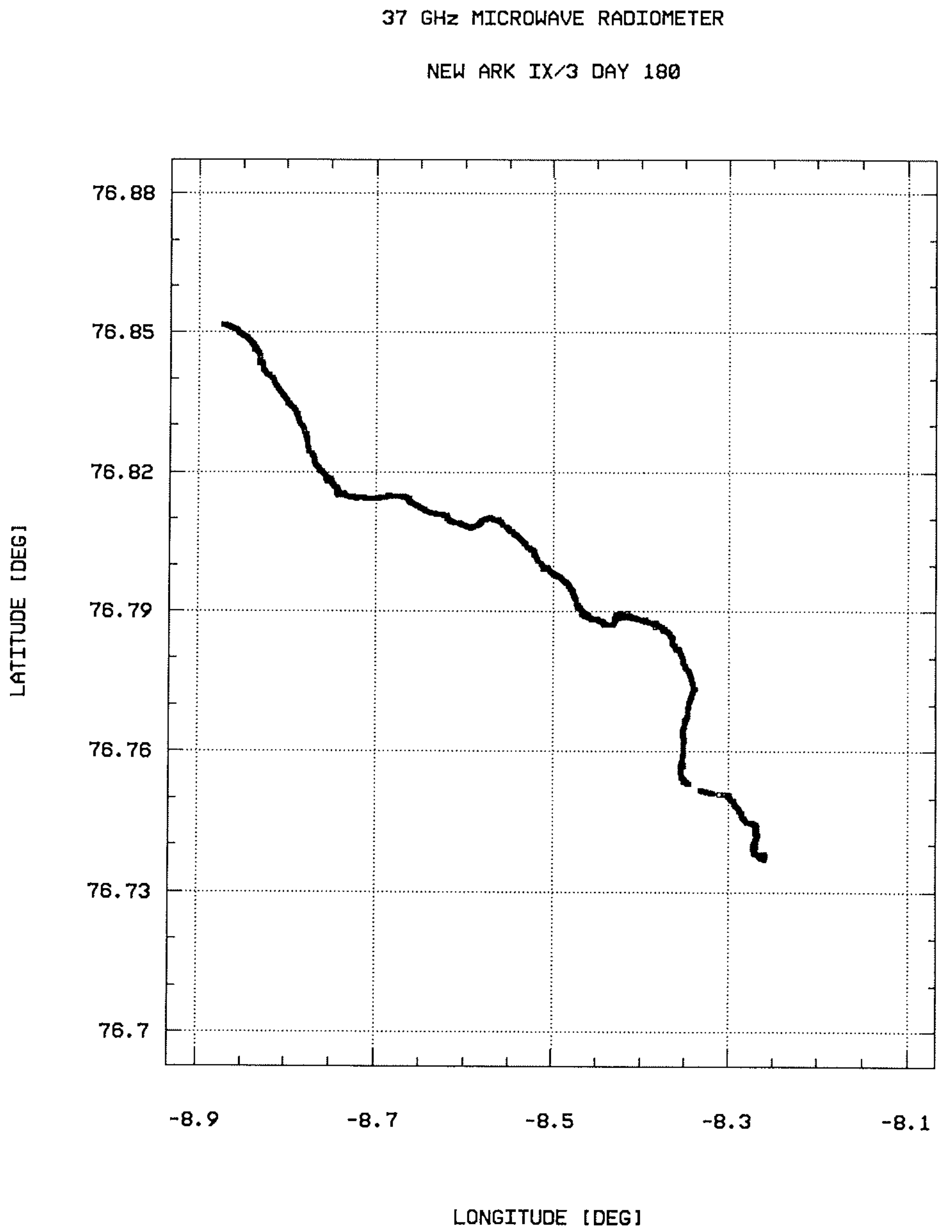

Fig. 4.11. Cruise track for a radiometric data file. The ship position was measured using a GPS unit with the AES Ground-Based Radiometer softwaré package.

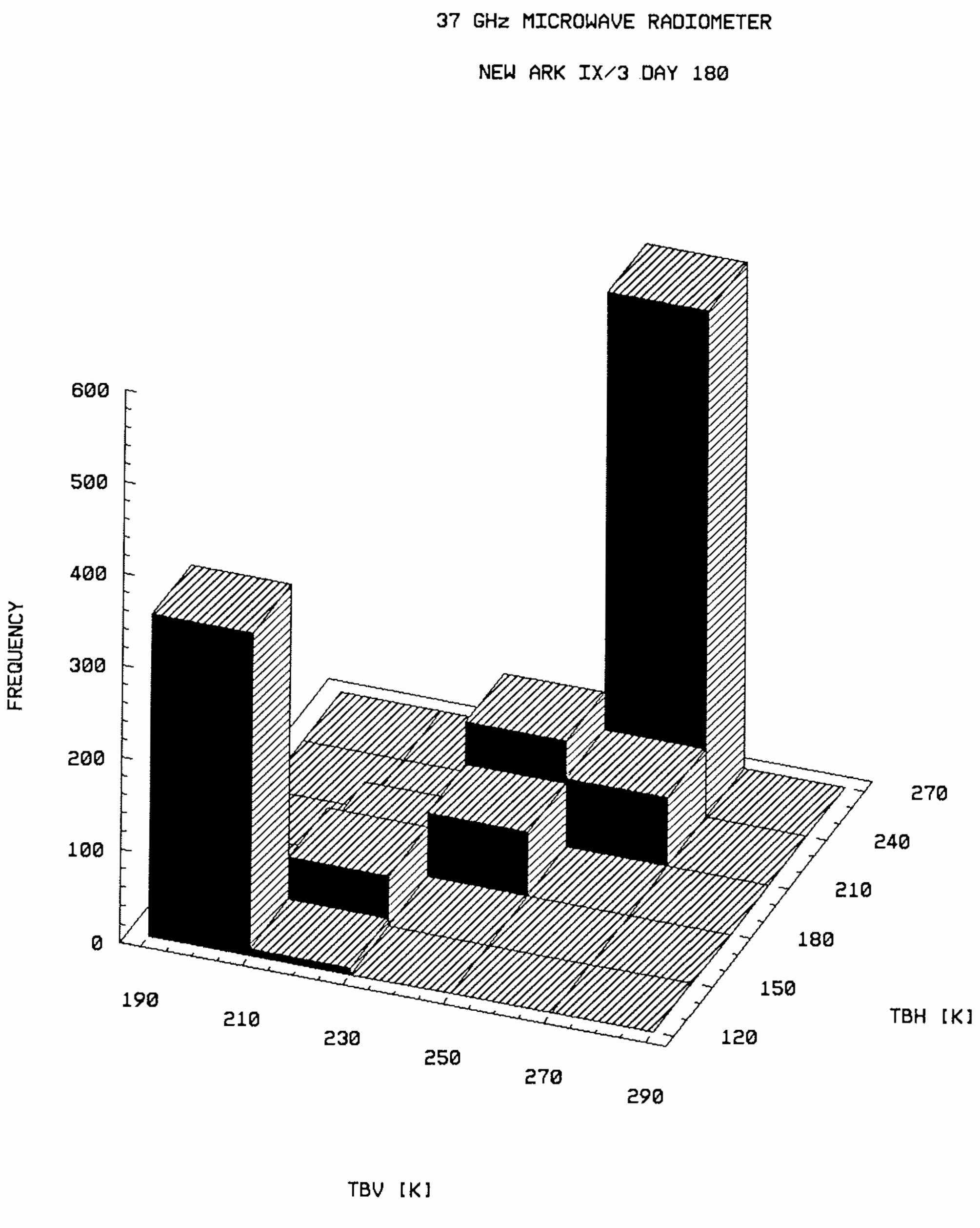

Fig. 4.12. Frequency plot of vertical (TBV) and horizontal (TBH) brightness temperature as measured from the ship-based radiometer. The data file corresponds to the cruise track shown in Fig. 4.11.

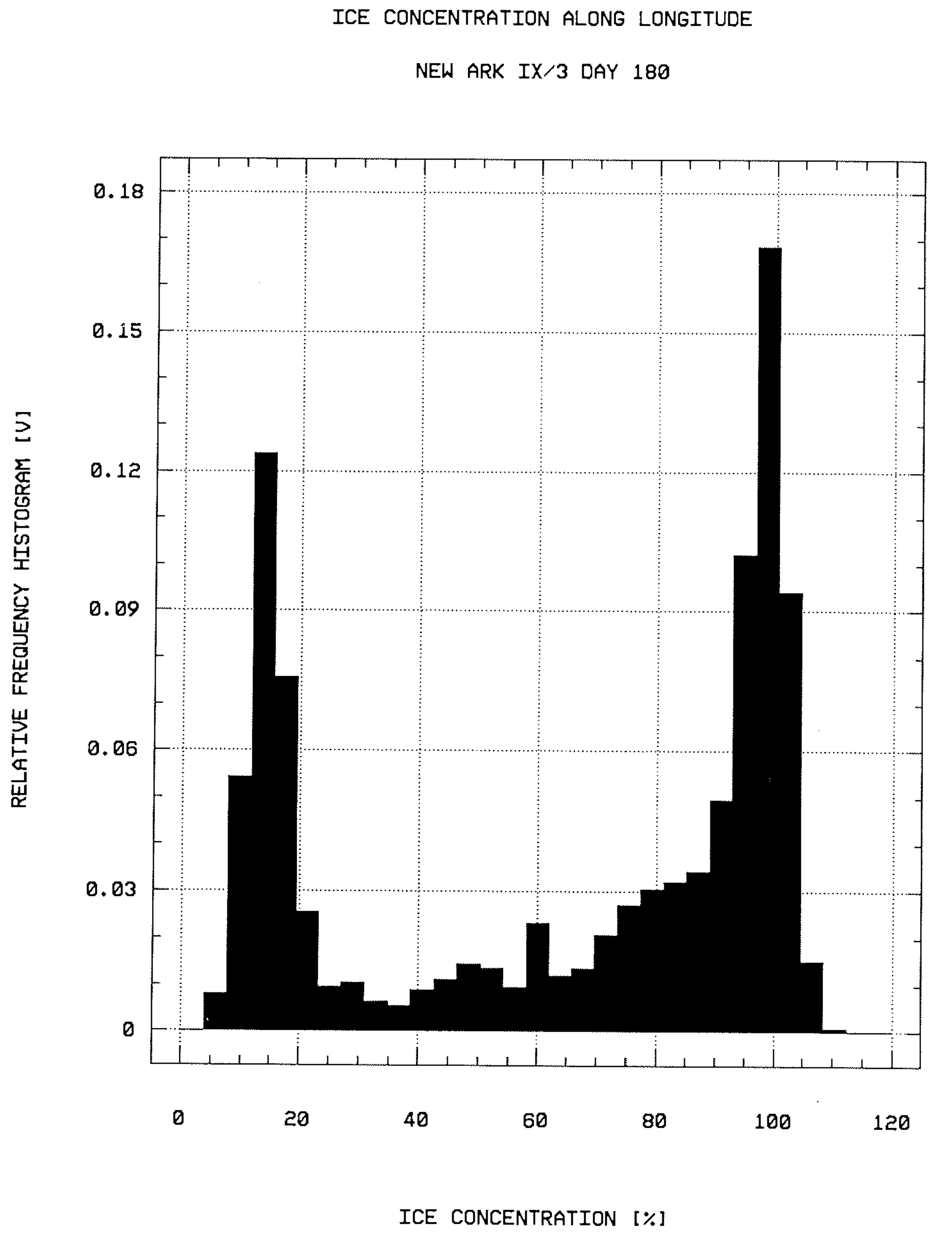

Fig. 4.13. Total ice concentration frequency plot corresponding to the data file in Fig. 4.12. The ice concentrations were calculated using a linear algorithm. Adjustments to the algorithm is required due to the shift in ice concentrations to greater than 100 %.

peak first year ice. Based on a plot like this, it is possible to indicate the relative ice fractions along the ship's track during the entire RV "Polarstern" NEW experiment. The total ice concentration for a portion of the ship's track was calculated as an example. A linear algorithm is used and depending on the TB tie point, the calculated ice concentration may exceed 100% as is the case in Fig. 4.13. The ice concentration in Fig. 4.13 was based on the vertical TB and a frequency plot of ice concentration along the ship track. It is the intention to calculate the ice concentration for each TB measurement made along the ship's track to provide an ice map specific to the ship's position.

Acknowledgements: The Canadian Atmospheric Environment Service and Microwave Group- Ottawa River thank thank the Alfred-Wegener Institute for providing RV "Polarstern" as a research platform, its crew for its dedication as well as the crews of the Wasserthal Helicopter Service. We thank the authorities of the German Aerospace Establishment (DLR), especially Dipl.-Ing W. Markwitz, Director of the German Remote Sensing Data Centre, for providing the opportunity and funding for the participation of Dr. König in the NEW experiment.

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5 MARINE CHEMISTRY

5.1 Nutrients, DOC, TOC and DON

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The main goals of the chemistry group were the determination of the distribution of dissolved inorganic nutrients, the evaluation of the nitrogen budget by the further measurement of dissolved and particulate organic nitrogen (DON and PON) and the analysis of total (TOC) and dissolved organic carbon (DOC). The latter also included questions related to sampling and determination methods of TOC/DOC and other topics related to the character and distribution of the organic material, such as evaluation of the contribution of dissolved humic substances to the DOC pool. These determinations will provide a better comprehension of the distribution and dynamics of the chemical properties of seawater in the NEW according to the circulation patterns of the region and the influence of the plankton activity.

Materials and methods

Water samples taken with CTD casts were analysed for nitrate, nitrite, phosphate, ammonium and silicate with a Technicon Autonalyzer system according to standard methods. Nutrients were determined at nearly all stations at 12 depths distributed between surface and bottom. The sampling schedule included light-penetration levels and standard oceanographic depths and was carried out in accordance with the microplankton group. Also coastal samples from Esquimonaes, taken by the Polish group, were analysed.

For the determination of DON the persulphate wet oxidation method was used. Samples for DON were taken at about 90 stations, which were selected according to their hydrological and biological characteristics as indicated by CTD profiles. TOC/DOC were measured at 107 stations by high-temperature catalytic oxidation (HTCO) with a Shimadzu TOC-Analyzer. The possible influence of contamination from plastic CTD-bottles on the TOC/DOC content of the samples was tested using glass bottles with 20 or 10 L volumes for comparing their TOC/DOC concentrations with the concentrations from the CTD-bottles. Additional samples were taken and preserved by freezing or filtering and acidification. The samples were analysed directly on board and these values will be compared to those obtained from the conserved samples on land. Different methods like wet oxidation will be compared with HTCO determinations on conserved samples. 100 samples for humic substances were taken and frozen for further fractionation and fluorescence and carbon analysis on land. 20-liter samples were taken at six different locations and concentrated on XAD2-resin. The adsorbed substances were eluted and frozen for further analyses.

Preliminary results

Nutrients: The surface nutrient distribution reflected the influence of phytoplankton uptake and of the upwelling at the Norske Øer Ice Barrier which constitutes the southern boundary of the NEW. This is clearly exemplified by the nitrate distribution, which showed the following features during ARK IX/2: in the southern part of NEW a tongue of nitrate-rich water (about 4 µM) extendend from the ice barrier to the north, reaching Sta. 55. Towards the coast and along it, concentrations were significantly lower, decreasing to the north. Very close to the coast, at Eskimonæs, nitrate was almost exhausted, with values near zero. A core with the highest chlorophyll values showed low nitrate concentrations (1-3 µM) extending from the coast (near Sta. 41) to the SE across the sampling region. The south-north transect (Sta. 49 to 43) shows a slight reduction of nitrate in the surface layer whereas in phosphate no clear trend was occurred (Fig. 5.1). No severe depletion of all nutrients was detected at any location exept the along the shore of Eskimonæs.

During ARK IX/3 nutrients became more depleted which is exemplified by the south-north transect (Sta. 218 to 229, Fig. 5.2) comparable to that on ARK IX/2 but with a much longer extension to the south. In this southern part no station work was possible during ARK IX/2 due to the heavy ice conditions. Fig. xx shows that nitrate was depleted in the surface layer along this transect with only few exceptions. Also silicate and phosphate were reduced but not depleted. Along the

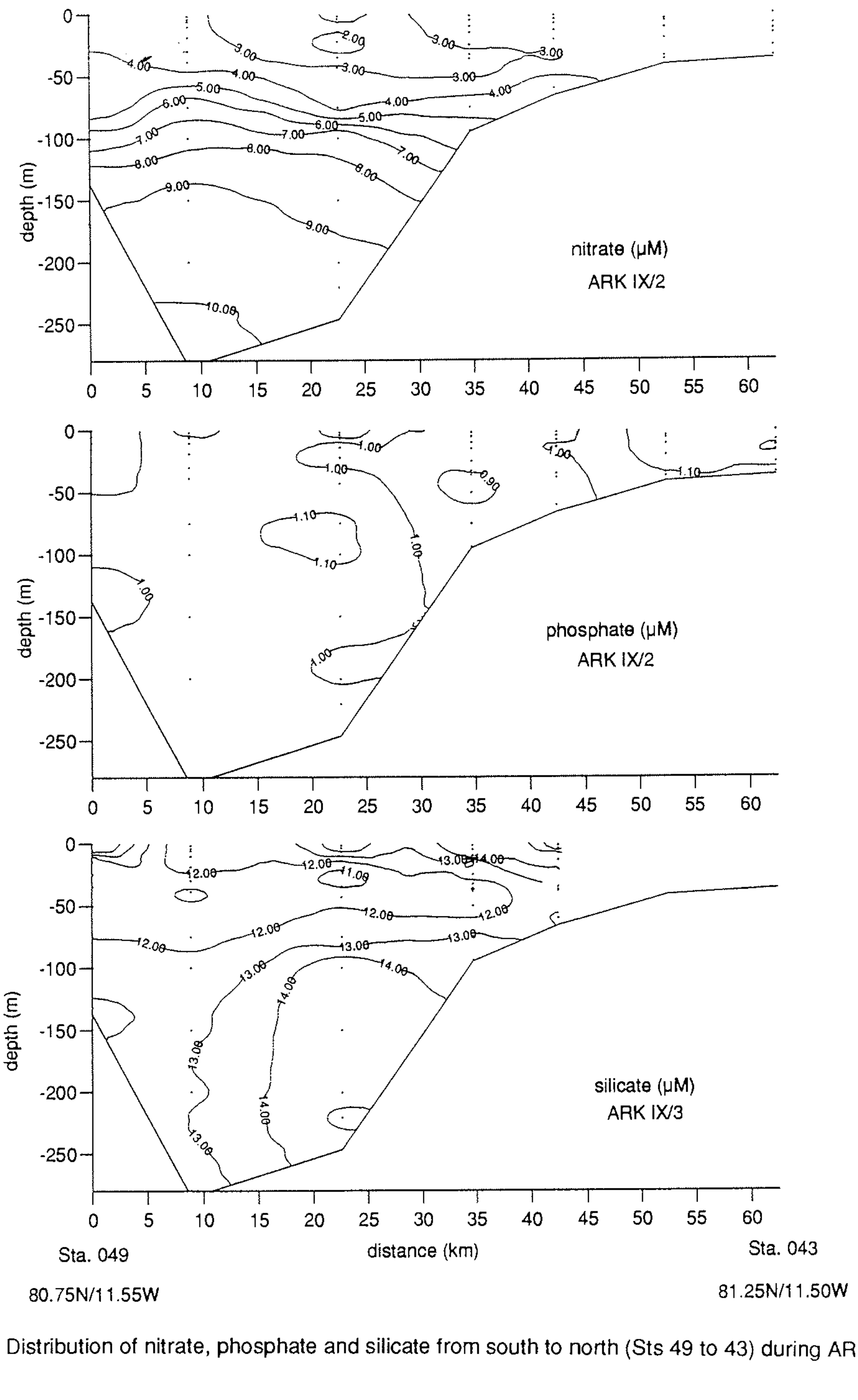

Fig. 5.1. Distribution of nitrate, phosphate and silicate from south to north (Sts 49 to 43) during ARK IX/2

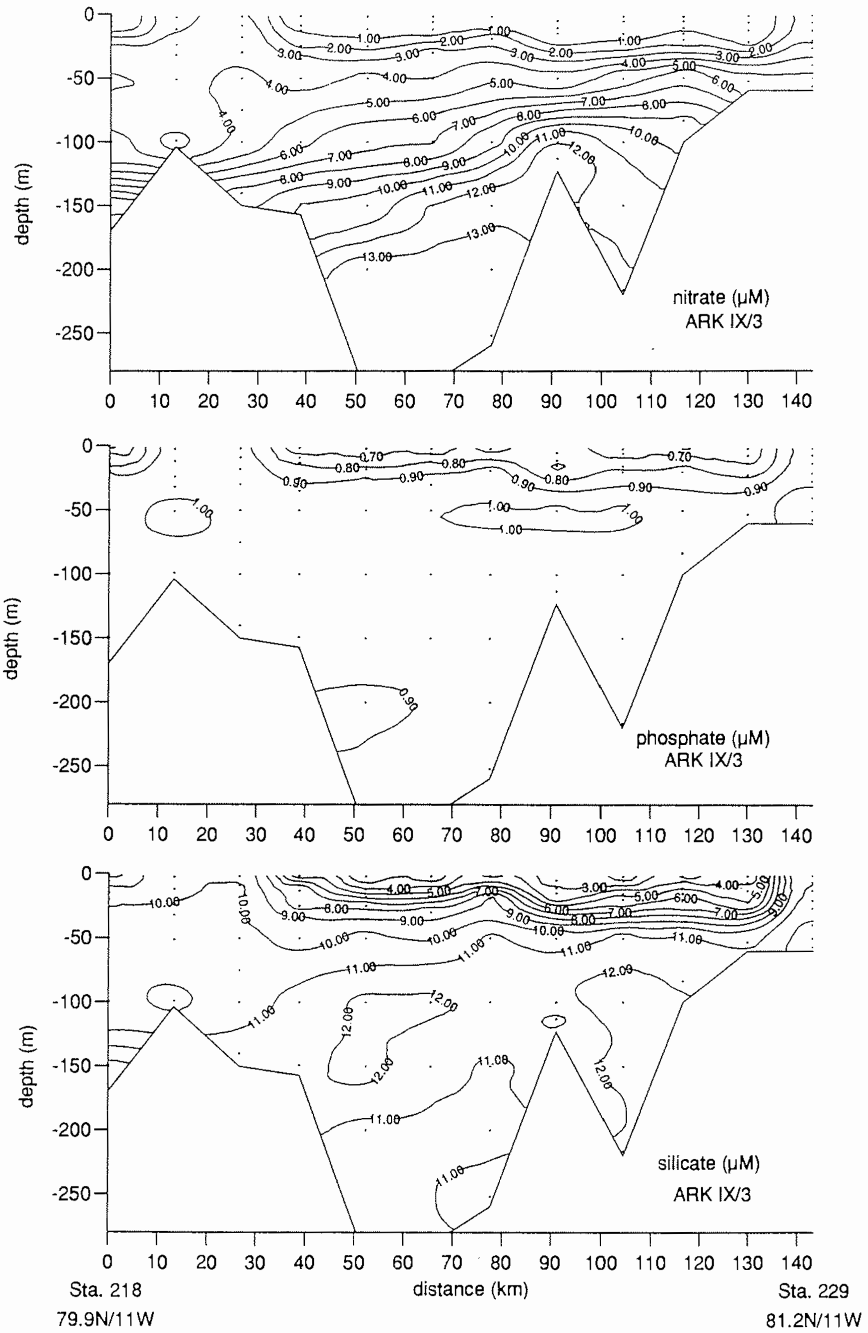

Fig. 5.2. Distribution of nitrate, phosphate and silicate from south to north (Sta. 218 to 229) during ARK IX/3

Norske Øer Ice Barrier no reduction of nutrients was found at the end of this leg due to the upwelling of deeper Polar Water.

DON, DOC: In general, the distribution of DON showed a decrease with depth. On the average, surface concentrations were in the range 4-7 μM N, and in deeper layers, below the euphotic zone they were around 2-4 μM N. As overall trend, there was a slight inverse relationship with dissolved inorganic nitrogen (DIN), which was particularly marked at stations with high chlorophyll. On a previous NEW cruise (ARK VIII/1, 1991) the correlation between DIN and DON was highly significant, probably due to a different, more extended phytoplankton development. The analysis of these information together with chlorophyll data will provide a better insight into the observed DON distribution. The raw TOC/DOC data suggest that concentrations of organic matter in the polynya might be higher than those usually found in other marine environments. The comparison of TOC/DOC concentrations in samples taken with CTD-bottles and with the glass samplers did not show any significant differences between both sampling methods.

5.2 Inorganic carbon

M. Gerlache, J.-M. Theate

Our aim was to determine the distribution of the different species of inorganic carbon (carbonate ions, bicarbonate ions and dissolved carbon dioxide) within and in the vicinity of the NEW polynya. Knowledge of these parameters allows us to obtain information about the fate of inorganic carbon in the form of calcite and aragonite and to describe the buffering capacity of the water. Such a study of CO_2 flux at the air-sea interface indicates the ability of the NEW to regulate the variations of CO_2 concentration in the atmosphere. Coastal areas are often sites of quite important air-sea CO_2 fluxes and a global inventory is urgently needed to get a better understanding of the oceanic carbon budget.

Methods and sampling

pH and Total Alkalinity (Talk): pH is measured on seawater from NISKIN sampling by using a classical pH meter and a ROSS combined glass electrode calibrated with NBS phosphate and borax standards. As for dissolved gas samples, this sampling should have priority (usually after oxygen and pCO_2). This measurement is carried out as soon as possible. Sampling is done using a 250ml BOD bottle. After pH determination the seawater is kept for Talk titration.

Talk is determined by titrating GF/C-filtered seawater with 0,1N HCl according to the now classical GRAN-plots method. About 250 ml of seawater is needed for two titrations. The accuracy of the method has been estimated to 0.5% using standard carbon solutions.

Both pH and Talk are used to calculate the CO_2 speciation in seawater using temperature and salinity data. As a result the following information will be provided:
- pH, Talk
- pCO_2 (partial pressure in dissolved CO_2)

- TCO_2 (sum of concentrations of all inorganic carbon species)
- carbonate alkalinity
- borate ions concentration
- concentration in bicarbonate and carbonate ions and dissolved CO_2
- The over saturation in calcite and in aragonite
- information about the buffer factor of the seawater

An inventory on the samples taken is included in Table 6.1.

CO_2 chemistry intercalibration: CO_2 chemistry in seawater is the subject of a current important challenge because a great accuracy is needed to investigate efficiently the role of the ocean in the global carbon cycle. Assuming that acidity constants are known, the complete CO_2 speciation in seawater can be calculated using two among the four following experimental parameters: pH, total alkalinity (Talk), total inorganic carbon (TCO_2) and the partial CO_2 pressure (pCO_2). Measuring more than a couple of parameters makes it possible to intercalibrate experimental data between themselves. During the Polarstern/Polar Sea intercalibration meeting, pH and Talk have been measured by the Polarstern team while both pCO_2 and TCO_2 have been determined by the USCG Polar Sea team.

Preliminary results

The results will allow to discuss CO_2 dynamics and the biological activity. The dissolved CO_2 system in seawater is fundamentally dependent on the biological activity and can be used to discuss photosynthesis/respiration processes as well as calcification. CO_2 data should then be included in the whole data set related to biological indicators (chlorophyll, oxygen, primary production, nutrients, organic carbon, etc.). Determination of the partial pressure of CO_2 in the surface layer allows to calculate the direction and the magnitude of the CO_2 flux at the air-sea interface, using appropriate exchange coefficient (wind speed is needed).

6 MICROPLANKTON

6.1 Biodiversity, succession and spatial coverage of nanoplankton
H. A. Thomsen, J. B. Østergaard

The main purpose of our research is to provide a fine-scale successional and spatial resolution of the distribution of non-diatomaceous nanoplankton (organisms < 20 µm) within the NEW polynya. Efforts have been made to additionally analyze community structure differences between the sea ice biota and the water column. The purpose of this comparison is to e.g. evaluate the potential of the sea ice biota as a seeding population for the water column during ice melting. There is at present a surprising shortcoming of data on e.g. species composition and area coverage of the non-diatomaceous components of arctic microplankton. Once fully analyzed we anticipate that the NEW material is likely to partly provide such data for the arctic region of the Atlantic Ocean.

An Arctic/Antarctic comparison between water column and ice biota communities of non-diatomaceous nanoplankton is a major goal for our ongoing polar research. The NEW material will in a preliminary way render possible such a comparison.

Materials and methods

Single cell and community structure analysis: During ARK IX/2 samples used for an analysis of single cell and community structure were collected from 27 stations: 5, 8, 10, 13, 15, 21, 24, 30, 32, 33, 36, 40, 46, 51, 54, 55, 60, 61, 62, 73, 76, 82, 85, 89, 93, 99, 100, and 3 ice camps: 30, 60, 94. During ARK IX/3 samples were processed from 42 stations: 109, 110, 112, 113, 115, 116, 118, 119, 121, 138, 141, 143, 145, 147, 155, 157, 159, 161, 165, 166, 168, 170, 172, 175, 177, 186, 194, 201, 206, 210, 217, 218, 221, 223, 226, 229, 259, 261, 263, 265, 266, 267 and 4 ice stations.

Samples from 6 depths were processed at most stations during the first leg. During the second leg most stations were only sampled at the depth of the chlorophyll maximum. The nanoplankton was concentrated by gravity filtration and/or centrifugation. Samples (permanent preparations) were prepared for both transmission/scanning electron microscopy and light microscopy. Ice samples were slowly melted in filtered seawater (ca. 1:1) at 0°C to prevent loss of organisms due to osmotic changes. At ARK IX/2 stations listed above samples (100 ml) from 6 depths were preserved with Lugol's solution. Material for thinsectioning and ultrastructural examination was prepared from cultures established during the first leg (Sta. 55), from tank experiment 2, and from brine samples collected during the second leg.

During ARK IX/3 efforts were made to document the live appearance of cells from the water column and the ice biota. A Leitz Dialux 20 microscope fitted with interference contrast optics and a flash system was placed in a cold container maintained at ca. 0°C. The total number of films (Ilford PANF Plus) exposed exceeded thirty.

Tankexperiments: The succession of nanoflagellates in 2 x 2 1000 L nutrient enriched tanks was monitored at 5-days intervals during ARK IX/3. Tanks 1 and 2 (Sta.126) were sampled on six occasions, whereas the second set of tanks were sampled 3 times only before the experiment was ended. These experiments were initiated and supervised by Dr. E. Bauerfeind (SFB, Kiel). The techniques used to process samples were similar to those described above.

Preliminary results

The following brief summary of community dominants is based exclusively on onboard light microscopy of whole cell preparations. A detailed analysis of the nanoplankton diversity and area coverage must await the electron microscopical examination of the material collected.

Autotrophic nanoplankton (water column): The flagellate stage of *Phaeocystis pouchetii* (Prymnesiophyceae) was abundant at all stations sampled. Species of *Chrysochromulina* (Prym.) became increasingly abundant towards the centre of the polynya. The picoplanktonic *Micromonas pusilla* (cell size ca. 1.5-2 µm) was abundant at most stations, and in several areast the single most significant organism in terms of cell numbers. Species of *Pyramimonas* (Prasinophyceae) made up another important chlorophyll a+b component of the polynya nanoplankton. Three species (ca. 5, 10 and 15 µm respectively) could be distinguished at the light microscopical level. A small, reddish cryptophyte (ca. 8 µm long) and dinoflagellates (mostly *Gymnodinium* spp.) occasionally contributed significantly to the autotrophic nanoflagellate biomass.

Heterotrophic nanoplankton (water column): A substantial element of heterotrophic nanoplankton species was found at most stations. The species diversity was generally high and the material analyzed indicate noteworthy community changes during space and time. Dominants among the raptorial feeders were *Telonema* spp. (one type observed is identical to *Telonema antarctica* sp. inedit.), *Leucocryptos marina*, and dinoflagellates (*Amphidinium*, *Gymnodinium*, *Gyrodinium*, *Protoperidinium* a.o.). The loricate choanoflagellates were the single most important group of filter feeders. Coccolithophorids from the enigmatic polar genera (*Wigwamma*, *Papposphaera*, *Pappomonas*, *Turrisphaera*, *Trigonaspis* a.o.) were found at most stations, and particularly abundant in samples from the ice covered areas. Examination of hundreds of cells using alternatively phase-contrast and epifluorescence microscopy clearly documented that these are all heterotrophic organisms. Autotrophic prey was never observed inside the cells. The nutritional mode and feeding behaviour of these organisms remain to be studied. The type species of the genus *Papposphaera* (*P. lepida* Tangen) was observed in samples from the ice covered southern part of the area sampled. Also this species is without chloroplasts.

Icebiota: It is evident that the species composition of the ice community is significantly different from that of the water column. *Dinobryon* spp. (Chrysophyceae) and *Chlamydomonas* (Chlorophyceae) are common photosynthetic components of e.g. brine samples, and the heterotrophic flagellate community comprises genera such as: *Actinimonas*, *Amastigomonas*, *Anisonema*, *Bodo*, *Cryothecamonas*, *Ebria*, *Goniomonas*, *Kiitoksia*, *Protaspis*, and *Thaumatomastix*. The loricate choanoflagellate community comprises species that have hardly been observed in any of the water column samples analyzed (viz. *Acanthocorbis* spp. nov., *Diaphanoeca grandis*, *D. multiannulata* (identical to the Antarctic icebiota form of this species), *D. sphaerica*, *Parvicorbicula manubriata* sp. inedit., *Stephanoeca diplocostata*).

Tank experiments: Despite the fact that no essential changes were evident in any of the monitoring parameters measured (e.g. nutrients and chlorophyll) it became obvious that significant shifts in community structure occurred throughout the ca. 30-days experimental period. The loricate choanoflagellate species composition at day 0 (Fig. 6.1) was typical for major parts of the polynya. However, as indicated in Fig. 6.1, this community rapidly vanished and was followed in turn by a short bloom of *Bicosta antennigera* (Fig. 6.1a, day 5), and from day 10 and onwards (Fig. 6.1b) an undescribed species of *Parvicorbicula* (*P. manubriata* sp. inedit.). A successional development was indicated at day 25. The *P. manubriata* dominance is vanishing, and species such as *Acanthocorbis unguiculata* and *Diaphanoeca grandis* are becoming increasingly more abundant (Fig. 6.1b). Cultures established during the first leg (Sta. 55) were found to be basically similar to the day 25 tank 1 community when examined approximately one month later during ARK IX/3. It is of further interest to notice that the day 25

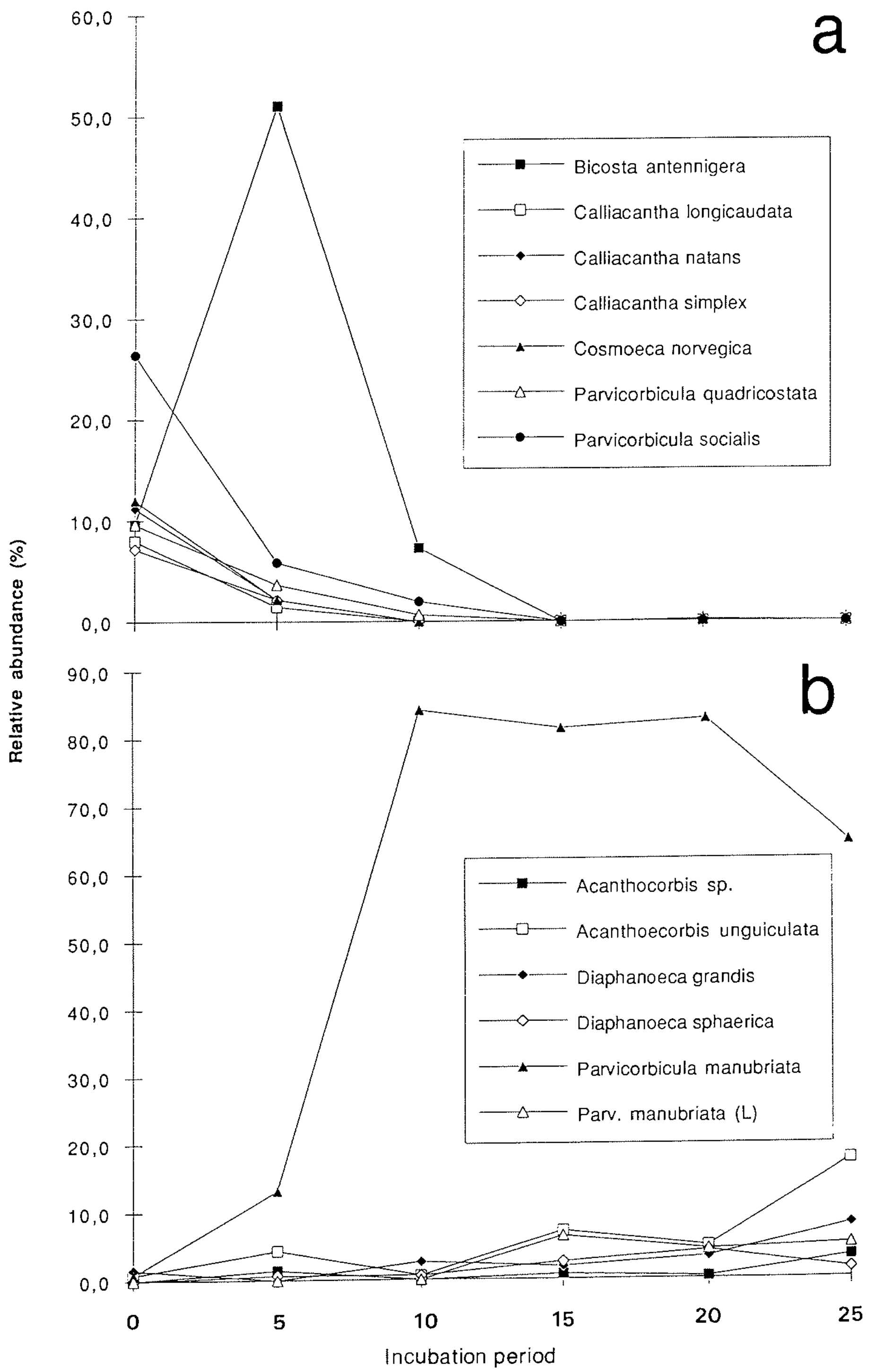

Fig. 6.1. Graph showing relative abundance data for loricate choanoflagellate species benefitting from incubation.

loricate choanoflagellate community of tank 1 (Fig. 6.1b) is much like that found in ice samples. It thus appears that the enclosure of a water column sample somehow simulates the directional selection of species that occurs within sea ice brine channels and pockets. The general validity of e.g. ecosystem modelling based on enclosure manipulations is questioned by the results preliminarily reported here.

6.2 The microbial food web
P. K. Bjørnsen, T. G. Nielsen, A. C. Nielsen

In order to evaluate the fate of pelagic primary production in the NEW polynya, it is imperative that all potential carbon pathways are included in the investigation. Within the past decades the importance of bacteria and protozoan in the pelagic food web has been documented for lower latitude ecosystems. However, the major part of the literature concerning the fate of primary production in polar regions still focus on the role of the large zooplankton (e.g. calanoid copepod and krill) species. At present very few studies on the microbial components of the high Arctic ecosystems are available. The aim of the this investigation is to provide data that makes it possible to evaluate the role of the microheterotrophic processes in the NEW polynya area.

Materials and methods

Sampling: On basis of the vertical distribution of salinity, temperature and fluorescence 5 depths from the upper 200 m of the water column were selected; if present the fluorescence peak was always included. During ARK IX/2 one station was sampled daily (26 stations in total), while sampling effort during ARK IX/3 was concentrated along transects (47 stations). Microzooplankton growth was determined at 37 stations.

Bacterioplankton: Bacterial abundance and biomass was determined from formalin fixed samples stained with acridine orange, filtered onto Iragalan black stained 0.2 μm Nucleopore filters. The filters were mounted in paraffin oil on microscope slides prior to counting under epiflourescense microscope at 1250 x magnification. Biomass was estimated assuming a carbon content of 20 pg C per cell. Bacterial production was measured from incorporation of ^{3}H-thymidine and ^{3}H-leucine into bacterial DNA and protein, respectively. From each depth two sets of triplicate samples and a pre-fixed blank were incubated with 5 nM methyl-^{3}H-thymidine or 10 nM ^{3}H-leucine, respectively. After 5 hours incubation at 0°C, the samples were filtered onto cellulose nitrate filters, washed 10 times with ice-cold TCA and counted onboard. Thymidine and leucine incorporation rates will be converted into bacterial production in terms of cells and carbon using conversion factors from the literature. These conversion factors were evaluated twice by calibration experiments (cf. below). Isotope saturation and linearity with incubation time were checked twice, as was the relationship between isotope incorporation and incubation temperatures around 0°C.

Nanoflagellates: Abundance, biomass and classification into major trophic groups (autotrophs / heterotrophic, dinoflagellates / other flagellates) will be determined on proflavine hemisulfate stained samples (50 ml) using epifluorescence microscopy.

Microzooplankton: Two 100 ml samples for determination of abundance and biomass was fixed in 1 % (final concentration) Lugol's and glutar aldehyde, respectively. The microzooplankters in the samples will be quantified using inverted microscope. Microzooplankton growth and grazing was determined in size-fractionated water samples (<300 mm to remove larger predators) incubated on a plankton wheel for 48-72 hrs at $2^{\circ}C$ and 20 mE m^{-2} s^{-1}. The growth rate is calculated from the change in abundance during incubation.

Microcosm experiments: Two microcosm experiments were carried out in duplicate 2.6 L polycarbonate bottles in the cold container. The bottles were manipulated by size fractionation (300 and 15 µm) and by addition of nitrate and phosphate, to invoke bottom-up and top-down control. The aim of this experiment was to evaluate the importance and regulation of the microbial food web by comparing the development of the plankton in the different bottles. The experiments based on water from Sts 134 and 143 which was sampled every fourth day for determination of nutrients, primary production, bacterial biomass and production and samples for enumeration of protozoa.

Temperature experiments: Growth experiments with the components of the microbial loop (bacteria; heterotrophic nanoflagellates, ciliates and dinoflagellates) were carried out at -2, 0, 2 and $5^{\circ}C$. This experiment was based on cultures prepared during ARK IX/2. The aim was to investigate the growth potential and temperature dependence of these groups at low temperature.

Conversion factor experiments: Calibration experiments were carried out twice using water from 200 m depth and from the chlorophyll maximum. Potential grazers of bacteria were removed by 1 µm fractionation, and the water was diluted fivefold with sterile filtered water. Duplicate batches were run for 16 days and cumulative incorporation of thymidine and leucine were related to increases in cell number, biovolume and particulate organic carbon.

Preliminary results

Generally, the spatial variations in bacterioplankton production followed the pattern observed for phytoplankton biomass as described above. Thus, most of the bacterial activity was found in the photic zone. The transect along the trough (stations 134 to 145) showed a 30-fold increase in bacterial production towards the northeastern stations. Increased bacterial activity was recorded at coastal stations and in the ice edge.

The impression from the microzooplankton samples inspected is that two distinct communities develop depending on the size composition of the phytoplankton. When small cells dominated the phytoplankton, the microzooplankton biomass was low and dominated by smaller oligotrich ciliates (e.g. *Lohmaniella oviformis*) and small naked dinoflagellates (*Gymnodinium* spp.). However, where larger diatoms dominated the biomass, large naked dinoflagellates (*Gymnodinium* spp. 70-150 µm) dominated the microzooplankton biomass.

6.3 Quantitative and functional importance of phagotrophic protozoa in the Northeast Water

T. Sime-Ngando, P. Yager

This program was intended to assess the quantitative and functional importance of the "microbial loop" in both water column and sea ice during the opening stages of the NEW. Here we aimed to focus on spatio-temporal distributions of species composition, abundance, biomass, grazing rates and DOC uptake rates of phagotrophic protozoa, for evidence of their response to food availability in the cold NEW. Such data are very scarce in the polar environments. Our main hypothesis is that: if phagotrophic protozoa assemblages are as abundant and active in the arctic ecosystems as in temperate and tropical waters, then the known apparent disparity between bacterial and algal production (ratios between 0.005 and 0.05) in this environment may allow these organisms to be one of the first levels of the food web to quickly respond to any increase in algal production. This is because of their relatively fast turnover rates and their ability to exploit food items other than bacteria, such as viruses, submicrometer particles, and both colloidal and high molecular weight substrates which are highly concentrated in the arctic sea ice and sea water.

Materials and methods

Sea ice and plankton samples (from five to six depths on ca. 100 Sts.) were taken from mid-May to late July, 1993. Ciliated protozoa were preserved in alkaline Lugol solution, while flagellates, bacteria and viruses were preserved in buffered formalin. Viable bacteria counts were made using a DNA specific inhibitor (free nalidixic acid). About 15 grazing experiments were conducted with chlorophyll-maximum depth samples and melted ice cores, using two different methods: dilution of sea water and fluorescently labelled prey (algae, bacteria, mini-cells). In addition, preliminary and successful experiments have been done to improve the dilution method with cold water samples. 5 experiments involving flagellate uptake of dissolved organic carbon (DOC) were conducted, using fluorescently labelled polysaccharide dextran of 8 different molecular weights.

Preliminary results

Although nearly all of our experimental results require further processing time, instantaneous grazing rates of microzooplankton (g) in relation to phytoplankton potential growth (k) obtained from our dilution experiments have been generated onboard. In the water column, g varied from 0,005 to 0.40 d^{-1}(mean = 0.16 d^{-1}) while k varied from 0.18 to 1.21 d^{-1} (mean 0.53 d^{-1}). On average, microzooplankton ingests about 36 % of the phytoplankton potential production per day, a value which is higher than in eutrophic (coastal) waters (20 %) but lower than the expected value (70 %, from energetic considerations) in oligotrophic waters such as the NEW (Chl. a <5µg L^{-1}). In the ice biota, k is similar to that in the water column but g seemed to be one order of magnitude lower, i.e. decreasing gradient in g from more productive ice biota to less productive water column. Spatially, k seemed to decrease from the north to the south while g are likely strongly related to the size distribution of phytoplankton which seems very patchy. Furthermore, this cruise allowed us to conduct the first quantitative measurements of dissolved organic carbon (DOC) utilisation by natural flagellate populations. In these waters we found that sea-ice and planktonic flagellates ingested high molecular weight polysaccharides at maximum rates of 7.2 and 140 pg C $cell^{-1}$ hr^{-1}, respectively, with a preference for heavier substrates up to at least 2000 kDaltons. Bacteria provide only 12-50 % of flagellate carbon requirements, while direct assimilation of DOC provides the balance. This "short-circuit" flow in the microbial food web can produce 6-7 times more biomass from DOC than the conventional bacteria-mediated pathway, and may help explain the apparent disparity between algal and microbial production in arctic seas. It thus effectively gets around the "Pomeroy effect" of cold temperature inhibition of bacterial production and may also be critical to survival of other arctic consumers during long seasons of low primary production. Simple extrapolation from our results indicates that recovery of DOC by flagellates is quantitatively important in other aquatic ecosystems and that the proposed role of the microbial loop as carbon sink may need to be reconsidered.

Overall, the ARK IX cruise was very successful for us, and may, in the future, allow us to present data on species composition, and both time series and spatial data on the quantitative and functional (grazing) importance of phagotrophic protists which are very scarce and eventually non-existent in polar environments.

6.4 Phytoplankton and ice algae

6.4.1. Species composition

C. Hellum

The pattern of seasonal variation in phytoplankton standing crop and production is of fundamental significance to the marine ecosystem. The availability of phytoplankton determines the ecology of both benthic and pelagic herbivores, and this influence permates in the higher levels of the food web (Clarke et al. 1988). Changes in light levels have been shown to be of critical importance for the growth of under-ice algae and would also be a major controlling factor in the diversity of phytoplankton (Perrin et al. 1987). In addition, water temperature, salinity and nutrients, all of which exhibit seasonal fluctuation have been shown to have considerable effect on the phytoplankton and ice algal abundance and species composition (Horner 1977, Legendre et al. 1981). Seasonal variation in a limiting factor might also produce clearly evident seasonal effects on individual species that provide life history information as well as the opportunity to interpret the fossil record in the sediment (Fryxell 1989). The trend of succession depends upon composition of initial stock at any time, and it may vary from year to year.

A significant amount of the primary production in ice-covered oceans takes place in localized ice edge plankton blooms. The dynamics of these blooms appear to be closely related to seasonal melting of sea ice. Algal cells released from ice are a possible source of ice edge planktonic assemblages, but evidence for this "seeding" has been equivocal (Garrison et al. 1987). Everitt & Thomas (1986) found that the combination of overwintering planktonic and benthic adapted diatoms in the sea ice illustrated how diatoms survived the winter in sufficient concentrations to dominate the water column for most of the ice-free period near

Davis Station, East Antarctica. Some investigations especially from the Arctic, have shown that the ice algal bloom and the spring phytoplankton bloom can be clearly separated in time (Appolonio 1965, Clasby et al. 1973, Grainger 1977, Booth 1984) and sometimes by the species present (Horner 1977, Horner & Alexander 1972, Fryxell & Kendrick 1988). The species composition of ice and plankton can however differ from one year to the next (Horner 1969). Besides, the species composition also depends on the age of the ice (Syvertsen 1985). Syvertsen (1991) describes for example how different types of ice algal assemblages found in the Barents Sea undergo a succession terminated by the dominance of ice specialists. The youngest ice is dominated by planktonic species, older first year ice of the pennate diatom *Nitzschia frigida* Grunow and multi-year ice of the centric diatom *Melosira arctica* (Ehrenberg) Dickie and its associated epiphytes. Already Gran (1897) mentioned that one way for Arctic planktonic diatoms to survive unfavorable conditions is to form resting spores that may settle in the ice and later germinate when conditions again become favorable.

The spring plankton in the Arctic is dominated by diatoms, while the summer and autum plankton have a greater part of dinoflagellates and flagellates and the winter plankton of small flagellates (Braarud 1935, Horner 1969, Schandelmeier & Alexander 1981, Ellertsen et al. 1982, Horner 1984). The spring bloom in the Arctic often starts with pennate diatoms which gradually are replaced by centric diatoms (Grøntved & Seidenfaden 1938, Bursa 1961). Of the centric ones *Thalassiosira* species often blooms ahead of *Chaetoceros* species (Grøntved & Seidenfaden 1938, Bursa 1961, Horner 1969, Hellum 1989). Some investigations also show that pennate *Fragilariopsis* species often bloom during a longer period of time than for example *Thalassiosira* and can therefore be found in relatively high numbers also during a bloom of *Thalassiosira,* but then often at a greater depth than *Thalassiosira* (Saito & Taniguchi 1978, Hellum 1989).

The ice algal assemblages can be divided into different types of assemblages, infiltration assemblage (in the seawater infiltrated snow-ice interface), pool assemblage (pools on the ice surface), band assemblage (bottom ice algal layers frozen into the ice), brine channel assemblage (in brine channels and cracks), interstitial assemblage (between ice crystals and platelets) and sub-ice assemblage (mats and/or strands loosely attached to the under surface of the ice) (Horner et al. 1988). Especially the surface assemblages have received little attention and there is still considerable confusion about them. Pool assemblages can vary whithin short distances. For example investigations in the northern Barents Sea in the summer 1991 showed pool assemblages of five different types and all of them were quite different from the phytoplankton samples. These pools were situated on two ice floes close to each other (Hellum 1992).

Ice algae would be an especially important food source early in spring when little or no primary production occurs in the water column and the ice algae are concentrated at the ice-water interface (Horner 1989). Still it is debated in which degree grazing does occur in the ice and studies on this are needed. Grazing of loosened ice algae also occurs in the water column together with the phytoplankton. Cells that are not grazed in the water column may sink to the bottom and either be utilized by benthic invertebrates or be incorporated into the sediments (Horner 1989). The amount of the material reaching the benthos, however, may depend on the structure of the grazing community. It is also possible that the grazing sometimes is selective. For example fecal pellets found in the Weddel Sea 1990 often consisted of one or two species even though there were several different species both in the ice algal assemblages and in the phytoplankton from the same area (Hellum, unpublished observations 1990).

The NEW sampling are going to be part of a project which main objectives are:

- to study the influence of ice, distance from land and hydrographic conditions on the development of phytoplankton.
- to increase the knowledge about the relationship between ice and the water column near the ice with regard to the origin and fate of the cells in the ice.
- to determine the importance of leads for the development of the algal composition and the production in the area.
- to study intraspecific variation in growth habitat and size, life stage and abundance (relative and absolute) of ice-related species.
- to study the variation in algal species composition throughout the year and which implication this has upon the production in an area. Hereto comes also a comparison between the different years if possible.
- to increase the knowledge about pool assemblages.
- to study which algal species are the best food base for zooplankton.
- to compare phytoplankton and ice algal composition in the Arctic and the Antarctic.

The results from the NEW will be compared with results from the Barents Sea (spring 1985, 1986), north and west of Spitsbergen (sommer 1990), east of Spitsbergen (sommer 1991), Resolute Bay, Northwest Territories (sommer 1989), northern part of Norway (1991, 1992, 1993) and from the Weddell Sea, Antarctica 1989/90, 1993).

Materials and methods

Phytoplankton for abundance estimates was collected from water samples to provide estimates of absolute abundance and from net samples (0-25 m) to provide material for relative abundance and identification. Phytoplankton samples were taken both in areas with and without ice. The samples were preserved in neutralized formaldehyde or lugol.

Ice algae were collected by melting ice cores taken by an ice corer, or melting small pieces of coloured ice. Because of the boat algae from the underside of the ice loosened, long strands of ice algae were sometimes found floating at the water surface. These were possible to collect by hand. Algae from pools on the ice surface were collected by a special syringe with a rubber tube attached to it.

Sampling survey:

Water samples	147
Net samples	99
Pools	43
Melted ice (ice cores from leg 1 are also included)	32
"Hand sampling" of *Melosira arctica*	5

The net and ice algal samples were studied both uncleaned and cleaned (Simonsen 1974). Cleaning facilitates the identification of diatom species. The permanent mounts were/and will be counted and the relative abundance calculated. The water samples will be counted in an inverted microscope (Hasle 1978) to provide estimates of absolute abundance.

Preliminary results

More than 100 species have been found and identified from the material of collected ice algae and phytoplankton, in addition to several so far, unidentified species. The pool assemblages consisted mostly of pennate diatoms of the genera *Haslea*, *Fragilariopsis*, *Gyrosigma*, *Navicula*, *Nitzschia*, *Pinnularia*, *Pleurosigma*, etc., if not of *Melosira arctica* and its associated epiphytes. Most of the cells, including the diatoms, were dead (emty frusules) or only cell remnants making it difficult to determine whether the cells actually lived and grew in the pools or were incorporated into the ice as dead cells. Some of the diatoms were of typical benthic origin and not species that are found in the phytoplankton. Some of the species might have been from fresh water, but most of the observed species were salt water species. Some of the pool assemblages had almost similar composition as the phytoplankton. This is probably the case when pools are formed as a combination of flooding and melting, by flooding alone, or when algae from the water pass through cracks and holes in the ice. Big strands of *Melosira* from the underside of the ice were for example often found in holes seen in the pools.

The cores studied so far had a big variety of assemblages as described for the pools and pennate diatoms of the same genera as for the pools were often dominating. This indicates that there might have been more than one way of origin also for the assemblages in the ice.

The strands of algae which were found floating at the water surface consisted of *Melosira arctica* and its associated epiphytes *Gonioceros septentrionalis*, *Pseudogomphonema arcticum* and *Synedra hyperborea*. The relative amount of the three epiphytes varied, but they were always found together in the different samples of *M. arctica*. The ephiphytes were also found on other species than *M. arctica*, such as *Fragilariopsis oceanica* and *Nitzschia frigida* etc., but then sometimes one or two were missing. *M. arctica* were associated with both first year and multi-year ice.

Diatoms were most abundant in the phytoplankton samples, but also dinoflagellates and different types of small flagellates were recorded. Big centric diatoms of the genus *Chaetoceros* (*C. atlanticus*, *C. decipiens*), *Proboscia alata* and *Rhizosolenia hebetata* f. *semispina* were most common at the beginning of the cruise. These species are often found in Atlantic water. The pennate diatom *Fragilariopsis oceanica* was found dominating on several of the stations, and *Chaetoceros socialis* at the stations closest to the coast. A few stations had a situation inbetween with relatively high numbers of both *F. oceanica* and *C. socialis*, but also different *Thalassiosira* species (*T. antarctica* var. *borealis*, *T. gravida*, *T. hispida*, *T. hyalina*, *T. nordenskioeldii* etc.). The most abundant autothrophic flagellate in the phytoplankton samples was the Prymnesiophyte, *Phaeocystis pouchetii*. The species composition reflects the blooming situation and consequently typical stages (from early to late) of a bloom in the Arctic were found. This was also illustrated by a different amount of resting spores. Especially *F. oceanica* and *M. arctica* were found with a high number of resting spores at some of the stations. Samples from same location, but from different time of the cruise, also sometimes showed different blooming stages.

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6.4.2 Biomass and primary production

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An important goal is to compare how differences in the factors which control the generation of polynyas are reflected in their biological communities. The contribution of the Microplankton team to achieve these goals consists of determining the rate of primary production, the community structure of primary producers (both in terms of size distribution and taxonomic composition), the flux of biogenic carbon from the euphotic zone, and the recycling of production to the microbial food web and grazers. A station list with the parameters measured is presented in Table 6.1.

Table. 6.1: Inventory of the microplankton measurements including CO_2

STATIONS:		2	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	25	26	27	28	29	30	31*	32	33	34
PRIMARY PRODUCTIVITY	14C PROTOCOL		X					X					X								X						X	X	X	X	
in DECK INCUBATORS	15N PROTOCOL		X					X					X	X													X	X	X	X	
P-I CURVES	14C PROTOCOL																														
in a PHOTOSYNTHETRON																															
CHLOROPHYLL a	TOTAL (GF/F)	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X
	FRACTIONATED ON 5µ	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X
	FRACTIONATED ON 20µ																														
POC/PON	TOTAL	X	X					X					X								X						X	X	X	X	
	FRACTIONATED ON 5µ	X																										X		X	
BIOGENIC SILICA	TOTAL	X	X					X					X								X						X	X	X	X	
	FRACTIONATED ON 5µ																														
CELL PRESERVATION		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X
SINKING RATES (SETCOL)																												X		X	
SEDIMENTATION RATES (SEDIMENT TRAPS)																												X			
PICO-ALGAE															X	X												X			
HPLC			X			X		X					X					X												X	
PIGMENT LABELING																															
LIPIDS																															
BIOCHEMICAL COMPOSITION																															
ABSORBANCE SPECTRAL ANALYSIS																															
PH, TalK, TCO2, pCO2 (Univ. Liège)		X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X		X	X	X			X	X	X
UREA		X	X			X		X																			X		X	X	
BACTERIAL PRODUCTION			X			X		X					X					X			X								X		
BACTERIAL BIOMASS			X			X		X					X					X			X								X		
NANOFLAGELLATE BIOMASS			X			X		X					X					X			X								X		
MICROZOOPLANKTON BIOMASS			X			X		X					X					X			X								X		
MICROZOOPLANKTON GROWTH			X			X		X					X					X			X								X		
NANOFLAGELLATE COMMUNITY STRUCTURE			X			X		X			X		X					X			X						X		X	X	
DIATOM COMMUNITY STRUCTURE																															

STATIONS:		35	36	37	38	39	40	41	42	46	48	49	51	52	53	54	55	56	57	58	59	60*	62	64	66	68	70	72	74	76	81	82	84	85	86	87	88
PRIM. PRODUCTIVITY	14C		X				X		X	X				X			X				X	X						X		X				X			
in DECK INCUBATORS	15N		X				X			X				X	X	X	X	X				X	X					X		X		X		X			
P-I CURVES	14C																																				
in a PHOTOSYNTHETRON																																					
CHLOROPHYLL a	total	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	5µm	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	20µm																X																				
POC/PON	total		X				X		X	X							X				X	X						X		X				X			
	5µm																																				
BIOGENIC SILICA	total		X				X		X	X							X				X	X						X		X				X			
	5µm																																				
CELL PRESERVATION		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SINKING RATES			X			X											X					X										X		X			
SEDIMENTATION RATES						X																X							X								
PICO-ALGAE																							X														
HPLC			X				X			X							X									X		X		X				X			
PIGMENT LABELING							X										X													X							
LIPIDS																																					
BIOCHEMICAL COMP.																																					
ABSORBANCE ANAL.																																					
PH, TalK, TCO2, pCO2		X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
UREA			X				X			X					X	X	X	X				X	X					X		X		X		X			
BACTERIAL PROD.			X				X			X			X				X					X	X							X		X		X			
BACTERIAL BIOMASS			X				X			X			X				X					X	X							X		X		X			
NANOFLAGEL. BIOMASS			X				X			X			X				X					X	X							X		X		X			
MICROZOOPL. BIOMASS			X				X			X			X				X					X	X							X		X		X			
MICROZOOPL. GROWTH			X				X			X			X				X					X	X							X		X		X			
NANOFLAGEL. COMM.			X				X			X			X			X	X					X	X							X		X		X			
DIATOM COMMUNITY																																					

	STATIONS:	89	90	91	92	93*	95	98	99	100	101	102	103	104	105	108	109	110	113	114	115	116	118	119	120	121	123	128	129	130	133
PRIM. PRODUCTIVITY	14C	X				X	X		X	X			X			X		X			X			X		X				X	
in DECK INCUBATORS	15N	X				X	X		X	X			X					X			X			X		X					
P-I CURVES	14C																				X										
in a PHOTOSYNTHETRON																															
CHLOROPHYLL a	total	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	5µm	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	20µm	X				X										X		X			X			X		X				X	
POC/PON	total	X				X	X		X	X			X			X		X			X			X		X				X	
	5µm					X										X		X			X			X		X				X	
BIOGENIC SILICA	total	X				X	X		X	X			X			X		X			X			X		X				X	
	5µm															X		X			X			X		X				X	
CELL PRESERVATION		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SINKING RATES		X				X	X											X			X			X		X				X	
SEDIMENTATION RATES						X																									
PICO-ALGAE						X												X			X			X							
HPLC		X				X							X			X		X			X			X		X				X	
PIGMENT LABELING																															
LIPIDS																		X						X		X					
BIOCHEMICAL COMP.																										X					
ABSORBANCE ANAL.																															
PH, TalK, TCO2, pCO2		X	X	X		X	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X		X			X	X	X
UREA		X			X	X	X		X	X			X					X			X			X		X				X	
BACTERIAL PROD.		X					X		X	X			X			X		X			X			X		X				X	
BACTERIAL BIOMASS		X					X		X	X			X			X		X			X			X		X				X	
NANOFLAGEL. BIOMASS		X					X		X	X			X			X		X			X			X		X				X	
MICROZOOPL. BIOMASS		X					X		X	X			X			X		X			X			X		X				X	
MICROZOOPL. GROWTH		X					X		X	X			X			X		X			X			X		X				X	
NANOFLAGEL. COMM.		X				X			X	X							X	X	X		X	X	X	X		X					
DIATOM COMMUNITY																X	X	X	X		X		X			X	X		X	X	X

STATIONS:		134	135	136	137	138	140	141	142	143	144	145	155	156	157	159	163	165	166	168	169	170	172	175	176	177	178	179	186
PRIM. PRODUCTIVITY	14C	X	X	X	X	X		X	X	X	X	X	X					X	X	X		X	X	X		X		X	X
in DECK INCUBATORS	15N											X	X					X		X				X					X
P-I CURVES	14C	X				X						X								X						X			
in a PHOTOSYNTHETRON																													
CHLOROPHYLL a	total	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X
	5µm	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X
	20µm	X	X	X	X	X						X	X					X	X	X		X	X	X		X	X	X	X
POC/PON	total	X	X	X	X	X						X	X					X		X				X				X	X
	5µm	X	X	X	X	X						X	X					X		X				X				X	X
BIOGENIC SILICA	total	X	X	X	X	X						X	X					X		X				X				X	X
	5µm	X	X	X	X	X						X	X					X		X				X				X	X
CELL PRESERVATION		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X
SINKING RATES		X		X		X						X	X					X		X				X				X	X
SEDIMENTATION RATES																													
PICO-ALGAE												X						X						X					X
HPLC		X	X	X	X	X		X	X	X	X	X				X		X	X		X	X	X	X	X			X	X
PIGMENT LABELING						X										X													
LIPIDS		X				X						X	X					X		X						X		X	X
BIOCHEMICAL COMP.		X				X						X						X		X								X	X
ABSORBANCE ANAL.		X				X						X								X									
PH, TalK, TCO2, pCO2		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
UREA		X	X	X	X							X	X					X		X								X	X
BACTERIAL PROD.		X	X	X	X	X		X	X	X	X	X						X	X	X	X	X	X	X		X			
BACTERIAL BIOMASS		X	X	X	X	X		X	X	X	X	X						X	X	X	X	X	X	X		X			
NANOFLAGEL. BIOMASS		X	X	X	X	X		X	X	X	X	X						X	X	X	X	X	X	X		X			
MICROZOOPL. BIOMASS		X	X	X	X	X		X	X	X	X	X						X	X	X	X	X	X	X		X			
MICROZOOPL. GROWTH		X				X		X				X						X	X	X									
NANOFLAGEL. COMM.						X		X		X		X	X		X	X		X	X	X		X	X	X		X			X
DIATOM COMMUNITY		X		X		X	X		X	X		X	X			X	X	X	X	X	X	X	X	X		X	X	X	X

STATIONS:		189	192	194	195	196	197	199	201	206	210	217	218	219	220	221	223	224	225	226	227	228	229	231	238	240	242	244	246
PRIM. PRODUCTIVITY	14C	X					X		X	X	X	X		X		X	X			X			X		X				
in DECK INCUBATORS	15N	X										X																	
P-I CURVES	14C									X																			
in a PHOTOSYNTHETRON																X							X						
CHLOROPHYLL a	total	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	5µm	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	20µm	X					X					X		X	X	X	X			X			X		X				
POC/PON	total	X					X					X				X	X			X			X	X	X				
	5µm	X					X					X				X	X			X			X		X				
BIOGENIC SILICA	total	X					X					X				X	X			X			X	X	X				
	5µm	X					X					X				X	X			X			X						
CELL PRESERVATION		X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SINKING RATES		X	X	X								X				X	X						X						
SEDIMENTATION RATES																													
PICO-ALGAE												X																	
HPLC		X	X				X		X			X	X	X		X	X			X			X						
PIGMENT LABELING												X										X							
LIPIDS							X					X				X							X						
BIOCHEMICAL COMP.							X					X				X							X						
ABSORBANCE ANAL.										X		X				X							X						
PH, TalK, TCO2, pCO2		X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
UREA		X					X					X		X		X	X						X						
BACTERIAL PROD.												X	X	X	X	X	X	X	X	X									
BACTERIAL BIOMASS												X	X	X	X	X	X	X	X	X									
NANOFLAGEL. BIOMASS												X	X	X	X	X	X	X	X	X									
MICROZOOPL. BIOMASS												X	X	X	X	X	X	X	X	X									
MICROZOOPL. GROWTH												X				X				X									
NANOFLAGEL. COMM.				X					X	X	X	X	X			X	X			X			X						
DIATOM COMMUNITY		X	X		X		X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

STATIONS:		248	250	252	255	CAL	258	260	261	262	263	264	265	266	267
PRIM. PRODUCTIVITY	14C				X						X		X	X	X
in DECK INCUBATORS	15N														
P-I CURVES	14C														
in a PHOTOSYNTHETRON					X						X				
CHLOROPHYLL a	total	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	5µm	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	20µm				X		X	X	X	X	X	X	X	X	X
POC/PON	total				X		X				X		X	X	X
	5µm				X										
BIOGENIC SILICA	total				X	X									
	5µm				X	X									
CELL PRESERVATION		X	X	X	X		X	X	X	X	X	X	X	X	X
SINKING RATES															
SEDIMENTATION RATES															
PICO-ALGAE															
HPLC															
PIGMENT LABELING															
LIPIDS					X		X				X				X
BIOCHEMICAL COMP.					X		X				X				X
ABSORBANCE ANAL.					X		X				X				X
PH, TalK, TCO2, pCO2															
UREA															
BACTERIAL PROD.								X	X	X	X	X	X	X	X
BACTERIAL BIOMASS								X	X	X	X	X	X	X	X
NANOFLAGEL. BIOMASS								X	X	X	X	X	X	X	X
MICROZOOPL. BIOMASS								X	X	X	X	X	X	X	X
MICROZOOPL. GROWTH											X				X
NANOFLAGEL. COMM.									X		X		X	X	X
DIATOM COMMUNITY		X	X	X			X	X	X	X	X	X	X	X	X

Materials and methods

Primary production:^{14}C and ^{15}N labeling integrated on 7 or 4 photic depths (100, 50, 30, 15, 5, 1, 0.1%) and fractionated on Whatman GF/F and 5 µm pore size polycarbonate filters. 24h incubation in a deck incubator. Assay by LSC on board.

Chlorophyll *a*:: Fluorometric determination of chlorophyll *a* and phaeopigments on a Turner fluorometer model 112. Samples from 11 depths (7 photic depths including *in vivo* fluorescence maximum and 4 metric depths in the aphotic zone including bottom water sample). Fractionation on Whatman GF/F, 5 µm pore size polycarbonate filters and on 20 µm nylon textile filters.

POC/PON: Analysis on a Perkin-Elmer CHN analyser. Samples from 11 depths (7 photic depths including *in vivo* fluorescence maximum and 4 metric depths in the aphotic zone including bottom water sample). Filtration on pre-combusted GF/F filters. Pre-filtration on 5 µm pore size polycarbonate filters. Filters preserved at -20°C for later analysis.

Biogenic silica: Analysis according to Paasche 1980, Limnol. Oceanogr. Samples from 11 depths (7 photic depths including *in vivo* fluorescence maximum and 4 metric depths in the aphotic zone including bottom water sample). Filtration on 0.4 µm pore size polycarbonate filters and on 5 µm pore size polycarbonate filters. Filters preserved at -20°C for later analysis.

Cell preservation: Preservation of samples (200ml) in acidic lugol and/or alkaline formol at all photic depths and bottom depth.

Sinking rates (SETCOL): Sinking rates of particulate material from the in vivo fluorescence maximum are determined with the use of settling columns, according to Bienfang (1981, Can. J. Fish. Aquat. Sci.). Rates are established from fluorometric determination of chlorophyll *a* and phaeopigments. Subsamples are fractionnated on Whatman GF/F and 5 µm pore size polycarbonate filters. Preservation of subsamples in acidic lugol for taxonomic determination.

Sedimentation rates: 24h deployments of ice-moored and drifting sediment traps at 15 m and 25 m. Trap design: cylindrical with a width to height ratio of 1:6. Equiped with a baffle of a width to height ratio of 1:3. Analyses: Chlorophyll *a*, POC/PON, Total particulate matter, biogenic silica, pigment composition, taxonomy, nutrients.

Ice algae: Ice core sampling on first year ice. Analyses: Primary productivity, Chlorophyll *a*, POC/PON, biogenic silica, lipids, proteins, photosyntate allocation, spectral analysis, photosynthesis vs irradiance, pigment composition, taxonomy, nutrients, salinity.

Pigment composition: Analysis on High Performance Liquid Chromatography (HPLC). Samples from the photic depths (100, 50, 30, 15, 5, 1, 0.1%). Filtration on Whatman GF/F filters. Filters preserved in liquid nitrogen for later analysis.

Pigment labeling: Analysis on High Performance Liquid Chromatography (HPLC). ^{14}C labeling and 24h incubation in a deck incubator. Samples from surface water only.

PI curves: ^{14}C labeling on 2 photic depths (100 and 1%). Innoculation of 1mL of sample. 1h incubation in a photosynthetron deck incubator. Assay by LSC with water-accepting cocktail.

Biochemical composition: Samples from 2 photic depths (100 and 1%) and at *in vivo* fluorescence maximum. Filtration onto pre-combusted Whatman GF/F filters for later determination of proteins and free amino-acids (Clayton et al. 1988), lipids (Paasche 1980) and carbohydrates (Kochert).

End products: ^{14}C labeling of 2 photic depths (100 and 1%) and at *in vivo* fluorescence maximum. 24h incubation in a deck incubator. Fractionnation on Whatman GF/F, 0.4 and 5 µm pore size polycarbonate filters. Polycarbonate filters assayed by LSC on board and GF/F frozen under N_2 gas for later end-product and lipid class analysis.

Preliminary results

Although chlorophyll concentrations and primary productivity have not been computed for all stations, greatest abundances and biomass were observed along the northern part of the Norske trough (Transect 134-145) and on coastal waters. Highest algal biomasses were recorded in bottom ice during ARK IX/2 while phytoplankton biomass encountered during ARK IX/3 were greatest. Sedimentation rates and sinking rates from the euphotic zone were greatest at ice stations.

6.5 The Ecology of Arctic Melt Ponds

M. Carstens

In Arctic summer, melt processes at the ice/air interface lead to the formation of small puddles and larger ponds which in total may cover a large proportion of the ice surface (up to 60 % and more). Little is known about the ecology of these habitats which offer life conditions different from those prevailing in the sea-ice during most of the year. This study was designed to provide more details about melt ponds and the organisms inhabiting these particular habitats, their origin and the environmental conditions dominating their existence.

Materials and methods

Melt ponds from a total of 24 ice floes of various types were examined. In addition, samples were obtained from melt puddles in glacier ice and, for comparison, from a pond on land near the coast in the Kilen area. Furthermore, the drift experiment of ARK IX/3 offered the opportunity to mark a selected pond on a particular floe and revisit it at the end of the cruise. An inbetween visit had to be cancelled because of fog.

Routine measurements included temperature, pH, salinity and nutrients as well as pond dimensions and water depth. Chlorophyll a measurements were carried out on board using a Turner Fluorometer, whereas samples for CHN analysis were filtered onto Whatman GF/F filters and stored frozen to be worked up at home. Water samples were fixed with formaldehyde (1-1.5 % f. c.). For the determination of abundances of bacteria and small protists, DAPI-stained filter mounts were prepared on board and stored frozen until being analyzed in the home laboratory. The Utermöhl technique will be applied as well to supplement epifluorescence counts.

Preliminary results

The timing of ARK IX/3 was just right to match with this year's "melt pond season" in the investigated area. While melt ponds were reported to have been a rare sight during the previous leg, the situation had changed when "Polarstern" returned into the ice: melt puddles and ponds were common in the beginning and to be seen virtually everywhere later on. Towards the end of the cruise, re-freezing seemed to have started, as indicated for example by the changes the marked pond had undergone when we revisited it. More details about large-scale changes of the ice surface will be given by the Remote Sensing Group.

The majority of melt ponds investigated (Table 6.2) was freshwater with a water depth of 10 to 25 cm. The deepest one examined, however, was a lake-like pond of about 27.000 m^2 with a depth of at least 65 cm on the last floe visited.

The melt pond biota was dominated by bacteria and both auto- and heterotrophic flagellates. Brackish ponds were furthermore characterized by high numbers of large, rod-shaped bacteria. Nutrient and chlorophyll a values were low. In comparison with freshwater and glacier ponds, the land pond examined was thriving with life. A common organism in this pond was a Dinobryon-like flagellate. Dinobryon- and Protaspis-like flagellates were also present in melt pond waters. Diatoms were relatively abundant in foam and "dirty ice" found occasionally at the edges of some ponds as well as on the ground of the ponds. Further details must await closer microscopic examination of the material.

Table 6.2:. Melt ponds examined during ARK IX/3 and their characterisitics

Site #	Pond #	Ice Type	Position	Date	Pond Length	size Width	(m) Depth	Salinity (o/oo)
1	1	old	76°44,2'N	29.06.93	3,2	2,2	0,1	0,5
	2	old	08°16,7'W		17	9	0,15	0
	3*	old			nm	nm	nm	nm
2	4	old	76°52,1'N	29.06.93	52	34	28	0
	5	old	08°59,5'W		1,1	0,8	0,11	0
3	6	old	78°01,0'N	02.07.93	1,35	1,5	0,1	0
	7	old	16°36,3'W		7	3	0,13	0
	8	old			0,5	0,5	0,15	0
4	9	old	80°27,7'N	05.07.93	17,5	16,5	0,17	0
	10	old	13°40,1'W		28	11	0,2	0
	11	old			4	2	0,12	0
5.1	12	old	80°30,37'W	06.07.93	8,1	3	0,12	0
	13	old	10°34,37'W		64	60	0,2	0
	14*	old			nm	nm	nm	0
5.2	15	old	80°30,9'N 10°34,7'W	07.07.93	32	24	0,37	0
6	16	old	80°29,1'N	07.07.93	6,5	3	0,1	0
	17	old	10°15,52'W		28	15	0,13	0
	18*	old			nm	nm	nm	0
7	19	first year	80°28,06'N	07.07.93	15	6	0,45	0
	20	first year	09°59,89'W		12	7	0,11	0
	21	old			21	9	0,15	0
8	22	old	80°02,82'N 06°45,96'W	08.07.93	5	3,5	0,07	0
9	23	old	80°28,2'N 04°37,44'W	09.07.93	39	32	0,2	0
10	24	first year	80°02,7'N	09.07.93	6,3	2,7	0,1	1,5
	25	old ice	04°40,68'W		13	6	0,1	0
	26	old ice			1	0,8	0,08	0
11	27	first year	79°53,22'N 12°42,9'W	13.07.93	4	3	0,11	0
12	28	glacier	80°57,0'N	15.07.93	4	1	0,15	0
	29*	glacier	15°46,86'W		brook	0,4	0,3	0
13	30	fast ice	81°17,82'N	15.07.93	50	50	0,45	0
	31	fast ice	10°56,58'N		6	1	0,19	0
14	32	fast ice	81°18,61'N 11'31,2'W	16.07.93	46	13	0,2	0
15	33	land pond Kilen	80°58,85'N 14°39,79'W	21.07.93	666	407	0,65	0
16	34	old ice	80°07,72'N 16°55,33'W	22.07.93	48	12	0,42	<0,5
17	35	glacier	80°26,46'N 16°44,7'W	25.07.93	27	6	0,15	0
18	36	old ice	80°34,38'N	25.07.93	2,2	1,6	0,1	2
	37	Wegener Isld.	16°50,04'W		9	5	0,2	1
19	38*	old ice	79°50,46'N 05°30,12'W	27.07.93	nm	nm	0,2	0
20	39*	old ice	79°47,82'N 05°33,96'W	27.07.93	nm	nm	0,2	0

Site #	Pond #	Ice Type	Position	Date	Pond size (m) Length	Width	Depth	Salinity (o/oo)
21	40	old ice	79°13,38'N 03°28,68'W	28.07.93	30	5	0,4	1
22	41	old ice	79°10,62'N 03°30,66'W	28.07.93	channel	4	0,2	8
23	42	old ice	79°10,26'N	28.07.93	25	2	0,2	<0,5
	43*	cracked part	03°29,70'W		nm	nm	nm	1
24.1	44	old ice	78°47,88'N 10°01,02'W	29.07.93	28	11	0,3	0
24.2	45	old ice	78°45,24'N 10°50,16'W	29.07.93	27	16	0,22	1,5
25	46	first year	78°29,40'N 04°54,06'W	31.07.93	87	43	0,12	1
26	47	first year	78°32,28'N 04°57,84'W	31.07.93	32	18	0,2	0
27	48	first year	78°41,46'N 06°09,06'W	31.07.93	205	130	0,5	0

6.6 Sedimentation

E. Bauerfeind, O. Haupt, M. Wunsch

The NEW is a high production area surrounded by ice covered regions having a different production regime and lower productivity. The superior question of the working group is: Does the material produced in the polynya sediment in this region or is it exported to areas outside the Polynya? To solve this question we planned to examine the fate of the biogenic particles and quantify the vertical particle flux to the deeper layers as well as the modification of primary particles on the way through the water column. As the particulate organic material sedimenting to the seafloor represents the main food source of benthic organisms the determination of the particle flux also gives an estimation of the food potentially available to the benthos. To answer these questions it will be necessary to characterize the potential for biological productivity and to know the breakdown rates of detritus as a potential sink for biomass. We will also investigate the intensity and quantity of the detritus modification.

Materials and methods

For the investigation of the vertical particle flux different approaches were used:
- To study the seasonal pattern of the vertical particle flux in the polynya two longterm moorings were deployed during the NEWP 92 cruise of the US coast guard icebreaker Polar Sea in cooperation with American colleagues in July 1992. This moorings were part of 2 mooring lines across the northern trough of the polynya (Fig. 6.2). The moorings were deployed at a water depth of 335 m (E) and 295 m (F). Each mooring consisted of a sediment trap in 120 m, 1 current meter 20 m below the sediment trap and 1 current meter and transmission meter 12 m above the sea floor. The sampling intervals of the sediment traps were 10 days in the period August/September 92, 4-6 weeks during winter and 10 days from March to June 93.

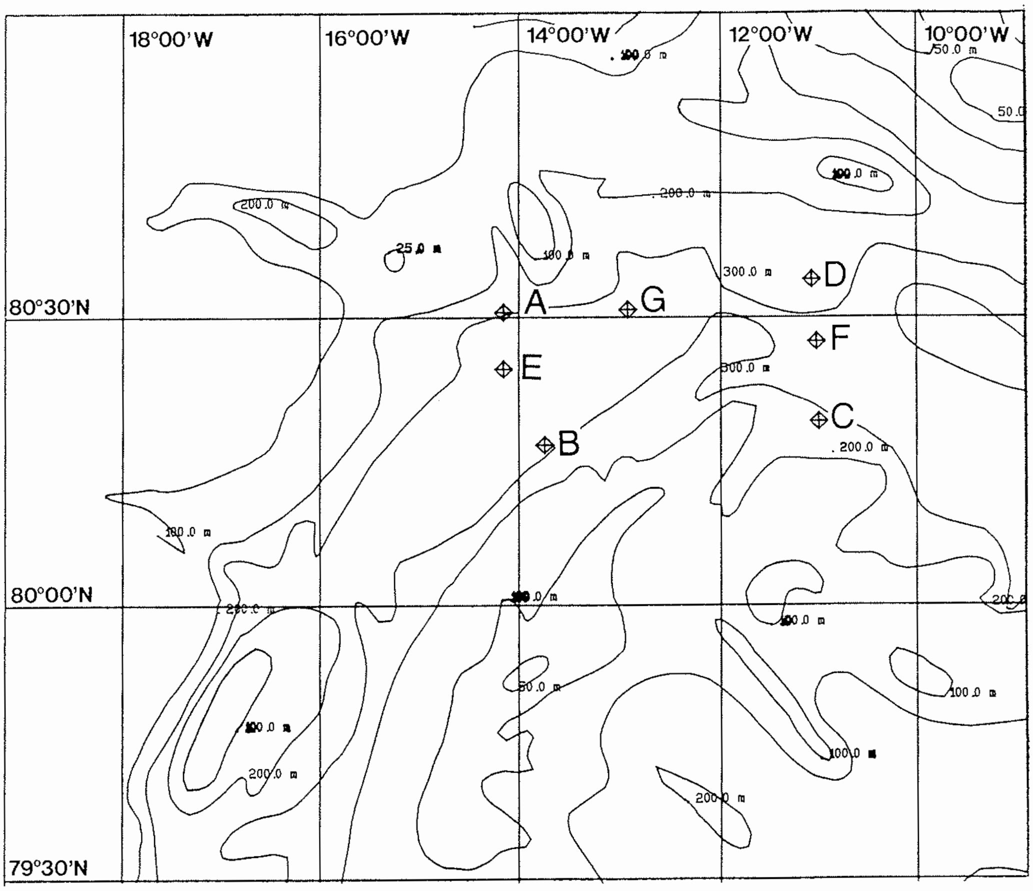


Fig. 6.2. Positions of the mooring lines across the Northern Trough of the North East Water Polynya. A, E, B - western line, C, F, D - eastern line. Moorings E and F were recovered during Polarstern cruise ARK IX/3. G - position of short-term mooring, deployed during leg ARK IX/2.

- To study the particle flux during the intensive investigations of Polarstern a short term mooring was deployed during leg 2 of the cruise on May 29 in the vicinity of the time series station at 80°30.75N 12°55.306W at a water depth of 298 m (G in Fig. 6.2). This mooring was equipped with 1 sediment trap in 130 m. The sediment trap in the short term mooring was programmed to sample in 3 day intervals till July 24.
- Drifting sediment trap. To study the sedimentation of particulate material from below the ice and along the drift path of an ice floe a sediment trap was installed beneath an ice floe. This study was done in close cooperation with the Canadian ice group. This group installed instruments for the measurement of oceanographic parameters underneath the same ice floe (see 3.3, this volume). This experiment was started on July 7 at 80°30.46N 10°35.46W. The drift path of the ice floe was traced by means of an ARGOS transmitter (Fig. 3.4).
- Mesocosms and zooplankton faecal pellet production. Three 1000 L tanks (ARK IX/2, see protocol) and two tanks (ARK IX/3, sta. 126) were filled with seawater. Samples for the analysis of nutrients, chl a, phytoplankton content, analysis of DOC, determination of primary production, bacterial production and the determination of nanoflagellates were taken in regular intervals. During ARK IX/2 also samples for lipid concentration of the particulate matter, nitrogen compounds and plankton abundance were taken.
- To measure the detritus breakdown we filled up 20 L bottles with filtered seawater (0.2 µm). In this water we suspended concentrated detritus of one tank and plankton of different size classes and took samples to analyse different nitrogen and carbon parameter. Through its feeding activity zooplankton concentrates phytoplankton and produces fast sinking particles which occasionally form a large fraction of the particles caught in sediment traps. To get a better insight in the origin of various forms of faecal pellets different groups of zooplankton occurring in the Polynya (copepods, ostracods, amphipods and pteropods) were incubated, the produced faecal pellets were collected, measured and their form and shape documented. Samples of the produced faecal material were also stored deep frozen for later analysis of their biochemical composition.

ARK IX/2

Station 18:	Filling of mesocosms tanks
Station 27:	Water sampling for preparing the short term mooring NEWP 93 G
Station 31:	Mooring of short term mooring NEWP 93 G and sampling of nutrients, C/N, Chl a and for microscopy
Station 38:	lowering of a 24-hours drifting sediment trap in a depth of 30 m
Station 59:	Icecamp II: mooring of a sediment trap 5 m under the ice. Sampling of the sedimented material for C/N and HPLC
Station 74:	lowering of a 24-hours drifting sediment trap in a depth of 30 m
Station 94:	Icecamp III: mooring of sediment traps 5 m and 10 m under the ice. Sampling of sedimented material for HPLC, C/N, Chl a and PSi
Station 98:	Sampling for TOC/TON
Station 99:	Sampling for TOC/TON, DOC/DON
Station 100:	Sampling for DOC/DON
Station 101:	Sampling for DOC/DON
Station 103:	Sampling for TOC/TON, DOC/DON
Station 104:	Sampling for DOC/DON
Station 105:	Sampling for TOC/TON, DOC/DON

Preliminary results

ARK IX/2: In the mesocosms the biological activity (primary production, bacterial production) showed very high rates and a sharp decrease of nitrate and silicate concentrations. The silicate concentrations suggest that the diatoms were the dominating phytoplankton in the tanks which is confirmed by microscopical observations. These results suggest a high biological production potential in the water column of the NEW which we did not find in the euphotic zone itself. The samples of the drifting sediment traps showed only few material. This can be explained by the early stage of the bloom in the open water aeras of the polynya. A detailed analysis of the different parameters will follow. In contrast to the drifting traps the samples from the under-ice-moored traps shows a lot of fluffy material because of the high abundance of the under ice flora. A detailed analysis of the material will follow.

ARK IX/3: All moorings were recovered successfully during ARK IX/3, however one current meter of mooring F was lost. First macroscopic examinations of the sedimented material showed some differences between the two mooring sites. At the western mooring site (E) a high amount of material sedimented shortly after the deployment of the sediment trap during August and September 92. After this period only very little material sedimented and not before June 93 a slight increase in the sedimented matter is apparent. At the eastern mooring site (F) highest sedimentation was also recorded during August/September albeit the material in the collector cups appeared to be less than at mooring site E. Another difference between the two mooring sites are the amount of swimmers in the samples. At mooring site F a considerable amount of swimmers (mainly copepods) are present in the samples during the whole deployment period, whereas at the western mooring site (E) only a few swimmers were observed in the samples after September 92. One may speculate that the observed differences are due to differences in the ice coverage, as mooring E was deployed in the open waters of the polynya whereas at mooring site F ice coverage was 90% at the time of deployment in 1992.

First results of the short term mooring (G) showed an increase of total flux from the beginning of the deployment towards the end of June when highest sedimentation (91 mg DW m^{-2} d^{-1}) was recorded (Fig. 6.3). After this period sedimentation decreased rapidly and stayed at about 15 mg DW m^{-2} d^{-1} till the end of the sampling period (July 24). The same pattern exhibiting a sedimentation pulse in the period June 15 - 28 was observed in the flux of Chl a equivalents (Fig. 6.3). During this period ca. 55% of total flux and flux of Chl a registered for the entire mooring period (June 1 - July 24) was recorded. During the time of deployment total flux (DW) amounted to 1.085 g m^{-2}. First microscopical analyses of the samples showed that the sedimented matter was dominated by phytoplankton organisms and ice algae were only present in smaller amounts. Most of the sedimented algae were healthy looking and chloroplast containing cells, indicating that particles of high nutritious value had sedimented to the seafloor. A detailed analysis of the species composition as well as the chemical and biochemical content of the sedimented matter will be done later on and will yield a more detailed information of the origin and nature of the sedimented particles.

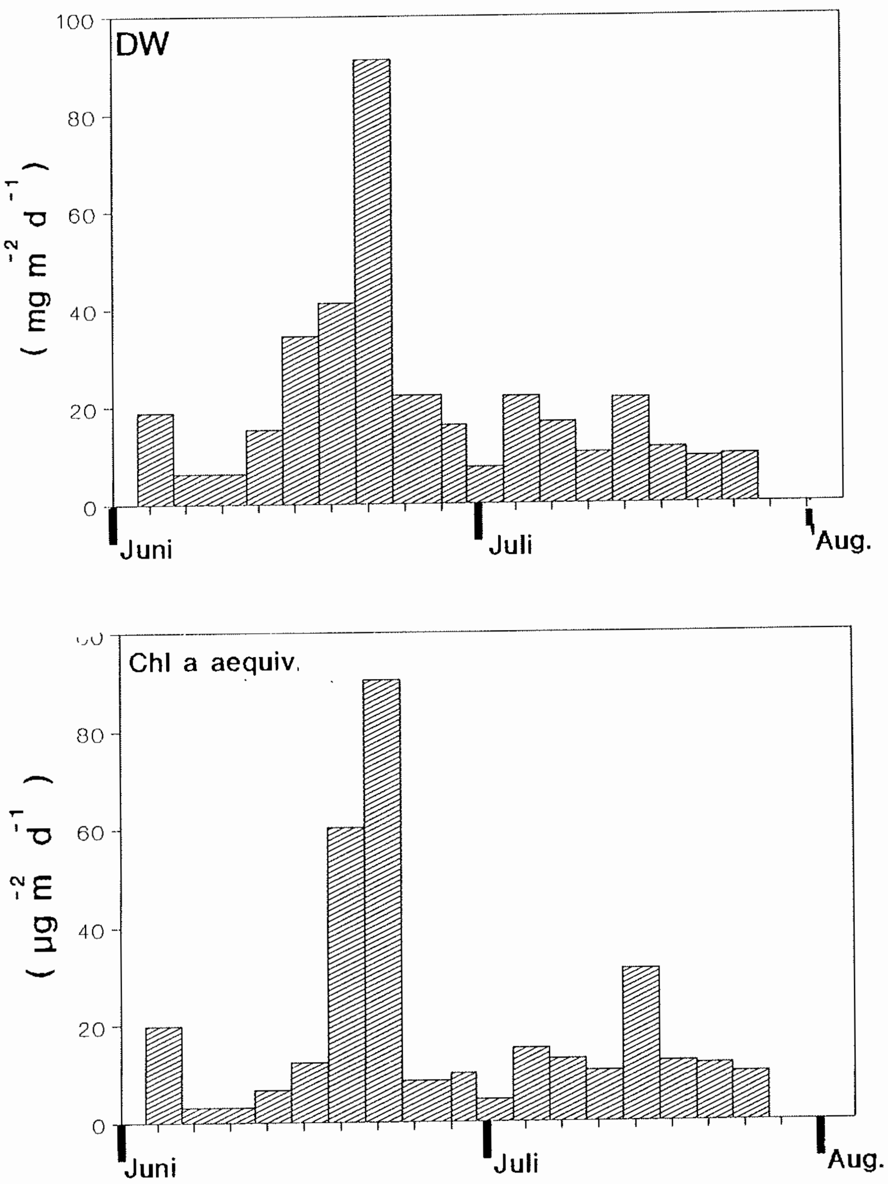


Fig. 6.3. Total flux (DW) and flux of Chl. a equivalents recorded during June / July 1993 in the short- term mooring in the NEW - Polynya at a depth of 120m.

The amount of sedimented matter observed in the drifting sediment trap beneath the ice floe which was sucessfully recoverd on July 29 at 78°48.07N 10°59.56W was less than expected. The ice floe drifted along the axis of the northern trough of the Polynya in southeasterly direction then turned to the south and drifted parallel to the continental slope following the 1000 and 1500 m isobath (Fig. 3.4). At 78°41.00'N 04°22.00'W the ice floe was influenced by an eddy that rapidly moved to the west. By following this eddy the ice floe drifted into shallow waters till its drift was slowed down by the ice pack at 10°W. During the 22 days of the experiment the ice floe drifted a distance of about 250 nm. The drift track of the ice floe may indicate the area into which biogenic particles produced in the Polynya are transported with the outflowing water.

7 ZOOPLANKTON

The central hypotheses of the zooplankton work are:

- the zooplankton communities inside and outside the polynya will differ in taxonomic composition, developmental stage structure, biomass and activity rates. Differences are also expected to exist on the vertical axis, between the Polar Surface Water (PSW) and the underlying Arctic Intermediate Water (AIW).

- the residence time of these communities in the polynya is sufficient for herbivores to exploit and incorporate a significant fraction of the high algal biomass that is assumed to develop in the open water.

- a change in the food web structure, with the short food web (diatoms - herbivorous copepods) dominating the open waters of the polynya, and a microbial web dominating the ice-covered areas. According to the hypothesis, the export of primary production to depth or higher trophic levels of the plankton should be inefficient where the microbial web dominates. An exception to this low efficiency may exist, when appendicularians "shunt" the microbial loop. Appendicularians, which filter picoplankton cells and bacteria, produce faecal pellets that can sink rapidly to deep waters. In addition, they are directly preyed upon by some species of fish larvae. Thus the pelago-benthic coupling is to a large extent dependent on the food web structure in the water column.

To address these hypotheses the main objectives are:
- to estimate abundances of planktonic herbivores and carnivores
- to compare the seasonal development of zooplankton communities in relation to the spring-summer production cycle within and outside the polynya.
- to measure rates of ingestion, egg and faecal pellet production
- to compare the grazing impact of copepods versus that of appendicularians
- to assess ingestion rate and diet of dominant planktonic carnivores
- to compare the abundance, first-feeding success and growth of fish larvae and early postlarvae in and outside the polynya and
- to relate these variables to the local availability of larval fish food, i.e. copepod eggs and nauplii.
- to obtain a preliminary estimate of the carbon flux through the herbivorous zooplankton compartment

- to estimate the role of predation in controlling herbivorous biomass by establishing a tentative budget of predation impact on prey populations for open and ice-covered waters.

7.1 Biomass and abundance of zooplankton

J. L. Acuna, K. Daly, D Deibel, L. Fortier, H.-J. Hirche, M. Michaud, B. Niehoff, P. Rowe, J. Wegner, V. Øresland

Materials and methods

A Bongo net equipped with 200 µm and 300µm mesh was towed vertically at 0.5 m s^{-1} used for the collection of mesozooplankton. The catch of the 200 µm net was split in two parts: one part was filtered on a GF/C filter and frozen for determination of dry weight and ash free dry weight; the other part was preserved in 4% buffered formalin for faunistic inventory. The catch of the 500 µm net was sorted for live animals to be used in various experiments such as egg production, gut evacuation, faecal pellet deposition or for analysis of gut pigments. A small net with an opening of ca. 12 cm and 90 µm mesh was attached to the Bongo net. The catch was also preserved in formalin. It should provide information on the food of larval fish.

A multinet (Hydrobios, Kiel) was equipped with 150 µm mesh to study the vertical distribution of zooplankton. Stratified samples were taken vertically either in intervals of 100 m or in intervals of 0-25-50-100-200-bottom. The whole catch was preserved. During a short period the WP-2 net with 100 µm mesh was used in vertical tows to collect potential prey organisms for carnivorous plankton.

Somatic growth will be derived from seasonal variations in population structure (stage frequencies) and weight increases of developmental stages. At various locations developmental stages of the dominant herbivorous copepods were measured and deep frozen for carbon analysis. In Table 7.1 the activities of the zooplankton groups are summarized.

Table 7.1: Inventory of zooplankton samples. Different net types: bongo net, multi net, RMT, WP-2. Samples were preserved for analysis of abundance, biomass, egg production of Calanus glacialis (EP), grazing by HPLC gut pigment analysis (GHPLC: H=Calanus hyperboreus, G=C. glacialis, M= Metridia longa), faecal pellets, gut content of carnivores (GCC), fish larvae (B=Bongo, R=RMT), appendicularians, grazing by gut fluorescence (GFlu).

Sta.	Bongo	MN	RMT	WP	Abund	Biomass	EP	GHPLC	FP	GCC	Fish L.	App.	GFlu
1	X				X	X				X			
2	X	X	X		X	X				X	X		
3	X				X	X				X			
4	X				X	X				X			
5	X	X			X	X	X			X		X	
6	X				X	X	X	X	XH	X			X
7	X				X	X	X	X		X	X		X
8	X	X			X	X	X	X		X		X	X
9	X				X	X	X	X		X	X	X	X
10	X				X	X	X	X		X		X	X
11	X	X			X	X	X	X		X			X
12	X				X	X				X			X
13	X					X							
14	X				X	X	X	X		X	X		X
15	X				X	X	X			X			X
16	X				X	X	X	X	XG	X			X
17	X	X			X	X	X	X		X			X
18			X								X		
19	X				X	X	X	X		X			X
20	X				X	X	X	X		X			X
21	X	X			X	X	X	X	XG	X			X
22	X				X	X		X		X			X
23	X	X			X	X	X			X			X
24	X				X	X	X	X		X		X	X
25	X				X	X	X			X		X	X
26	(X)				(X)		X			X			
27	X	X			X	X	X	X		X			X
28	X				X	X	X			X			X
29	X				X	X	X			X			
33	X			X	X	X	X	X		X			X
34	X		X		X	X				X	X		X
35	X			X		X		X		X	X		
36	X					X				X			
37	X			X		X				X	X		
38	X		X			X				X	X		
39	X			X		X	X	X		X	X	X	X
40	X					X	X	X		X		X	X
41	X		X	X		X	X	X		X	X		
42			X								X		
43	X					X				X	X	X	X

Sta.	Bongo	MN	RMT	WP	Abund	Biomass	EP	GHPLC	FP	GCC	Fish L.	App.	GFlu
44	X		X	X		X	X	X	XG	X	X		X
45	X		X			X	X	X	XH	X	X	X	X
46	X			X		X	X	X		X			
47	X		X			X	X	X		X	X		X
48	X			X		X	X			X			X
49	X					X	X			X			
51	X			X		X	X			X			X
52	X			X		X	X			X	X		X
53	X		X	X		X	X			X	X		X
54	X			X		X	X	X	XH	X			X
55	X		X	X		X	X	X	XH	X	X	X	
56	X			X		X	X	X	XH	X	X	X	X
57	X		X	X		X	X			X	X		X
58	X			X		X	X			X			X
60								X	XH				X
61	X	X				X	X			X			
62	X					X	X	X		X			X
63	X		X			X	X			X	X		X
64	X			X		X	X			X			
65	X					X	X			X	X		X
66	X					X				X	X		X
67	X					X	X			X			X
68	X					X	X	X		X			X
69	X				X	X				X	X		X
70	X				X	X				X	X		
71	X		X		X	X	X			X	X		
72	X			X	X	X				X			
73	X				X	X	X			X			
74	X			X	X	X	X	X		X			X
75	X				X	X	X	X		X			X
76	X		X		X	X	X	X		X	X		X
77	X				X	X	X			X			
80	X	X			X	X	X			X			X
81	X				X	X	X			X			X
82	X				X	X	X			X			X
83	X				X	X	X			X	X		X
84	X			X		X							
85	X	X		X	X	X	X	X		X			
86	X			X	X	X				X	X		
87	X				X	X	X			X	X		X
88	X		X		X	X	X			X	X		
89	X			X	X	X	X	X	XH	X		X	X
90	X			X	X	X	X	X		X			
91	X		X		X	X	X	X		X	X		X
92	X				X	X	X	X		X			X
93	X			X	X	X	X	X		X			X

Sta.	Bongo	MN	RMT	WP	Abund	Biomass	EP	GHPLC	FP	GCC	Fish L.	App.	GFlu
93	X			X	X	X	X	X		X			X
94	X				X	X	X			X			X
95	X				X	X	X			X			
98	X				X	X	X	X	X M	X		X	X
99	X				X	X	X			X			X
100	X				X	X	X	X		X		X	X
101	X				X	X	X			X	X		X
102	X				X	X	X			X			
103	X				X	X	X	X	X H	X			
104	X				X	X				X			
108	X	X	X		X	X		X	H				
109	X	X		X	X	X	X	X	H				X
110	X	X		X	X	X	X	X					X
111	X	X			X	X	X						
112	X			X	X	X	X						X
113	X				X	X	X						X
114	X	X			X	X	X						X
115	X				X	X	X						X
116	X				X	X	X				B		X
117	X	X		X	X	X	X					X	X
118	X			X	X	X	X	X	H		B	X	X
119	X			X	X	X	X				B	X	X
120	X	X		X	X	X	X					X	X
121	X				X	X	X	X	G				X
123	X	X			X	X	X					X	X
125	X				X	X	X				B	X	X
126	X				X	X	X						X
127	X		X		X	X							X
128	X				X	X							X
129	X		X		X	X							X
130	X				X	X	X						X
131	X		X		X	X	X				R		
132	X				X	X							X
133	X		X		X	X					R		X
134	X	X			X	X		X	H				
135	X		X		X	X	X	X	H				X
136	X	X			X	X	X	X	H				X
137	X		X		X	X	X	X	H		R		X
138	X	X		X	X	X	X	X	H				X
139	X	X			X	X	X						X
140	X			X	X	X	X						X
141	X	X			X	X	X						X
142	X				X	X	X	X	G, H				X
143	X	X			X	X	X	X	H				X
144	X		X		X	X	X	X	H		R		X
145	X	X		X	X	X	X	X					X

Sta.	Bongo	MN	RMT	WP	Abund	Biomass	EP	GHPLC	FP	GCC	Fish L.	App.	GFlu
147	X	X		X	X	X	X						X
148	X	X		X	X	X	X					X	X
149													X
150	X				X	X	X					X	X
151	X				X	X	X					X	X
152	X				X	X	X						
153	X				X	X	X					X	X
154	X				X	X	X					X	X
155	X			X	X	X	X					X	X
156	X			X	X	X	X						X
157	X		X		X	X	X				R		X
158	X				X	X							
159	X		X		X	X	X				R		X
160	X				X	X	X						
161	X		X		X	X					R		X
162	X				X	X					B		
163	X		X	X	X	X	X				R		X
165	X			X	X	X	X	X	H				X
166	X		X		X	X					R	X	X
167	X				X	X		X					
168	X		X		X	X	X	X			R		X
169	X				X	X	X	X					
170	X		X		X	X	X				R		X
171	X				X	X	X						
172	X		X		X	X	X				R		X
173	X				X	X	X	X	G				
174												X	X
175	X				X	X	X						
176	X				X	X	X	X			B	X	X
177	X	X			X	X	X					X	X
178	X				X	X	X						X
179	X				X	X	X	X	H				X
180	X		X		X	X	X				R		
181	X				X	X	X						
182	X		X	X	X	X	X				R		
183	X				X	X	X						
184	X				X	X	X						
185	X			X	X	X	X				B		
186	X		X		X	X	X	X	H		R		X
187	X				X	X							
188	X		X		X	X	X				R		
189	X				X	X		X				X	X
190	X				X	X	X						
191	X		X		X	X					R	X	X
192	X				X	X	X				B	X	X
193	X				X	X							

Sta.	Bongo	MN	RMT	WP	Abund	Biomass	EP	GHPLC	FP	GCC	Fish L.	App.	GFlu
194	X		X		X	X	X				BR	X	X
195	X				X	X	X						
196	X				X	X							
197	X		X	X	X	X	X	X	H		R	X	X
198	X				X	X	X						
199	X				X	X	X						
200	X				X	X	X						
201	X		X		X	X	X	X	H				X
202	X				X	X	X						
203	X				X	X	X						
204	X				X	X							
205	X				X	X	X						
206	X		X	X	X	X	X				R		X
207	X				X	X	X						
208	X				X	X	X					X	
210	X				X	X	X						
211	X				X	X							
215		X											
216		X											
217	X				X	X		X					X
218	X	X			X	X	X	X				X	X
219	X			X	X	X	X	X			"RF"		X
220	X				X	X	X				B		
221	X				X	X	X						X
222	X		X		X	X	X				BR		
223	X				X	X		X	H, G				X
224	X				X	X	X						
225	X		X		X	X					R		X
226	X				X	X	X	X				X	X
227	X		X		X	X	X				R		
228	X				X	X	X					X	X
229	X		X	X	X	X					R		X
231	X				X	X							X
232	X	X	X		X	X					R		
233	X				X	X	X						
234	X		X		X	X	X				R		
235	X		X		X	X	X				R		
236	X	X		X	X	X	X						
237	X			X	X	X	X						
238	X	X			X	X	X						X
240	X		X		X	X	X				R		X
242	X				X	X							
244	X		X		X	X					R		X
246	X				X	X	X						
248	X		X		X	X					R		X
250	X				X	X							

Sta.	Bongo	MN	RMT	WP	Abund	Biomass	EP	GHPLC	FP	GCC	Fish L.	App.	GFlu
252	X		X		X	X					R		
254	X		X		X	X					R		X
259	X				X	X	X				B		
260	X		X		X	X	X				R		X
261	X	X			X	X	X						
262	X		X		X	X	X				R		
263	X	X		X	X	X						X	X
264	X		X		X	X	X				R	X	X
265	X				X	X	X						
266	X	X			X	X							
267	X				X	X	X						X
270													
271	X	X			X	X	X						
272	X				X	X	X						
273	X	X			X	X	X						
279	X	X			X	X							

7.2 Grazing of herbivorous zooplankton

J.L. Acuna, D. Deibel, K. Daly

Our specific goal was to evaluate the relative community ingestion rates of planktonic copepods and appendicularian tunicates along the spatial gradient from open water to beneath the ice.

There are many methods from which to chose to approach this goal, but few are appropriate to both copepods and tunicates, and few have the capability to be used in a broad-scale expedition with many stations spread over space and time. Thus, we elected to use the gut phytopigment method in which the pigment content of the guts of individual, wild-captured zooplankters is determined fluorometrically and some measure of gut turnover time is determined independently in short-term, shipboard incubations, in order to derive estimates of ingestion rate. During this cruise, we have become the first investigators to collect living appendicularians with nets and to conduct experiments with them onboard ship. This was made possible due to several new technical developments (see Methods).

Materials and methods

Gut pigment determination: The gut phytopigment method has the advantages of deriving "in situ" ingestion rates without lengthy shipboard incubations, can be applied to individual grazers and is relatively quick while on station. It may, however, yield underestimates of ingestion rate if digestion processes within the guts of the grazers results in the destruction of chlorophyll or phaeopigments to non-fluorescent products. We have made extensive examination of this problem over the past several years and are convinced that under most conditions the underestimates are not large for planktonic copepods (Deibel & Redden, unpubl.).

Tunicates and copepods were collected using vertical hauls of a 200 µm mesh net with a 0.5 m diameter mouth from 200 m depth to the surface. Codend contents were immediately taken to a 0°C cold container laboratory and diluted with filtered seawater from near surface. Following the removal of a sub-sample for taxonomy, ca. 50 copepods were sieved from the bucket with a 500 µm mesh cup and rinsed repeatedly in filtered seawater to remove phytoplankton. Next, the content of the sieve cup was concentrated and pipetted onto a 45 mm diameter disk of sharkskin filter paper, folded into an aluminum foil sleeve and flash frozen in liquid nitrogen. Samples were stored at -20°C until analysis.

Following removal of the copepod subsample, appendicularians were picked by hand from the remaining codend contents. Each was rinsed repeatedly in filtered seawater, and pipetted into a well slide. After 5-20 animals had been rinsed, each was identified and measured under red light in a dissecting microscope to the nearest 0.02 mm, and the number of fecal pellets present recorded. The house rudiment and tail were then surgically removed and the trunk and fecal pellets transferred to a 1.5 ml Eppendorf tube which was flash frozen in liquid nitrogen and stored as above for copepods.

The following summary contains the standard protocol used in our laboratory for gut pigment analysis. The sharkskin filters are thawed at 0°C and individual copepods identified, staged and measured under red light with a dissecting microscope. Copepods are mechanically ground and pigments extracted in 90% acetone. Pigment analysis is done by the standard fluorometric technique using a Sequoia-Turner model 450 instrument calibrated against a pure chlorophyll standard. Total phaeopigments are determined after acidification of the extract. The extracted samples are maintained at 0°C during the entire analysis. Sufficient animals are pooled within species and stage to avoid reading on the highest gain setting. Periodically, samples are set aside for detailed pigment composition analysis using HPLC.

Eppendorf tubes containing individual appendicularians are sonicated for 10 min and extracted in 90% acetone. Pooling and fluorometric analysis is done as above for copepods. Blanks for subtraction are determined on animals that have been maintained for at least 48 h in filtered seawater to allow for complete gut evacuation.

Gut passage time copepods: Copepods for gut passage time experiments were collected from the 200 µm mesh plankton net as above for gut pigment analysis. Following isolation with a 500 µm mesh sieve cup, the animals were backwashed into 500 ml of water collected with a Niskin bottle from the subsurface chlorophyll maximum (SCM). At the same time, 400 mL of water from the SCM was stained with 2 drops of concentrated neutral red stain. After a pre-incubation interval of from 1-12 h, 20 mL of the stained sample was poured into each of 20 petri dishes. Next, a single animal was pipetted into each dish and the initial time recorded. For the next 4 h each dish was examined microscopically for fecal pellets every 20 min, followed by examination each 60 min up to 6 h after time initial. All fecal pellets were recorded, and the time of appearance of the first fecal pellet containing stained phytoplankton recorded. The gut passage time was defined as the interval between the initial time and the time of appearance of the first stained phytoplankton in a pellet. The animals were then left for 12 h and examined to determine the total number that released stained fecal pellets. Following the experiment, each animal was identified and staged, and the cephalothorax length measured to the nearest 0.04 mm.

Gut passage time appendicularians: Appendicularians for gut passage time experiments were collected with a Reeve-Feigenbaum, large codend plankton net made of 110 µm mesh. The net is 1 m in diameter, and the closed, acrylic codend measures 30 x 60 cm. The net was towed very slowly from 100 m to the surface. Immediately after the tow the codend was carried to the 0°C laboratory container, and appendicularians in their houses removed with a custom designed, large diameter "super pipette" slurp syringe that we have recently developed (Acuna, unpubl.). Single animals were transferred to beakers of water collected from beneath the SCM, which was pre-filtered through 20 µm mesh. Next, the beakers were hung from the ceiling of the container from elastic bands. This independent suspension system was necessary because we found the appendicularians to be impossible to maintain in beakers on the laboratory bench apparently because of their sensitivity to ship vibrations, particularly during ice-breaking operations. We found appendicularians in these hanging beakers to behave normally, and to build a number of houses over 12-24 h time. We did not attempt to determine how long we could maintain appendicularians alive using this system.

After it was determined that an appendicularian was pumping normally within its house, a dilute suspension of cornstarch was added to the beaker and mixed gently. Over the next several hours each animal was observed continuously, and the time of appearance of each fecal pellet recorded. The gut passage time was defined as the difference between the initial time and the time of appearance of the first fecal pellet containing the white cornstarch marker. Fecal pellet production rate was calculated by dividing the total number of pellets produced by the incubation interval.

Particle size selection appendicularians: The small size retention capabilities of appendicularians are relatively well known, with a cutoff size of ca. 3 µm (Deibel and Lee, 1992) and with a proven capability to retain large colloids with appreciable efficiencies (Flood, Morris and Deibel, 1992). The large size cutoff is less well known, but is likely constrained by the pore size of the rectilinear mesh comprising the incurrent, "pre-filter" on the surface of the "house" within which appendicularians live. Flood (1991) has recently developed a technique for isolating houses onto permanent dry mounts for microscopic determination of incurrent filter pore size. We have used his technique on this cruise to make a catalogue of incurrent filter pore sizes throughout the polynya area, and have made Nomarski-DIC photomicrographs of some of the houses onboard ship, with the kind assistance of Dr. Helge Thomsen.

Part of the material, especially *Calanus hyperboreus, C. glacialis, Euchaeta norvegica, E. glacialis, and Metridia longa,* was frozen in liquid nitrogen for measuring chlorophyll pigments and their phaeopigment derivatives and carotenoid pigments by high performance liquid chromatography (HPLC) after the samples are returned to the laboratory.

Additional adult female copepods were sorted from net tows for live shipboard experiments, including gut passage time/ fecal pellet production, gut egestion rate, and ingestion rates. Pigment loss may occur during gut passage, therefore, pigment degradation in copepds also was measured using biogenic silica as a conservative tracer of feeding activity.

The contribution by copepods to the particle flux will be estimated from the fecal pellet production experiments. In addition, fecal pellets were collected from experiments for CHN analysis and pigment content. The results will be compared to the composition of material collected in sediment traps.

Summary of activities: We made 26 R-F net tows to collect living appendicularians for gut passage time experiments. A total of 21 appendicularians were observed for gut passage time, with 18 of them being used also for determination of fecal pellet production rate. 41 appendicularian houses were isolated, dried and mounted for measurement of incurrent filter pore size.

We collected samples from 83 Bongo net tows for the determination of gut pigment content in copepods and tunicates. 83 subsamples were processed for copepod gut pigment content, with ca. 50 animals per filter, or a total of 4,150 animals for pigment extraction. We conducted 15 gut passage time experiments with copepods, observing a total of 276 animals. 28 of the Bongo samples were further processed for the isolation of appendicularians for gut pigment analysis. 280 appendicularians were frozen for gut pigment determination.

Results and discussion

Spatial distribution of appendicularians: Two species of appendicularian tunicates were common in the area of the NEW polynya, *Oikopleura labradoriensis* and *Oikopleura vanhoeffeni*. However, the most abundant pelagic tunicate in many cases was a smaller species, *Fritillaria* spp. Appendicularians were most common in the East Greenland Current, and within the polynya, in a narrow band alongshore and all along the ice edge, including under the ice. A few appendicularians were encountered at almost every open water station within the polynya. In general, appendicularians were more common to the north, and were least abundant along the Norske Øer ice barrier.

Fritillaria spp. was most common nearshore to the north in the polynya, particularly just south of the northern ice nose. This tunicate was also abundant on the southeastern ends of the two transects made to the north of the northern ice nose. One Niskin bottle sample from this area contained >10,000 *Fritillaria* m^{-3}. It is worth mentioning that a number of animals were collected that possessed taxonomic characteristics intermediate between those of *O. vanhoeffeni* and *O. labradoriensis*. This may be a third species, perhaps undescribed. Resolution of this question must await further examination of animals at our home laboratory.

Gut pigment content: At present, we have analyzed only a portion of the appendicularians from ARK IX/2. Gut pigment content ranged from < 2 to ca. 40 ng per animal, with >95% of the total piments being phaeopigments. It already appears that gut pigment content in appendicularians in the NEW polynya can be predicted from a log-linear relationship with body size, particularly when samples are grouped according to station and/or food concentration. Analysis of the gut pigment content of copepods and appendicularians from ARK IX/3 will be done at our laboratory onshore.

Gut passage time: Table 7.2 contains an initial descriptive statistical analysis of the gut passage time (GPT) experiments done with copepods. GPT ranged from ca. 1 h for adult females of *C. finmarchicus* to ca. 3 h for adult females of *C. glacialis*. The GPT results are most distinguished by their variability, with coefficients of variation within stages ranging from 29-85%. In many cases the GPT data were not normally distributed, therefore the median GPT's are reported in Table 7.3. In general, GPT decreased with increasing stage and body size within each species, with significant regressions between GPT and body size in *C. finmarchicus* (n=23, F=3.37, p=0.08) and *C. hyperboreus* (n=86, F=6.21, p=0.01), and between GPT and stage in *C. hyperboreus* (n=86, F=5.60, p=0.02). In all cases, the above regression slopes were negative. However, due to the high variability of the GPT data, the proportion of variance accounted for by the above regressions was never > 10%. It should be remembered that many factors can affect GPT, including temperature, body size, food concentration, time of day, etc. How much of the total variance remaining that may be explained by these other factors awaits further data analysis onshore.

Table 7.2: Summary statistics of the gut passage times of developmental stages of 3 copepod species in the NEW polynya, determined on single individuals fed naturally occurring phytoplankton pre-stained with neutral red.

Species	Stage	Sex	n	Mean gut passage time (min)	confidence limits (95%)	CV (%)
C. finmarchicus	C2	-	4	169	58-280	44
	C3	-	4	164	26-302	56
	C4	-	8	140	82-198	59
	C5	-	6	116	46-186	85
	C6	f	1	61	-	-
C. glacialis	C4	-	13	172	116-228	58
	C5	-	37	144	114-174	63
	C6	f	2	186	69-303	29
C. hyperboreus	C3	-	16	156	124-188	41
	C4	-	21	161	123-199	54
	C5	-	38	129	107-151	52
	C6	f	11	100	60-140	68

These GPT data are similar to data we have collected on *C. finmarchicus* and *C. hyperboreus* in coastal Newfoundland waters and on the Grand Banks at similar water temperatures to those in the NEW polynya. Using the more conventional gut pigment evacuation rate technique, we have determined rates of ca. 1 h for adult *C.finmarchicus* (Redden & Deibel, unpubl.). Using the neutral red technique used on this cruise, we have found GPT's ranging from 1-2.5 h for developmental stages of both of the above species in Newfoundland waters.

Table 7.3: Median gut passage times of 3 copepod species from the NEW polynya, including the proportion of animals that did not feed during our experiments.

Species	Stage	Sex	n	Median gut passage time (min)	% of animals not feeding
C. finmarchicus	C2	-	4	169	33
	C3	-	4	151	50
	C4	-	8	122	43
	C5	-	6	85	63
	C6	f	1	-	83
C. glacialis	C4	-	13	159	24
	C5	-	37	115	14
	C6	f	2	186	0
C. hyperboreus	C3	-	16	127	45
	C4	-	21	166	19
	C5	-	38	115	16
	C6	f	11	64	21

Table 7.4 contains summary statistics of the gut passage time experiments done with appendicularians using a cornstarch marker.

Table 7.4: Statistical summary of the gut passage times of 2 appendicularian tunicate species in the NEW polynya, determined using a cornstarch marker technique.

Species	n	Mean length (mm)	SD length	Mean gut passage time (min)	SD passage time	CV (%)
O. labradoriensis	12	1.46	0.33	78	21	27
O. vanhoeffeni	10	2.73	0.58	70	23	32

The mean GPT's of the appendicularians were similar to those of adult female copepods, i.e. ca. 1 h. Also, the appendicularian results were somewhat less variable than were those of the copepods, with CV's of ca. 30%. Using a non-parametric test, there was not a significant difference between *O. labradoriensis* and *O. vanhoeffeni* in GPT (Kruskal-Wallis, p=0.26). Body size was unrelated to GPT in *O. labradoriensis* (p=0.96), whereas there was a significant linear regression between GPT and body size in *O. vanhoeffeni* (n=10, r-squared=50%, p=0.02). The slope was positive, which indicates that GPT was longer as body size increased.

Fecal pellet production appendicularians: The mean fecal pellet production rate of *O. labradoriensis* and *O. vanhoeffeni* was essentially the same, ca. 40 pellets per day, with coefficients of variation ranging from 27-42%. Fecal pellets of appendicularians often remain trapped within the house, which is shed at regular intervals. The houses of appendicularians have sinking velocities of ca. 100 m per day, which means that these fecal pellets can make a significant contribution to the vertical flux of carbon, nitrogen and pigments. Dr. Bauerfeind has found many houses of appendicularians in the contents of his sediment traps that had been moored in the northern trough for the past year. This indicates that at least in summer, the vertical flux of tunicate feces and mucous material is substantial.

Incurrent filter pore size: We have managed to examine the incurrent filter pore dimensions of 3 specimens of *O. labradoriensis* onboard, during the cruise. The 3 animals ranged in body size from 1.4-2.0 mm, and had mean incurrent filter pore widths of 73, 72 and 20 µm. This suggests that the first two individuals could potentially ingest rather large particles, including both solitary and chain-forming diatoms, whereas the third animal would ingest primarily microplankton, nanoplankton and smaller microbial cells. This disparity in pore width within the same species is not typical (i.e., 70 vs. 20 µm), and suggests there may be a third species of appendicularian in the NEW polynya, as mentioned above.

Ingestion rates: Since much of the fluorometric work remains, it is difficult at this time to present community ingestion rate results. However, by combining gut pigment determinations from the two legs, we can at least illustrate how the calculations are made. From Table 7.4, we see that the mean gut passage time of *O. labradoriensis* is ca. 1 h. The gut pigment data from leg 2 (data not shown) indicate a mean of ca. 20 ng per animal. The pigment ingestion rate is simply the gut content divided by the passage time, or in this case, 20 ng per h. If the carbon:chlorophyll ratio is taken to be ca. 50, this indicates an ingestion rate of ca. 1 µg C h^{-1}, or 24 µg C d^{-1} (appendicularians feed continuously on a diel basis), in the form of pigmented food only. Any contribution of detrital, microbial or colloidal carbon to the daily ration will raise the total figure above 24 µgC d^{-1}. The rationale of the calculations is essentially the same for copepods. Of course, the estimation of a total community ingestion rate for tunicates and copepods awaits data on the abundance of both groups from the Bongo and Multinet samples.

7.3 Egg production of *Calanus glacialis*

H.-J. Hirche, B. Niehoff, J. Wegner

Materials and methods

For the assessment of the egg production of *Calanus glacialis* ten to forty females were sorted from the 300 µm bongo catch immediately after collection and incubated in 3 L beakers at -0.5°C in filtered sea water. If possible, two replicate experiments were set up. As the spawning interval of *C. glacialis* in Polar Water (≤0°C) is ca. 2 d, most incubations were run for 24 to 48 h. At some stations the length of individual females was measured and females were frozen for later carbon analysis. This data will be used to relate the carbon deposited as eggs to female carbon (specific egg production). To induce spawning, some females were removed from the catch, starved for 1 d and subsequently exposed to cultures of the diatom *Thalassiosira antarctica*, which is a frequent species on the East Greenland shelf, at concentrations >200 µg carbon L^{-1}. For up to 10 d egg production was checked daily and fresh food added. The effect of starvation on egg production was measured throughout the cruise by keeping single females in filtered sea water for several days. Egg production was checked daily and fresh water added.

7.4 Carnivorous zooplankton

V. Øresland

Materials and methods

Planktonic carnivores were sorted out from all bongo (200 µm and 500 µm) and WP2 (90 µm, 1/4 m^2) samples. Main species were investigated: the copepods *Euchaeta gracialis* and *E. norwegica* and the chaetognath *Eukrohnia hamata*. Some of the more common amphipod and ostracod species were also included in the analyses. Estimates of abundances, diet and predation impact will be carried out after the expedition.

Gut evacuation time of the two *Euchaeta* species were determined during the cruise. 20-30 *Euchaeta* were isolated in filtered seawater (30-40 L) within 10 min after the Bongo net was on deck. In total 8 experiments were carried out. The different experiments were stopped (animals were put in formaldehyde) after 20, 24, 30, 35, 40, 50, 60 and 70 h. The complete gut was dissected out of each animal and the diet determined.

Preliminary results

Detailed analyses of the gut evacuation time data has not yet been carried out. In gut evacuation experiments after 60 hrs still food items (*Calanus* spp. only) were found in *Euchaeta,* indicating digestion times of at least 60 hrs for large prey. Smaller prey items had shorter digestion times. *Euchaeta* was not abundant in areas with less than 250 m depth while chaetognaths occurred in relatively high numbers at both deep and shallow stations. Therefore predation impact by chaetognaths may be more important than that by *Euchaeta* over most of the shelf. Although, in deeper areas the predation impact from *Euchaeta* may be of importance.

7.5 Larval fish

L. Fortier, J. Michaud, P. Rowe

Materials and methods

Fish larvae and their potential prey were sampled with the Bongo net at each station, with the Rectangular Midwater Trawl (RMT) at selected stations and with the large-volume pump and different nets at the ice-camps. A 64-micron net was installed on the Bongo and the RMT for the collection of microzooplankton prey. Fish larvae captured in the vertical Bongo tows were in excellent condition. Morphometric measurements were taken while the fish were still alive after a gentle anaesthesia with MS222. The larvae were then preserved in ethanol for the later determination of age based on the analysis of otoliths. Some specimens were preserved in liquid nitrogen for the determination of lipid composition.

The RMT was equipped with a flowmeter and a self-contained CTD probe to monitor its trajectory and record temperature and salinity data during the tow. Usually the RMT was deployed to a depth of about 60 m and then retrieved in steps of 10 m, each lasting for 4 min. The small larvae captured in the RMT were in poor condition. These larvae were not measured and were preserved immediately in ethanol. The analysis of otoliths will allow back-calculation of the length of these fish based on the length-otolith radius relationship established for the larvae captured in the Bongo.

Seven complete profiles of zooplankton abundance (10 depths from 0 to 70 m) were obtained with the large-volume pump at the 3 ice camps. The self-contained CTD probe was installed on the intake of the pump to monitor the depth of the profile and the physical structure of the water column sampled. The pumped water was filtered on a 64-micron mesh. Subsamples were taken at each depth for the determination of chlorophyll a and phaeopigments. These profiles will provide excellent data on the vertical distribution and migrations of organisms under the ice. The few fish larvae captured with the pump were in good condition and were preserved in ethanol.

Preliminary results

During ARK IX/2, 506 fish larvae were captured, the vast majority Arctic cod (*Boreogadus saida*, 92%), a key-species in the Arctic ecosystem. The remaining 8% were comprised of two or more species of Cottidae. All Arctic cod larvae possessed a yolk sac. During ARK IX/3, 560 fish larvae were captured, the majority by RMT (over 97%, 39 stations). The catch again consisted of Arctic cod larvae and cottid larvae but with a higher percentage of the latter. The reduced catch in the Bongo nets suggests that the fish larvae were avoiding the net. This reduction in catch provided few larvae for live measurements. However, casual microscopic inspection revealed a general increase in larval length and evidence for larval feeding by the presence of prey in the gut. Figs 7.1-3 illustrate the geographic distribution of newly-hatched arctic cod larvae (by Bongo nets and by RMT) and their length-frequency distribution from ARK IX/2, and the geographic distribution of all fish larvae (by RMT) from ARK IX/3.

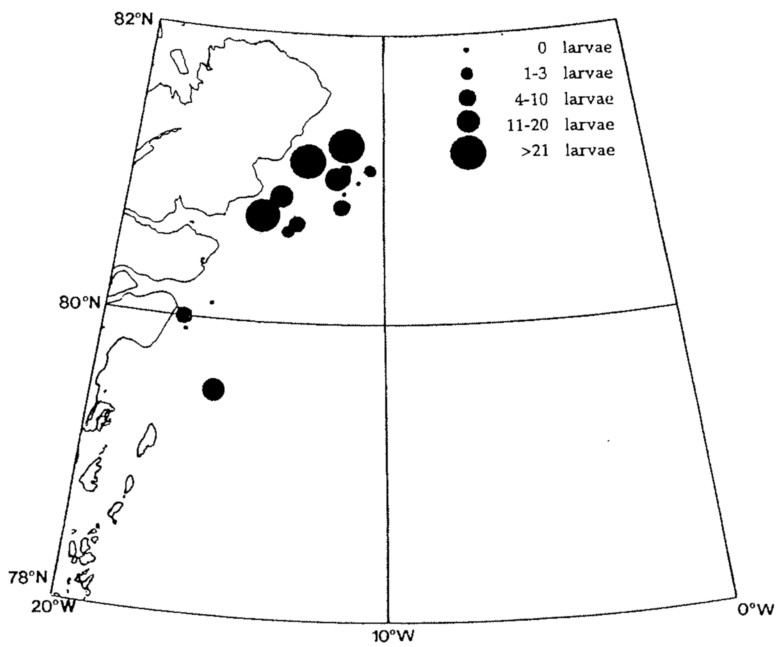


Fig. 7.1a. *Boreogadus saida.* Distribution of larval Arctic cod in the Northeast Water Polynya during ARK IX/2. Larvae collected by rectangular midwater trawl.

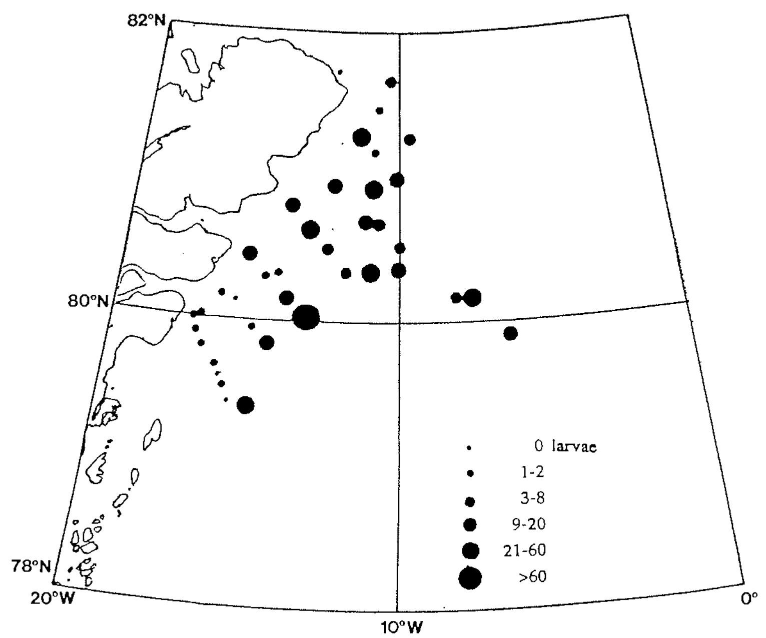


Fig. 7.1b. Distribution of larval fish in the Northeast Water Polynya during ARK IX/3. Larvae collected by rectangular midwater trawl.

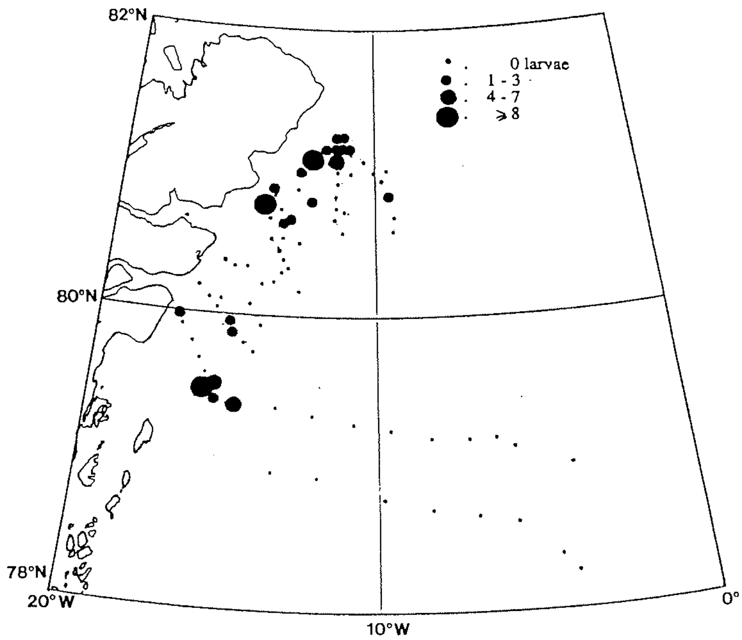


Fig. 7.2. *Boreogadus saida*. Distribution of larval Arctic cod in the Northeast Water Polynya during ARK IX/2. Larvae collected by vertical Bongo net tows.

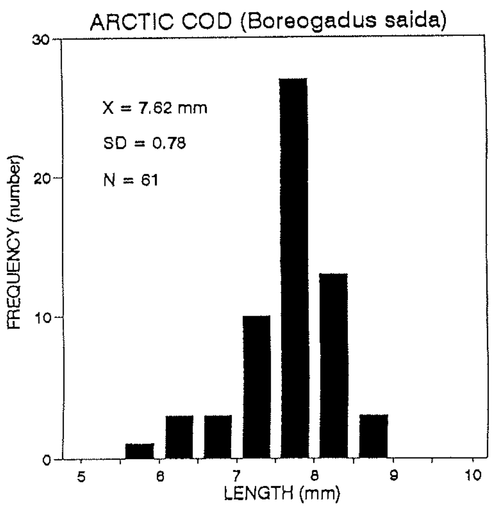


Fig. 7.3. *Boreogadus saida*. Length-frequency distribution of larval Arctic cod larvae, collected during ARK IX/2.

8 BENTHOS

W. Ambrose, M. Ahrens, A. Brandt, W. Dimmler, G. Graf, J. Gutt, R. Herman, P. Jensen, D. Piepenburg, Queisser, P. Renard, W. Ritzrau, A. Scheltz, L. Thomsen

The existing knowledge on the bottom fauna off Northeast Greenland suggests that both a polynya, the NEW, and a convergent anti-cyclonic gyre control the benthic ecology in this area. The shelf is characterized by a complex bathymetry with shallow banks (water depths < 20 m) and depressions (water depths up to > 400 m). It is expected that a large proportion of the presumably high pelagic and sympagic production in the polynya is partitioned to the benthos. The locally high biomass (and potentially high production) may be key elements in the food web of this marine ecosystem. Benthos as well as demersal and pelagic fish may provide the trophic basis for marine mammals and birds. In order to investigate the role of the polynya area for the bottom life benthic processes were measured from the early appearence of the polynya in May until late July.

Recent investigations have revealed that, in addition to vertical sedimentation, lateral advection of particulate matter may contribute significantly to the energy supply of the benthos. Physical resuspension but also biological activity of the benthic community, like bioresuspension or biodeposition, influence the concentration and distribution of particles in the bottom nepheloid layer (BNL) as well they affect the final incorporation of particles into the sediment.

The study of the benthic macrofauna includes
- an assessment of abundance, biomass and community properties (species composition, diversity, feeding types, size spectra),
- an evaluation of the population dynamics of selected key species,
- an investigation of dispersion patterns of epibenthic populations at two spatial scales (within-station, i.e. 100-1000 m, and between-stations, i.e. 10-100 km),
- measurements of the metabolic performance on the level of both, communities (micro- and meiobenthos) and individuals (macrobenthos),
- analyses of biodeposition, bioturbation, and bioentrainment rates of special benthic populations or individuals with the help of in-situ experiments.

The goal of these studies is to evaluate the relationships between the benthos and ecological relevant abiotic and biotic factors such as seafloor topography, habitat structure, advective flux, and biotic interactions. In addition, studies on trophic relationships are performed to answer questions concerning the flow of carbon in the polynya, and how it may differ from nearby ice-covered regions. Links between water-column processes, the benthos, and higher order predators can, thus, be determined and the role of the polynya in structuring food chains can be evaluated.

Materials and methods

For quantitative sampling of the Bottom nepheloid layer (BNL) up to 40 cm above the sea floor a bottom water sampler (BWS) was deployed. The description of the BNL includes the vertical distribution, the concentration, and biochemical properties (TPM, POC, PON, Chl a, ATP) of particles in the near bed area. In addition to bacterial abundance and biomass microbial activity was assessed by measuring ^{14}C amino acid respiration and incorporation. Near bottom current profiles combined with an optical assessment of the current direction allow estimates of the importance of lateral transport close to the sea floor.

The vertical distribution of biomass (DNA content) in the sediment, Chl a equivalents, metabolic activity (ATP content, heat production, oxygen consumption) was measured in processed multiple corer samples (MUC). In addition, the community structure and vertical distribution of meiofauna was investigated using cores taken with the MUC.

Quantitative macrofauna samples were taken with a box corer (50x50 cm). For assessment of within-station variation three replicates per station were taken whenever possible and subsamples for macrofauna, meiofauna, foraminifera, and sediment parameters were taken.

Abundances and dispersion patterns of epibenthic populations were investigated by use of imaging methods. The still camera system (FOT) consists of a vertically oriented camera combined with an oblique strobe and provides high-resolution still pictures of the sea bottom. At each station a series of 30 pictures were taken, imaging approximately 1 m^2 of the sea floor each and distributed along a transect of approximately 250 m length. The colour slides already developed on board demonstrate that our information on benthic biotopes normally based only on trawl catches or corer samples is considerably increased by this method. The photographs provide "in-situ"-views of epibenthic habitats and will be analysed to determine the identity, the absolute abundance, and the small-scale distribution patterns of epibenthic species (brittle stars etc). The excellent quality of the slides, due to the format of the film material used (size 60 x 60 mm) and to the constant and relatively low distance of the camera to the bottom (1.4 m), will allow the identification of even relatively small epibenthic animals.

The remotely operated vehicle (ROV) consists of four major components: The vehicle itself is a cube of approx. 80x80x80 cm, equipped with five thrusters, a compass, a depth sensor, two video cameras (black and white, colour), a still camera, lights and strobes which can be tilted. Two laser beams provide a scale in the images by generating two points of a distance of 33 cm on the object observed. The vehicle is connected to an underwater winch by a 150 m long floating cable. The underwater winch is connected to the board units by a special cable via an ordinary winch on the ship. The cameras and the movement of the vehicle can be operated by two joysticks and the video image can be observed on line. The vehicle is lowered to the sea floor when it is docked below the underwater winch. Approx. 20 m above the bottom the vehicle is mechanically released and can operate at a radius of 150 m around the underwater winch independent from the ship's up and down movement. To achieve at best straight transects the vehicle and the underwater winch were used together with the ship acting mainly as a drifting system. The opportunity of the active movement of the vehicle was used to avoide obstacles and to attain a very low altitude (approx. 20 cm) above the bottom in order to get high resolution images. The average length of a transect of a standard one hour cast was roughly estimated at 500 m with a width of 50 cm, which results in an average area observed of 250 m^2 per station. In addition to the video images, a minimum of 100 still photographs were made at each station.

An Agassiz trawl (AGT) and an epibenthic sledge (EBS) were deployed mainly to collect animals for laboratory experiments, populations dynamics assessments, and biochemical analyses. The EBS samples will also be used to study the community structures of crustaceans, mainly Peracarida, an important component of the epi- and hyperbenthos. These organisms were selected to represent different modes of life. A subset of the organisms caught were kept alive in aquaria for later lab respiration measurements in order to assess their metabolic rates and for flume experiments on feeding, particle uptake, and biodeposition. The specimens preserved in formalin or by freezing will be analysed for parameters of population structure (age, growth, production). Upon return to the laboratory, specimens of crustaceans, bivalves, ophiuroids, macroalgae, fish, and polychaetes sampled with these gears will be analyzed for lipid, carbohydrate, and protein content. Additional samples of some of these organisms, as well as samples of polar bear blood and POC will be analyzed for stable carbon and nitrogen isotopes in effort to determine trophic relationships among polynya organisms. In addition, fish and invertebrate gut contents will also be examined.

In total, on 35 stations benthic work had been done using either GKG, EBS, AGT or a set of these sampling gears. Whenever feasible, the whole array of different sampling methods (corers, trawl, imaging methods (the FOT was only employed during leg ARK IX/2)) was used at the same station for optimal coverage of the benthic biotopes and processes. This was achieved at a total of 8 stations, distributed on one transect along and one transect normal to the Norske Trough. These transects include a time-series station which was revisited four times during this cruise leg.

- The box corer (GKG) has been deployed successfully 80 times at 29 stations. Of these 29 stations, seven are at approximately the same coordinates (time-series station in the Westwind Trough).
- The epibenthic sled (EBS) has collected samples at 26 of 29 deployments in depths from 45 to 430 m. The Agassiz trawl (AGT) has been deployed ten times in depths between 60 and 490 m.
- The still camera system (FOT) was deployed at a total of 20 stations with depths ranging from 40 and 440 m. The ROV was operated at 28 stations at water depths between 35 and 487 m and at additional 4 stations for observations under the ice.
- The bottom water sampler (BWS) and the multicorer (MUC) were deployed 21 times successfully.

Preliminary results

Bottom nepheloid layer: Current velocities at 30 cm above the seafloor ranged from less than 1 cm s^{-1} to maximal 35 cm s^{-1} at the various locations and were generally directed along the trough axis following the anticyclonic gyre. Highest flow velocities were measured in the northern trough close to the shelf edge. Data indicate a tidal influence around the time series station with currents going from ENE to ESE producing higher residence times of particles and deposition areas along the southern part of the northern trough. Gradients in bacterial activity in the first 40 cm above the seafloor were found. Microbial rates close to the sea floor tend to be significantly higher than at 5 m and 50 m above the sediment. The total utilization of ^{14}C amino acids appears to be evenly partitioned into respiration and incorporation. Microbial activity in the bottom waters increased by a factor of maximal 4 at the time series station within 9 days. Maximal rates were found in early July, with a decreasing trend towards the end of the cruise.

Sediment: Sediments turned out to be highly oxidized, redox values ≥300 mV down to 10 cm sediment depth. Whole core incubations showed extremely low oxygen consumption. Converted into carbon remineralization most values do not exceed more than 10 mg m^{-2} d^{-1}, less than 50% of corresponding measurements in the Norwegian deep-sea. On the time series station (Sts. 30, 59, 95, 138, 165, 217, 258) an increase from 10 to 17 mg m^{-2} d^{-1} was measured over the period of 19 days. Most likely a result of sedimentation of ice-algae and water column phytoplankton. Common ice-algae species (e.g. several chain forming diatoms of which *Melosira* sp. is most abundant and a pennate diatom *Navicula* sp.) and significant concentration of Chl a and phaeopigments are present undamaged at least down to 10 cm sediment depth (Fig. 8.1). Incorporation of phytoplankton into the deep sediment strata is most likely caused by the feeding activity and burrow ventilation of macrofaunal species. Highest chlorophyll sedimentation occurred in early July.

Meiofauna: The meiofauna is dominated by nematodes and harpacticoid copepods; oligochaets, kinorhynchs and loriciferans appear in few numbers at a few stations. The abundance down to 10 cm sediment depth varies between 70 ind. 10 cm^{-2} (Sts. 18, 77) and 300 ind. 10 cm^{-2} (Stat. 60). Adult animals are small sized comparable to the Norwegian deep-sea fauna, with estimated biomass values in the range of 0.1 - 0.5 mg 10 cm^{-2}. Nematodes are the most species rich group including about 80 species. The juvenile/adult ratio is strongly biased in favour of juveniles, on average 5:1. Most abundant nematode species have first juvenile stages only, suggesting egg deposition at the end of May; this might have been triggered by a sedimentation event in May followed by microbial degradation on/in the sediments. These juveniles depend on microbes and food.

Next to the metazoan meiofauna, there exists a distinct protozoan meiofauna, composed of foraminifera. Live population densities (sieved at 200 μm mesh size) range from approximately 10 individuals 10cm^{-2} at fine mud sites (e.g. Sta. 271) to 100 individuals 10cm^{-2} on coarser sediments (e.g. the time series station). The coarser sediments usually contained a large fraction of empty tests. A reliable, quantitative description of the living community will be possible after staining with Rose-Bengal. Generally, less than 10 species are common at a particular location. Genera found repeatedly were *Buccella, Cassidulina, Islandiella, Elphidium, Melonis, Nonion, Pyrgo, Cibicides, Hyperammina* (taxonomy still to be confirmed). Calcareous forms (e.g. *Buccella, Cassidulina, Islandiella, Elphidium, Melonis*) are more numerous than agglutinated species (e.g. *Rhabdammina, Hyperammina, Saccorhiza, Saccammina, Cribrostomoides*), the latter of which seem to be more common in the southern trough than in the north. Living foraminifera were usually concentrated within the surface sediment (0-1 cm depth). An exception to this general pattern was found at St. 179, a station close to the Greenland coast, where the maximum in foraminiferal density correlated with a chlorophyll maximum at 2-4 cm depth. Foraminifers at this site (*Nonion labradoriensis*) bore a distinct yellow-green colour and possessed an average

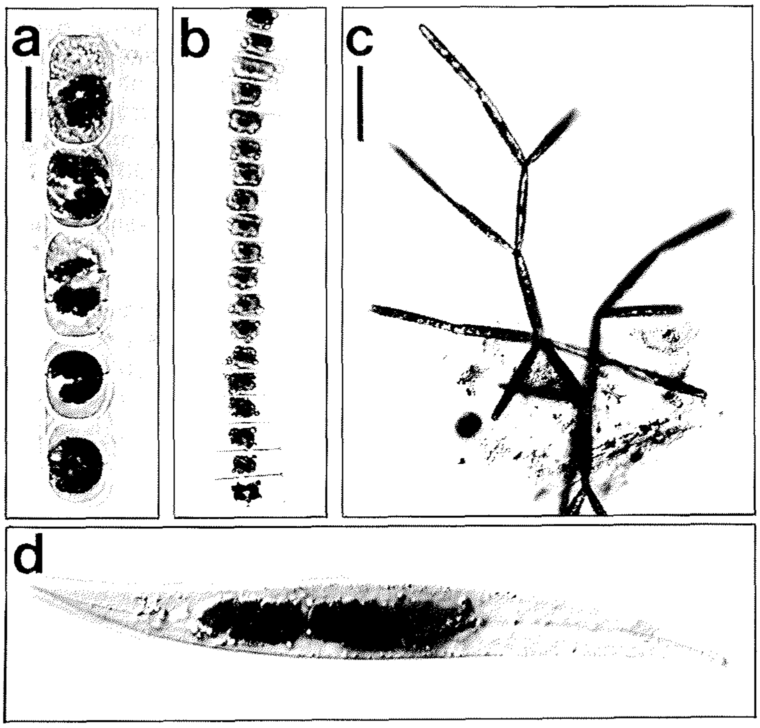


Fig. 8.1. Four unicellular algae species found at 5-10 cm depth in sediments from St. 59. They are identical with those attached to the ice cover and their presence in the sediments is likely mediated by macrofauna bioturbation subsequent to a sedimentation event. a-c are fragments of chainforming diatoms of which a is most abundant and belongs to *Meliosira*; d is a pennate diatom *Nitzschia sp.* Scale bars: a-b, d = 25 µm, c = 50 µm (Photos: P. Jensen).

chlorophyll a content of 5±3 ng individual^{-1} and a phaeopigment content of 3±3 ng indiv.$^{-1}$. ATP of individual foraminifers was extracted (noting size, taxonomy and plasma content) at every station (alltogether 590 samples), in order to assess the contribution of the foraminifera to the general benthic metablic activity. Measurements will be carried out at home.

Box coring: Infaunal samples from box cores and samples for physical characterization of the sediments have been preserved for laboratory analysis, but preliminary impressions are that densities are lowest at Station 18 and highest at Station 145. Station 145 is the eastern-most benthic station. Other stations are intermediate in density but considerably higher than station 18.

Only a few stations on Belgica Bank were sampled by the GKG, the shallowest of these (station 273) was still in 170 m depth. *Ophiura sarsi* has been found in some of these samples. At some of the deeper stations in the northern or the Westwind Trough, other brittle stars have been found, mainly of the genus *Ophiopleura*. Ob bank is shallow and is characterized by shallow coarse-grained sediments, for which the box-corer is not designed. High currents seem to have scoured the northern slope of the Westwind Trough in some areas and has led to unsuccessful attempts in one site here, despite the relatively deep 240 m sounding.

Trawls: The AGT catches differed considerably both in terms of abundance of animals, as well as in terms of diversity. In three of the catches (stations 57, 138 (time series station), and 234) the large number of rocks damaged most of the animals.

The deeper AGT catches (at 220 m depth) were dominated by brittle stars of the genus genus *Ophiopleura* and hundreds were found in some trawl catches. The ophiuroid genera *Ophioscolex, Ophiacantha, Ophiocten*, and *Gorgonocephalus* occurred less frequently. Isopods, amphipods, small shrimp, basketstars, bivalves, sea urchins, sea stars, basket stars, echiurids, sipunculids, pycnogonids, polychaetes, actiniaria, and various liparid and cottid fish were also common. Besides, some specimens of sepia and octopus have been sampled. The two shallow stations (42 and 89) produced hundreds of sea urchins, as well as considerable numbers of several shrimp species (*Eualus, Spirontocaris, Sabinea, Sclerocrangon*), a species of scallop (*Arctinula*), and the large isopod, *Arcturus*.

EBS samples were highly variable. In shallow areas, crinoids (featherstars), brittle stars (*Ophiocten*), isopods, lysianassid and gammarid amphipods, and a species of thin-shelled scallop bivalve (*Arctinula*) were common. The few stations in the troughs sampled with the EBS have yielded much lower epifaunal densities, samples consisting mainly of brittle stars and polychaetes. Several small fish specimens, including polar cod, have also been collected. At two stations on Ob Bank, large quantities of a red macroalga (*Phycodrys*) have been taken from depths greater than 50 m. This implies consistantly clear waters (low primary production) characteristic of these sites.

Seafloor imaging: The seafloor photographs and videos will be analysed after the end of the expedition. The following first impressions from the images can be given:

The benthic habitat structure and epifaunal assemblages differ mainly between banks and troughs. On the banks, the variability between stations is high. There are

- stations with indications of intensive iceberg scouring at depths <100 m: The sea floor is characterized by a complex microtopography and many stones (diameter of a few cm). Epifaunal densities and species diversities are low. Two types of red algae (*Phycodrys* and a calciferous species) were found, occasionally also patches of many ascidians.
- bank stations without signs of recent iceberg scouring. Characteristic are large boulders with epilithic suspension-feeding organisms, mainly *Heliometra*. Locally high abundances of brittle stars (*Ophiocten*), sea urchins (*Strongylocentrotus*), sea cucumber (*Psolus*) were found. In the troughs, the seafloor consists of soft sediments with only few large boulders. Epifaunal densities are generally lower than on the banks. The variability between stations is far less pronounced. The predominant megafauna organisms are a large brittle star species (*Ophiopleura*), burrowing cerianths, actiniarians and pennatularians. Occasionally, also the basket star *Heliometra* occurred. At some stations a number of holes in the sediment with a diameter of up to approx. 20 cm were seen. Their origin is unknown. In addition, mounds of approx. 10 cm height and approx. 20 cm diameter indicate the burrowing activity of larger infaunal organisms. The slopes of the troughs are intermediate in terms of faunal composition.

9 MARINE MAMMALS AND BIRDS

9.1 Shipboard observations
ARK IX/2

C. Joiris, L. Helsen

Our aim was to determine the ecological role of seabirds and marine mammals at sea

- as indicators of ecological events in the water column (i.e. biological fronts) or the benthos;
- to determine their distribution and density, in order to calculate their food intake from existing allometric equations, and so integrate them in the general ecological study of the polynya area;
- to establish the range and the feeding grounds of local bird populations, in coordination with NEWLand study of colonies of breeding birds.

Materials and methods

The data were obtained during transect counts from the moving ship, i.e. 10 min. counts, grouped in half an hour counts for facility, during transect helicopter counts (200 feet high, 100 knots) and occasional observations from stationary ship. As on June 23, more than 600 half an hour counts were performed, of which 341 in the study area (ARK IX/2), and as on July 29, more than 550 half an hour counts, of which 330 in the study area (ARK IX/3).

Results

The results clearly reflect the importance of coastal, benthic feeders, with about 200 walruses between Eskimonæs and Kilen, mainly on land fast ice in Antarctic Bugt (80 females, a few newborn pups and one adult bull at some distance; see also the Polar Bear report) and with 3000 eiders (80% Common, 20% King Eiders) off Kilen. The eiders were actively feeding in a very dense flock or resting on the ice edge, and later showed a clear tendency to disperse in pairs, the flock declining to 200 birds: they probably represent a locally breeding population in narrow connection with the polynya.

Numbers of plankton and small fish feeders were generally low, but increasing during our presence in the study area (e.g. Kittiwake, Fig. 9.1). The most abundant species were Ivory Gull, Fulmar, Kittiwake, and Glaucous Gull. Other species joined the region, and probably their breeding grounds, later on: 100 Sabine's Gulls along the glacier west of Kilen, and a few Arctic Terns around the Krøyer Islands and Kilen.

Ringed seals were scarce at the beginning; their numbers increased than (Fig. 2), indicating that they were leaving their winter breeding lair and became active on the ice, near their breathing hole, and in the water. Bearded seals were encountered as well, including twice a female with newborn pup.

An important group of narwhals was noticed along the pack ice at the southwestern limit of the polynya from helicopter only, since they avoid ships, probably disturbed by the noice of the engines. The maximum registred is 136 (R. Ramseier); later on, 40 to 70 were counted during different flights. This large group consisted of an association of smaller subgroups of one to six individuals, dispersed on more than 10 nmiles of ice edge. They were mainly adult males and females, with a few one year old and newborn calves.

Concentrations of Fulmars and Kittiwakes were noticed close to the colonies, off Mallemukfjeld. More interesting was the presence of actively feeding Fulmars in concentrations of up to 100 sitting on the water and picking up preys (zooplankton?) at the surface; in one occasion, they were accompanied by a Red Phalarope. These feeding grounds were all situated between 79°40' and 81°N, and 14°30' and 16°30'W, and concern a total of 273 individuals, encountered during 10 counting periods.

Other species were present in lower numbers: Red-throated diver (6 individuals), Long-tailed Skua (25), Thayer's Gull (2), Red Phalarope (3), Long-tailed Duck (2), Brent Goose (3), Snow Goose (1), Brünnich's Guillemot (20), Little Auk (35), as well as Snow Bunting (6 males on the pack ice and on Polarstern).

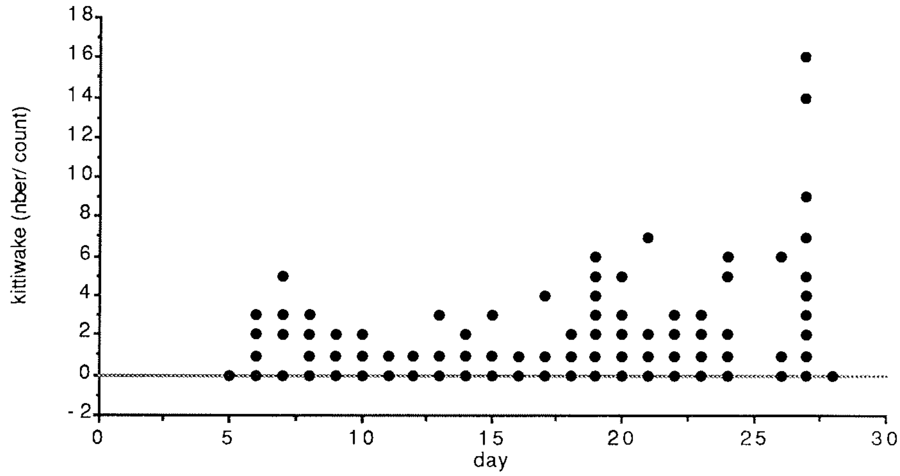


Fig. 9.1: Numbers of Kittiwakes *(Rissa tridactyla)* as a function of time in the study area . Day 1: May 22, 1993. Numbers per half hour counting period.

Table 9.1: Mammal and bird counts during ship's transects.

Transect	**S-N**		**E-W**		**study area**	
from	off Tromsö		3		13	
to station	3		13		98	
distance (nmiles)	780		200		1500	
nber counts	94		45		341	
	total	/ count	total	/ count	total	/ count
Fulmar Σ	609	6.5	53	1.2	911	2.7
Fulmar dark morph	451	4.8	52	1.2	939	2.8
Ivory Gull	95	1.0	144	3.2	707	2.1
Glaucous Gull	22	0.2	20	0.4	307	0.9
Kittiwake	809	8.6	63	1.4	351	1.0
Common Guillemot	30	0.3				
Brünnich's Guille.	918	9.8			19	0.1
Little Auk	65	0.7			31	0.1
Σ **birds**	**2602**	**27.7**	**253**	**5.6**	**2377**	**7.0**
Walrus					44	0.13
Bearded seal			11	0.24	19	0.06
Ringed seal			6	0.13	139	0.41
Hooded seal	5	0.05	2	0.04		
Σ **pinnipeds**	**5**	**0.05**	**20**	**0.44**	**202**	**0.59**
Polar bear					3	0.01
Killer whale	6	0.06				
Large whale	1	0.01				
Σ **cetaceans**	**7**	**0.07**				

ARK IX/3
J. Tahon, V. Vens

In addition to the methods used already during ARK IX/2, we established comparisons between the observed vertebrate life during the two legs (one mainly in June, the second mainly in July). As during ARK IX/2, the results of helicopter transects reflected the fundamental importance of the coast line for the polynya vertebrate life. Main data of the helicopter survey of July 25 are presented in Tables 9.2,3.
- The recently established population of walrus in NEW is in increasing trends, with a rather high ratio pups/adults (17/75).
- Male moulting Eiders (both Common and King species, hardly separable) were scattered in small flocks, apparently in much smaller numbers than during the previous leg. This probably indicates that a large amount of them migrated outside the polynya at the end of June (as previous report suggests) to breed in suitable places, west of Nordostrundingen. Practically all female Eiders we observed brooding 4 to 5 young, which is a good reproductive result for these species.

These results confirm preliminary data (ARK V/2 and 3, ARK VII/2, ARK VIII/1) on the importance of the polynya during spring (and maybe winter) for some arctic species. Presence of Black Guillemots, Ross´s Gulls, and Eiders should therefore be studied during these hard months.

The melting of the fast ice made comparisons with the previous leg very difficult. We had to stay at a distance from the shore, instead of moving close to the fast ice. It was clear that local Kittiwake (Mallemukfjeld and Kap Jungersen) were moving along the coast and were therefore out of our counts. Ivory Gulls were very abundant. They made movements from and to the coast, going directly at high heights (50 m) to the ice floes. They were absolutely not interested by the presence of Polarstern and were difficult to count from the bridge. Fulmars, practically all of the dark and intermediate phases, were not numerous in the Polynya. Small flocks feeding actively at sea at short distances from the coast (less than 5 km) were probably belonging to the small local population breeding on the cliffs of Mallemukfjeld (Fulmar cliff) and Kap Jungersen. None was colour-marked.

Sabine´s Gulls and Ross´s Gulls reported nesting on Henrik Krøyer Holme, have not been seen in the polynya but were sometimes observed on the drift ice, specially in difficult conditions when we were progressing through hard ice. It was clear that the breaking and turning of ice blocks often provided food for these subtile birds (also to Kittiwake, Ivory Gulls and Fulmars). Ross´s Gulls, often followers at long range, were numerous and sometimes the most common of the Gulls.

Other species seen in the previous leg were absent in July: Red-throated diver, Long tailed Skua, Thayer´s Gull, Red Pholarope, Long tailed Duck, Snow Goose, Brunnich´s Guillemot, Little Auk as well as the landbird Snow buntrings obviously seen during the migration movements.

The shy ringed seals were absent from the drift ice around the polynya. The most abundant seal species was the bearded seal. It is also the most tolerating species at close range (2-300 m). Harp seals and hooded seals were also present but in low numbers.

As whales only Narwhals were observed in the polynya. They were noted at close range when we first reached the polynya from the south along leads bordering the fast ice N 79°(01´-10´) W 15°(40´-25´). Pods of females (4, totalling 24 individuals) and of males (1 totalling 19 individuals)

9 Killer Whales (*Orcinus orca*) were noted in the Norwegian Waters. 6 Minke Whales (*Balaenoptera acutorostrata*) were observed in the Atlantic Waters. On June 29, at 76°50'N 08°47'W, when the ship was on station we observed a resting Bowhead (*Balaena mysticetus*) in a very small lead close to us (500 m) during more than one hour.

A total of four Polar Bears was seen: the three first were large animals, the last one was medium sized. None was colour-marked.

Table 9.2: Helicopter transects on July 25 (Visibility 10 km, clouds 0/8, waves 0, luminescense very good)

Section	Time	Place	Position	
A	13.40h	POLARSTERN	N 80°30´	W 12°54´
B	14.05h	NORDOSTRUNDINGEN	N 81°20´	W 11°58´
C	14.08h	KILEN	N 81°07´	W 12°51´
D	14.15h	ANTARCTIC BUGT (glacier)	N 81°00´	W 13°17´
E	14.28h	SOPHUS MULLER NÆS	N 80°51´	W 14°15´
F	14.50h	INGOLF FJORD N	N 80°41´	W 14°38´
G	14.55h	CAP JUNGERSEN	N 80°42´	W 15°03´
H	15.00h	INGOLF FJORD W(BOTN)	N 80°40´	W 16°20´
I	15.10h	WEGENER ØER (facing)	N 80°36´	W 16°00´
J	15.20h	ESKIMONÆS	N 80°28´	W 15°40´
	15.30h	POLARSTERN(+POLAR SEA)	N 80°30´	W 12°54´

Table 9.3: Species distribution during helicopter transects (Table 9.2)

WALRUS (*Odobenus rosmarus*):

Section	Amount	Spreading
D	6	1,5(1young)
E	24	1,<u>2</u>,4(2yg),3,10(4yg),4
F	13	4,4,1,2(1yg),2(1yg)
G	10	5,4(1yg),1
H	14	4,1,3,2(1yg),<u>2</u>,<u>2</u>(1yg)
I	26	<u>1</u>,<u>2</u>(1yg),3(1yg),4,<u>7</u>(2yg),<u>1</u>,3(1yg),<u>1</u>(sleeping),3,1
Total = 93	17 young,<u>19</u> swimming(1 sleeping at sea)	

Table 9.3: continued

EIDER, 2 species (*Somateria sp.*), males

Section	Amount	Spreading
B	32	12,12,8
C	116	25,15,12,17,30,17
F	6	6
I	14	14(moulting)
Total = 168	All along the fast ice or in little "ponds" close to the coast. Some of them already moulting.	

EIDER, 2 species (*Somatria sp.*), females & young (families)

Section	Amount	Spreading
C	101	10,17,2,15,10,20,25,2
D	18	15,3
F	2	2
G	22	15,4,1,2
H	6	1,3,2
Total = 149	All in little "rivers" close to the coastal laguna barrier. One family = an average of 4 to 5 young, most of them about 8 to 15 days old, some are older.	

ARCTIC TERN (*Sterna paradisaea*)

Section	Amount	Spreading
B	15	Nordostrundingen (point)
D	90	Kilen-Antarctic Bugt (tongue in front of glacier)
E	14	Sophus Muller Næs (point)
G	4	Cap Jungersen (between botn-ice and cliff debris)
I	50	Eskimonæs (point)
Total = 170	5 colonies.	

FULMAR (*Fulmarus glacialis*) (mostly dark phase)

Section	Amount	Spreading
D	140	80,60
I	22	22
J	2	2
Total = 164	most of them swimming, others scattered over the whole coastal area.	

BRENT GOOSE (*Branta bernicla* race *Hrota*)

Section	Amount	Spreading
F	2	2
Total = 2	on firm land, flying for 50 m and sitting at sea(moulting).	

Table 9.3: continued

KITTIWAKE (*Rissa tridactyla*)

Section	Amount	Spreading
A	1	1
B	1	1
C	19	4,1,10,2,1,1
D	12	10,2
E	5	5
F	2	2
H	4	4
Total = 38	very hard to count, because they are scattered along the coast and very close to it, at sea and at land.	

IVORY GULL (*Pagophila eburnea*)

Section	Amount	Spreading
B	1	1
C	13	1,2,5,5
E	2	2
Total = 16		

GLAUCUS GULL (*Larus hyperboreus*)

Section	Amount	Spreading
E	1	

Preliminary results

75 minutes of effective counting, 90 nm as a crow fly from Nordostrundingen (81°20N 11°58´W) to Eskimonæs (80°28´N 15°40´W)

Walrus (*Odobenus rosmarus*): 92 animals:
17 young (very high proportion, successfull breeding group
19 swimming (1 sleeping at sea)
Probability of more animals, because:
- a large ratio of observed animals was swimming, some could have been feeding during 5 to 10 minute dives
- there were a lot of small ice floes (= potential resting places) along the coast

Eiders (*Somateria* sp.):
males: at least 14 flocks totalling 258 individuals, most of them moulting, all of them were along the fast ice or in ponds on gravel flats.
females and young: individually or in small groups, always in openings in the lagunes. Aat the sea edge: 149 females noted; an average of 4 to 5 young per female, most of them 8-15 days old.

Terns (*Sterna paradisaea*):
5 colonies, 170 birds counted. Probably many more birds in these colonies. Allways at the very point (noess) of a flat muddy, stony cap.
Fulmars (*Fulmarus glacialis*):

3 large groups sitting at sea along the fast ice (feeding?) totally 160 counted birds. Mallemukfjeld (80°12'N 16°50'W) and Kap Jungersen (80°38'N 16°30'W), where they nest, is not far away, other individuals here and there.

Kittiwake (*Rissa tridactyla*):
38 noted, mainly in sections C to E, these counts are certainly very incomplete. Colonies in Mallemukfjeld and Kap Jungersen.

Ivory Gull (*Pagophila eburnea*):
3 noted few were probably missed.

Glaucus Gull (*Larus hyperboreus*):
1 in Ingolf Fjord N

Brent Goose (*Branta bernicla*):
2 in section F, flying only 50 m to sea, moulting. Moulting place in the surroundings?

The Greenland coast line with its small inland ponds, fast ice strips, gravels, lagunes, ice floes, glacier edges, etc. is of primary importance for the vertebrate life in the North East Water. In July Walrus, Terns and Eiders are exclusively found there. Fulmars and Kittiwakes, nesting on cliffs in Mallemukfjeld and Kap Jungersen, are feeding at close range from the land edge. Presence of Ivory gulls, Brent Geese and Glaucus Gull probably indicates the existence of nearby colonies. Glaucus Gull could be parasitic on Fulmar and Kittiwake colonies already cited. Danish birdwatchers, working inland of Greenland also noted breeding presence of Sabine's Gull and Ross' Gull in the Henrik Krøyers Holme (80°42'N 14°02'W). Earlier, at 79°05'N 15°31'W, we met pods of a total of 43 Narwals (*Monodon monoceros*) at the South end of the polynya, close to the ice edge.

All these data indicate the drastic importance of the Greenland coast for the vertebrate life in the NEW polynya. On the other hand we failed to see any other whale species in the polynya. Seals were rare in the polynya and completely absent at the coast line. Censuses by helicopters should be made by several observers at the same time, each noting, on prescheduled protocols, only one of a few species of animals. These flights, again, are the core of all the data collected in the NEW polynya in July.

9.2 Polar Bear studies

E.W. Born, J. Thomassen

During ARK IX/2 a Polar Bear study was conducted. The purpose of the study was to determine

- the spatial distribution of Polar Bears in NEW between late May and late June, and
- the long term use of NEW by adult female Polar Bears instrumented with satellite-linked radio collars. Because the transmitters allow for tracking of animals up to about 1.5 years the ecological importance of NEW to female Polar Bears can be studied over a longer time frame.

Methods

Between May 26 and June 18, 1993, a total of 40:28 hrs of flying were used during helicopter surveys designated to Polar Bear studies. In addition, extensive surveys serving other research purposes were flown over the pack ice and the land fast ice in the same period. During these surveys the pilot and other researchers looked for bears and bear tracks. Continuous watch for wildlife including bears was kept either from the ship's bridge or from the crow's nest.

Few signs of Polar Bear activity in the off-shore pack ice made us concentrate survey efforts on the land fast ice between 81°40'N 19°30W at Kap Ringkøbing and 78°52'N 18°05'W in 79-Fjorden. The areas between Kap Anne Bistrup (79°41'N 18°15'W) and Kilen (81°09'N 13°00'W) were surveyed several times. Surveys were flown at 600 feet altitude and an indicated airspeed of 100 knots. Furthermore, on several occasions ground stops on high cliffs were made to search for Polar Bears using a 20 x KOWA TSN-1 telescope. Observations of all other marine mammals were recorded.

Polar bears were darted from a B-105 helicopter with a maximum endurance of 3.5 hours. Cap-chur equipment and the drug Zolatil 100 (1:1 tiletamin:zolazepam; VIRBAC; 200 mg/ml solution) were used for immobilisation of the bears following routine procedures for capturing wild roaming Polar Bears. Eight satellite-linked radio collars (PTTs; Telonics, Arizona) were brought for instrumentation of adult female Polar Bears.

Preliminary results

A total of 21 Polar Bears (11 F; 10 M) were tagged including 9 adult females and 7 adult males (Table 9.4). The remainder were dependent cubs. Eight adult females were collared with satellite-linked radios (Table 9.5). Fig. 9.2 shows the position of the tagged bears at collection, while in Fig. 9.3 their movements from capture to mid November are shown. Samples taken from the handled bears are listed in Table 1. Samples of claw tips and blood were delivered to Drs. W. Ambrose and P. Renaud (East Carolina University, Greenville) for analyses of stable isotope ratios (N, C).

Table 9.4: Polar bear observations and samples.

Bear # (Tag ID)	Day/ month	Location (N/W)	Sex (F/M)	Est. age	Zool. length	Axillary girth (cm)	Samples: Tooth	Blood	Claw	Hair	Ear plugs	Sat. ID	fluoresc. marks	Family status	Remarks
D7118	26/05	7918/1336	M	Adult	215	144	-/ R pm1	1	3	1	2	-	1 on back	Single	
D7119	27/05	7954/1658	M	Adult	230	157	-/ R pm1	1	3	1	1	-	2 on back	Single	
D7120	27/05	7954/1658	M	Adult	266	164	-/ R pm1	1	3	1	2		3 on back	Single	
D7121	28/05	8032/1820	F	Adult	205	115	-/ R pm1	1	3	1	2	10782	4 on both hips	With D7122	
D7122	28/05	8032/1820	F	Yearling	162	96	-/ R pm1	1	3	1	2		5 on back	Cub of D7121	
D7123	30/05	8019/1353	M	Adult	242	157	-/ L pm1	1	3	1	2	-	6 on both hips	Single	
D7124	03/06	8058/1327	M	Adult	240	140	-/ R pm1	1	3	1	2		7 on both hips		
D7125	07/06	8014/1920	F	Adult	211	112	-/ R pm1	1	3	1	2	9678	8 on both hips	With D7126	Lactating
D7126	07/06	8014/1920	M	COY	124	67	None	1	3	1	1		9 on back	Cub of D7125	
D7127	09/06	8017/1308	F	Adult	215	117	-/ R pm1	1	3	1	2	9684	10 on both hips	Single	
D7128	10/06	7932/1557	M	Adult	226	135	-/ R pm1	1	3	1	2	-	11 on hips	Single	
D7129	11/06	7909/1711	F	Adult	205	98	-/ R pm1	1	3	1	2	9682	12 on hips	With D7130	
D7130	11/06	7909/1711	M	COY	115	61	None	1	3	1	2	-	13 on back	Cub of D7129	Scale weight: 35 kg
D7131	11/06	7911/1711	F	Adult	194	90	-/ R pm1	1	3	1	2	10780	14 on hips	Single	
D7132	11/06	7924/1625	F	Adult	217	119	-/ R pm1	1	3	1	2	10781	15 on hips	Single	
D7133	13/06	8004/1705	F	Adult	205	91	-/ R pm1	1	3	1	2	9683	16 on hips	With D7134 & D7135	
D7134	13/06	8004/1705	F	COY	93	51	None	None	3	1	2	-	17 on back	Cub of D7133	Rescued in crevice. Weight: 18 kg
D7135	13/06	8004/1705	M	COY	95	61	None	None	3	1	2	-	18 on back	Cub of D7133	Scale weight: 25 kg
D7350	15/06	8044/1400	M	Adult	250	170	-/ L pm1	1	3	1	2		19 on hips	Single	Rpm1 gone; Lpm1 broken
D7351	17/06	8031/1057	F	Adult	214	105	-/ R pm1	1	3	1	2	9679	20 on hips	Single	
D7352	18/06	7938/1758	F	Adult	198	109	-/ R pm1	1	3	1	2		21 on hips	Single	

Table 9.5: Polar Bear females with satellite-linked radios.

BEAR #	SYS #	SAT ID	Turn on	Put on	Location (N/W)	VHF ID	Family status
D7121	3449	10782	28/05/93	28/05/93	8032/1820	39067	With 1 yearling
D7125	6511	9678	07/06/93	07/06/93	8015/1920	8678	With 1 COY
D7127	6510	9684	09/06/93	09/06/93	8018/1308	8677	Single
D7129	6508	9682	11/06/93	11/06/93	7909/1711	8675	With 1 COY
D7131	3445	10780	11/06/93	11/06/93	7911/1711	39063	Single
D7132	3446	10781	11/06/93	11/06/93	7924/1625	39064	Single
D7133	6509	9683	13/06/93	13/06/93	8004/1705	8676	With 2 COYS
D7351	6512	9679	17/06/93	17/06/93	8031/1057	8679	Single

Although concentrations of Polar Bear tracks were found in certain areas of the off-shore pack ice, the pack ice and in particular areas with dense, multi-year ice generally were devoid of signs of Polar Bear activity. This thick multi-year ice had numerous ridges and very few ringed seals. Not surprisingly the Polar Bear tracks seen off-shore were found in areas with flat 1-year-old ice where basking ringed seals also occurred. This type of ice existed at the western fringes of the pack ice, i.e, close to land.

Tracks were frequently encountered at the edge of the land fast ice. However, no signs of bear activity were seen in the northern areas between Nordostrundingen (approx. 81°19'N 11°35'W) and Kap Ringkøbing. In this area, which had 10/10 multi-year ice, only two basking ringed seals were seen east of Nakkehoved. Few tracks were seen in Ingolf Fjord, Djimpna Sund and 79-Fjorden except at the entrance to these fjords. In particular there were many tracks on the eastern part of the land fast ice between Kap H. N. Andersen south to the east coast of Norske Øer.

Generally few basking ringed seals were observed. During the survey period the number of seals on the ice increased. The ringed seals concentrated on the flat young ice forming the edge of the fast ice in Ingolf Fjord, Djimpna Sund and 79-Fjorden whereas very few ringed seals were seen in other parts of these fjords. The general scarcity of ringed seals was confirmed by the fact that very few successful kills of seals in birth lairs or at breathing holes were observed. The Polar Bears had moved a lot along ridges and made fairly many unsuccessful attempts to excavate seal lairs. The numerous tracks gave a false impression of the presence of many bears, whereas they rather reflect the general scarcity of ringed seals.

Except for four bears (nos. 1, 6, 10 and 20; Table 9.4) that were tagged in the off-shore pack ice, all bears were taken on the land fast ice. In addition to these animals, Polar Bears were only seen off-shore on three other occasions.

A total of 23 different bears were observed from ship and helicopter in the NEW area. Of these four were observed from the ship, the remainder were seen from helicopter. Additionally, reports of the observation of at least four different Polar Bears at Kilen, Eskimonæs and Mallemukfjeld were received from the land parties. Of these latter bears, we are aware that at least two were not handled by us. Furthermore, on June 21, a female with two cubs of the year were observed

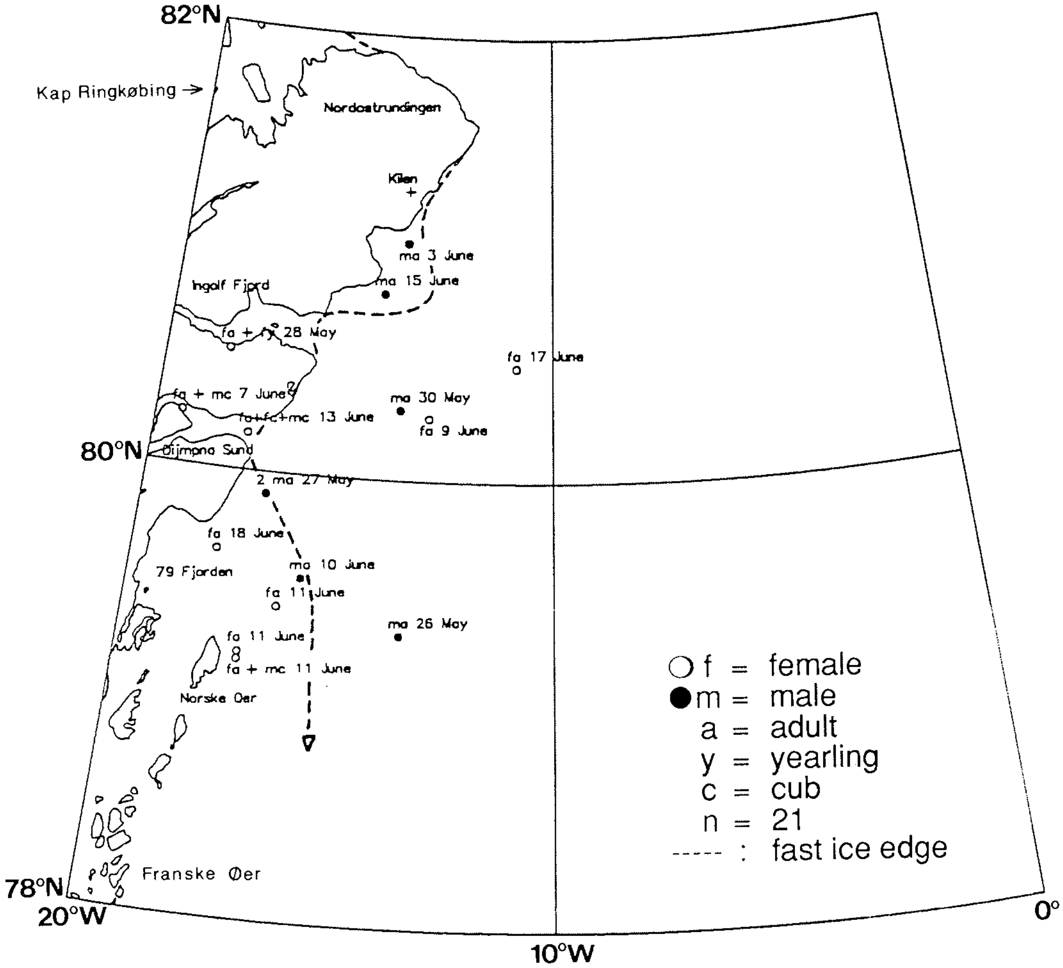


Fig. 9.2 Position of the tagged bears at collection.

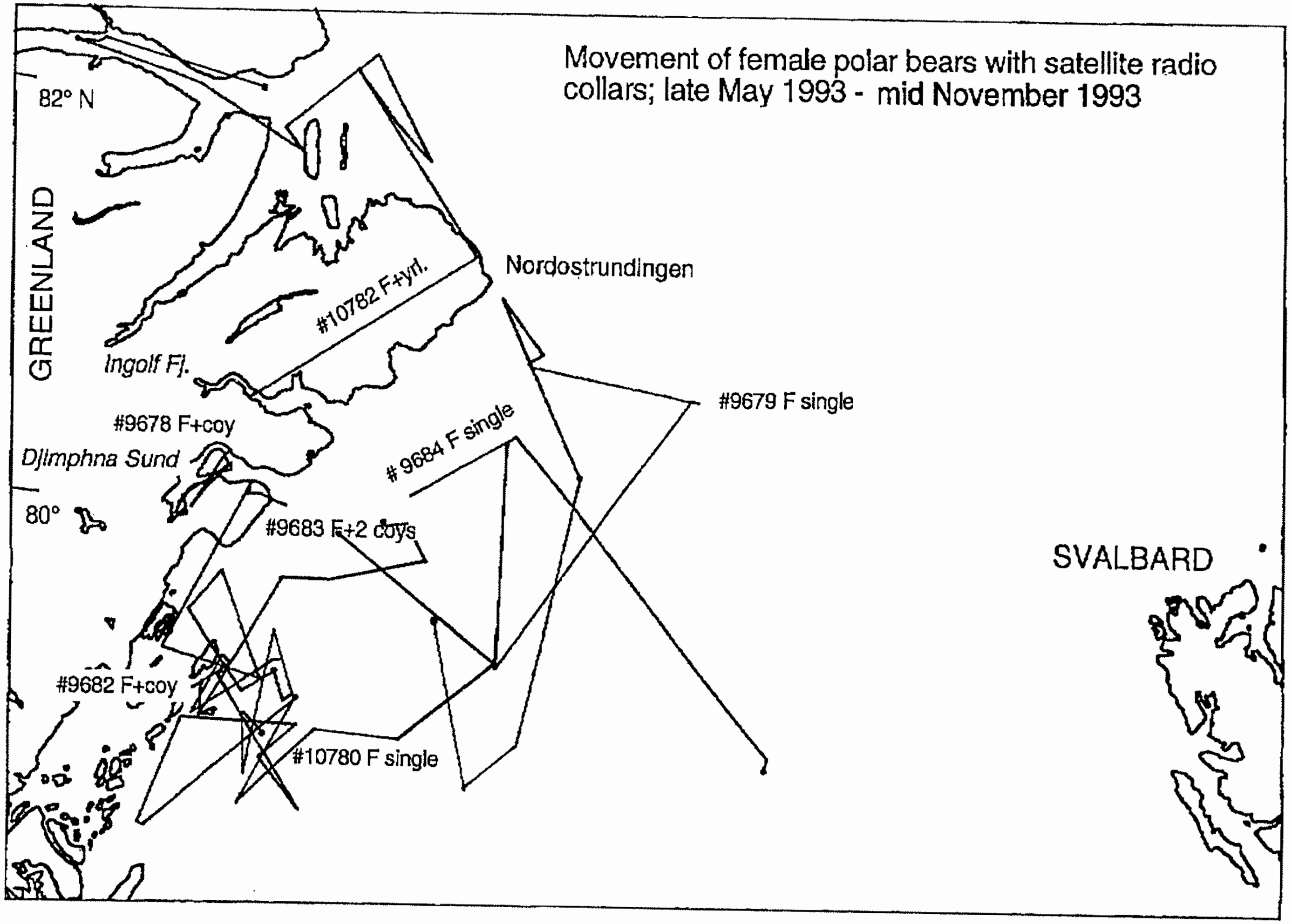


Fig. 9.3 Movements of tagged polar bears from capture to mid November.

from the ship in the offshore pack ice at 78°26'N 05°01'W. Various circumstances prevented that these bears and two other Polar Bears observed from the ship were tagged.

Polar bears with cubs prefer to move on stable substrate in areas where there are ringed seals. Hence, not surprisingly females with cubs were found on the stable ice in Ingolf Fjord, Dijmpna Sund and in 79-Fjorden ENE of Norske Øer somewhat remote from the coastal areas where the adult males occurred. The two females taken off-shore were both single (nos. 10 and 20; Table 9.4).

A total of seven re-sightings of tagged bears (= 5 bears) were made within the general study area. This indicates a fairly high degree of site fidelity and the presence of relatively few bears in the area during the study period.

Tentative conclusions: "Polarstern"'s cruise track and the allocation of time that the ship spent in different areas of the NEW was determined by station work serving inter-disciplinary scientific purposes. From a "Polar Bear" perspective this implied spending relatively much time in off-shore areas where the chances of encountering bears were few. Nevertheless, the access to helicopters with long endurance allowed for effective search for Polar Bears.

Despite that about 40 hours of flying were used searching for Polar Bears and an additional fair amount of flying hours devoted to other purposes also were used looking for bears, only 23 were seen. This indicates that relatively few bears were present in the NEW during the survey period. The coastal areas were apparently used for migration to other areas primarily by adult males. Adult females occurred on the stable ice in the fjords where relatively few ringed seals were seen during the surveys. The off-shore pack ice with few ringed seals appeared to be of little attraction to Polar Bears. We think that adult females and younger age classes are found farther south in the vicinity of Norske Øer, Franske Øer and Ile de France. The northerly situated cruise track of "Polarstern" did not allow for searching in these areas which happened to be outside the range of the helicopters.

9.3 Aerial survey of walruses 14 June 1993

E.W. Born, C. Joiris, A. Bochert

The purposes of the aerial survey were to 1. determine number of walruses between approximately 80° 10' N 13° W (northern part of Kilen) and 80° 40' N 14° 39' W at southern Henrik Krøyer Holme, and 2. the feasibility of using infrared camera for detecting walruses.

Methods

On 14 June 1993 a survey was conducted between 09:36 and 10:10 local time from north to south on a track situated between about 500 and about 1000 m from the edge of the fast ice. On the subsequent northward route designed for surveying birds, the survey track was placed further offshore (2-3 km from edge of fast ice) in the area where walruses were hauled out on the ice. Additional walrus observations obtained during a Polar Bear survey the same date (13:40-

14:00) between Henrik Krøyer Holme along the ice edge of Ingolf Fjord south to Eskimonæs are included. In this latter area the ice cover was 8-9/10 pack ice.

Aircraft: B 105 helicopter. Indicated airspeed: 110 knots. When infrared camera was used the indicated airspeed was 70 knots. Altitude: 600 feet. During the bird survey the altitude was 200 feet. Observer: Joiris left rear; Born co-pilot's seat front left; Bochert, right rear seat. The primary task of the left front observer was collecting detailed information on sizes of walrus groups. The right rear observer tended the camera. For the bird survey Joiris and Born changed seats. When walruses were encountered the infrared camera (8-12 micrometer infrared; 0.4-1.1 micrometer visible light) was activated. At 600 feet altitude the swath of the camera is 200 m on each side of the flight track. Hence, to use the infrared camera walruses had to be less than 200 m from the flight track when passed.

Weather conditions were: 0 Octas cloud cover. Temperature: ca. -5° C; Wind: approx. 3-8 m/s from NE; sea-state: 3-4. Ice cover: 1-2/10 consisting of small, white floes of multiyear and 1-year ice.

Preliminary results

During the first survey between Kilen and Henrik Krøyer Holme on 14 June a total of 76 walruses were observed . Of these 96% occurred along the ice edge in Antarctica Bugt. The detailed observations during the survey are listed below:

0936: 1 adult, water, northern Kilen

0945: 1 ad., water, 80°57', 13°53'W
1 ad., water, 80°57', 13°53'W
The site on the edge of the land fast ice where a minimum of 79 walruses hauled out on 3 June was detected as a greyish spot (80°57', 13°53'W)

0947 Airspeed:70 knots
14, floe (10 x 10m) among other floes close to fast ice edge.
Brownish faecal staining.
4, floe
6, floe

Above three groups were beyond swath limit.
Swing to go closer and "pick up" the groups (0948 I and II) within the swath of the infrared camera.

0948 (**I**): 8, floe (20 x 20m) 80°54.87', 14°07.05'W (on infrared and visible video). Emitted heat from walrus surface ca. 8.8°C. Water temperature: ca. 0°C (see attached)

(**II**) 10,8,5, on same floe (30 x 30m); group sizes presumably underestimated. Faecal staining (on infrared and visible video). Emitted heat from walruses was between ca. 8.4°C and 10,2°C.
5, floe (10 x 10m)
1, water

0955 Airspeed: 110 knots
Sea state: 3; glare in left side.
2, water
1, water
2, water, 400m from land, Sophus Müllers Næs
2, water, 400m from land, Sophus Müllers Næs

1001 East of northern Henrik Krøyer Holme, Ice 9/10 pack ice

1005 1 adult, water (in lead between fast ice and pack ice), south of southwestern Henrik Krøyer Holme

1010 80°40'N, 14°39'W. Beginning of northbound track (alt: 200 feet). From northern Henrik Krøyer Holme the flight track led directly to the southern edge of the glacier bounding the northern part of Antarctica Bugt; 2-3 km from the edge of the land fast ice.

1034 1 ad., water
1 ad., water, at southern edge of glacier
1 ad., water, at southern edge of glacier

1036 1 ad., water, 50m from glacier edge

1040 Observation stop approximately 7-8km south of hut at Kilen.
TOTAL: 76 walruses observed.

During the second survey on the same date a total of 18 walruses were seen near shore between Henrik Krøyer Holme and Eskimonæs. Hence, on this date 94 walruses were seen (Appendix). This can be compared with a count of 108 walruses between Henrik Krøyer Holme and Kilen on 3 June 1993. The infrared camera picked the two walrus groups that were allowed to be within the swath.

1345 1 ad., water, approx. 80°40'N, 14°39'W
5 ad., edge of ice floe (100 x 75m), no faecal staining, 1km east of Sommerterasserne.
8,4 hauled out in 9/10 pack ice approx. 3 km east of Eskimonæs (seen from hut).
TOTAL: 18 walruses observed.

The rough sea state and the glare during the southbound track of the first survey make it likely that not all walruses in water were detected. The fact that walruses appeared on the right hand side made it difficult for the left front observer to correctly determine group sizes and it is suspected that in particular larger groups were underestimated. Walruses had to be less than 200 m from the flight track to be within the swath of the infrared scanner. However, except for two instances this distance was considered to be too small to secure that walruses were not scared. Hence, other hauled walruses were passed at greater distances (> 500 m). Hence, the survey did not allow for a systematical evaluation of the feasibility of using this particular infrared camera for detecting and counting walruses. No signs of disturbance of the hauled groups were observed. However, the fact that the camera did pick up the walrus groups clearly demonstrates that it can be used for high altitude identification of hauled out walruses. However, "ground-truthing" data to obtain actual numbers in groups is necessary for calibrating information obtained by the infrared camera. To minimise the risk of disturbing the walruses it is, however, not recommended that such studies be conducted in this area.

Conclusions

The survey confirmed the findings of previous surveys during this cruise of "Polarstern" that the walruses occur nearshore primarily between Eskimonæs and Kilen. As also seen earlier during the ARK 9/2 cruise the majority was found along the ice edge in Antarctica Bugt. It may be speculated that this apparent site fidelity is caused by the presence of close by feeding grounds. This distribution pattern may well change during the summer.

For reasons given above the count of 94 walruses obtained on 14 June may well be an underestimate of the actual numbers. Furthermore, walruses have been seen offshore during the cruise of "Polarstern" and they therefore have a larger offshore range than that covered during the coastal aerial surveys. However, the result of the survey on 14 June is close to that obtained on 3 June when a total of 108 walruses were observed between Henrik Krøyer Holme and Kilen. Taking into consideration the various factors which may have led to an underestimate of the numbers it is still likely that this group of walruses does not number more than about 200 individuals

There seems not to be any reasons to make short term repetition of the aerial surveys over these walrus ground to obtain a more exact estimate than those already obtained. This statement shall be seen in the light of the fact that such repeated surveys increase the risk of disturbing this group of walruses which consists primarily of females with calves.

10 GEOLOGY

10.1 Geology and bottom topography

M. Antonow, H. Beese, R. Sauer

Goal of this study was to investigate the sedimentation regime in the Northeast Water Polynya. The shelf area of northeast Greenland is characterized by shallow banks surrounded by a trough system with depths up to 500 m. Brine formation may result in formation of dense water influencing direction and velocity of bottom currents. We expect properties and distribution of the sediments in the polynya to be a result of processes in the bottom nepheloid layer (BNL), i.e. resuspension, particle transport and (re)deposition of soft sediments on banks, in troughs or shelf depressions. For interpretation of the sediments documenting the geological past, investigations of the recent polynya hydrographic structures are neccesary. Another purpose of this geological survey is to provide other groups with bathymetric and sedimentological information.

Materials and methods

3.5 kHz subbottom profiling (1/4 sec sweep) was used following a preset geographical grid to improve information on bathymetry, regional distribution, thickness and acoustic character of the existing sediments.
Geological sampling: Short and long cores were taken for detailed downcore analyses of litholgical and palaeontological parameters.
Side scan sonar survey ("deep tow"): Resolves small scale topography and gives a visual impression of the underwater landscape. This topography influences strongly sediment distribution and benthic biology.
Oceanographic measurements: Directions and velocities current of the present water masses in several depth intervals of the water column were measured using an Acoustic-Current-Doppler-Profiling system (SC-ADCP, 150 kHz). The ADCP is mounted in a frame and was lowered down to about 200 m to resolve the current regime in the BNL. In addition to the shipmounted depth-limited ADCP of the AWI oceanographic group, information of the current profiles of the whole water column at depth greater 300 m exists.
Geological sampling and locations: 34 short sediment cores ("Rumohr"-Lot) along five transects across the trough system were taken (Table 10.1). Length of sediment cores reached 0.80 m in average. Due to the hard substrate, sampling at shallow areas was not very successful (max. 20 cm, but normally no sediment). North of Belgica bank a long sediment core (Kastenlot, PS 2383-2) was taken in the deep trough region, which is described in Fig. 10.1. All samples were airtight sealed and then kept refrigerated aboard. Sedimentological investigations, such as water content, granulometry, contents of carbonate and (total) organic carbon, will be measured in laboratory in Kiel. Isotopic composition of foraminifera tests are used for stratigraphic determination and SEM investigations will characterize particles of suspended and bottom sediments.

Preliminary results

A side scan survey across one transect was carried out using a "Tow Fish 990" (EG&G) combined with a Model 996 Digital Modem, a Graphic Recorder (EG&G Model 260), and an IBM computer. The scanning range was 300 m each side with a resolution of 0.75 m. The sonar unit (59 kHz) was close to the bottom between 25 and 30 m. The tow fish was trawled with a velocity of 3 to 4 knots over ground. A nearly 35 nm profile was produced along stations 13-16. Small scale topography was resolved in water depths between 40 and 280 m. An example of the side scan sonar is shown in Fig. 10.2. The side scan sonar survey picks up details affected by dynamic geological processes on the NE Greenland shelf. Sediment ripple marks indicating a steady regime of strong bottom currents have not been found. Most of the topographic features are plough marks generated by drifting ice. These marks show differences in size, depth and pattern. Three areas have been classified:
- areas with diffuse, large, "old looking" plough marks
- areas, where plough marks are grouped into small zones with parallel narrow marks with gentle relief
- areas with single "fresh looking" plough marks. These scours are deeper than most of the others.

The predominant direction of scours is NNE-SSW. Detailed investigation of the directions and distribution of plough marks will provide information on the general drift pattern in the areas investigated.

Table 10.1: List of geological samples

station	date	longitude	latitude	water depth	core number
011	26.5.93	79°22.29 N	13°33.27 W	140 m	PS 2376-1
012	26.5.93	79°23.50 N	14°58.15 W	49 m	PS 2377-1
013	26.5.93	79°24.85 N	15°37.00 W	40 m	PS 2378-1
014	26.5.93	79°30.63 N	15°48.36 W	130 m	PS 2379-1
015	27.5.93	79°35.81 N	16°01.59 W	195 m	PS 2380-1
016	27.5.93	79°41.39 N	16°16.02 W	308 m	PS 2381-1
017	27.5.93	79°59.06 N	17°05.52 W	130 m	PS 2382-1
018	27.5.93	79°54.90 N	16°57.90 W	300 m	PS 2383-1
018	27.5.93	79°54.80 N	16°58.20 W	302 m	PS 2383-2
019	28.5.93	80°22.23 N	15°41.28 W	77 m	PS 2384-1
020	28.5.93	80°20.00 N	15°18.44 W	230 m	PS 2385-1
021	28.5.93	80°20.16 N	14°50.45 W	327 m	PS 2386-1
022	28.5.93	80°12.93 N	14°16.16 W	309 m	PS 2387-1
023	28.5.93	80°04.49 N	14°39.62 W	207 m	PS 2388-1
026	29.5.93	80°19.73 N	13°21.01 W	266 m	PS 2389-1
027	29.5.93	80°22.78 N	13°34.45 W	281 m	PS 2390-1
028	29.5.93	80°27.86 N	13°42.76 W	320 m	PS 2391-1
029	29.5.93	80°31.92 N	14°01.09 W	233 m	PS 2392-1
032	01.6.93	80°36.85 N	11°19.11 W	255 m	PS 2393-1
047	05.6.93	80°55.81 N	11°32.21 W	155 m	PS 2394-1
048	05.6.93	80°49.61 N	11°32.63 W	280 m	PS 2395-1
049	05.6.93	80°44.62 N	11°35.12 W	142 m	PS 2396-1
059	07.6.93	80°27.21 N	13°40.41 W	326 m	PS 2397-1
060	08.6.93	80°18.20 N	13°31.73 W	267 m	PS 2398-1
061	09.6.93	80°30.60 N	14°05.70 W	280 m	PS 2399-1
073	11.6.93	79°41.54 N	16°15.00 W	300 m	PS 2400-1
074	11.6.93	79°48.14 N	16°34.36 W	244 m	PS 2401-1
077	12.6.93	80°05.11 N	15°44.07 W	405 m	PS 2402-1
080	13.6.93	80°13.11 N	13°54.19 W	206 m	PS 2403-1
085	14.6.93	80°35.70 N	09°23.67 W	246 m	PS 2404-1
099	19.6.93	78°54.37 N	12°05.51 W	269 m	PS 2405-1
100	20.6.93	78°45.24 N	09°51.31 W	430 m	PS 2406-1
101	20.6.93	78°41.16 N	08°21.37 W	191 m	PS 2407-1
102	20.6.93	78°38.50 N	06°59.22 W	227 m	PS 2408-1
103	21.6.93	78°35.76 N	05°49.44 W	320 m	PS 2409-1

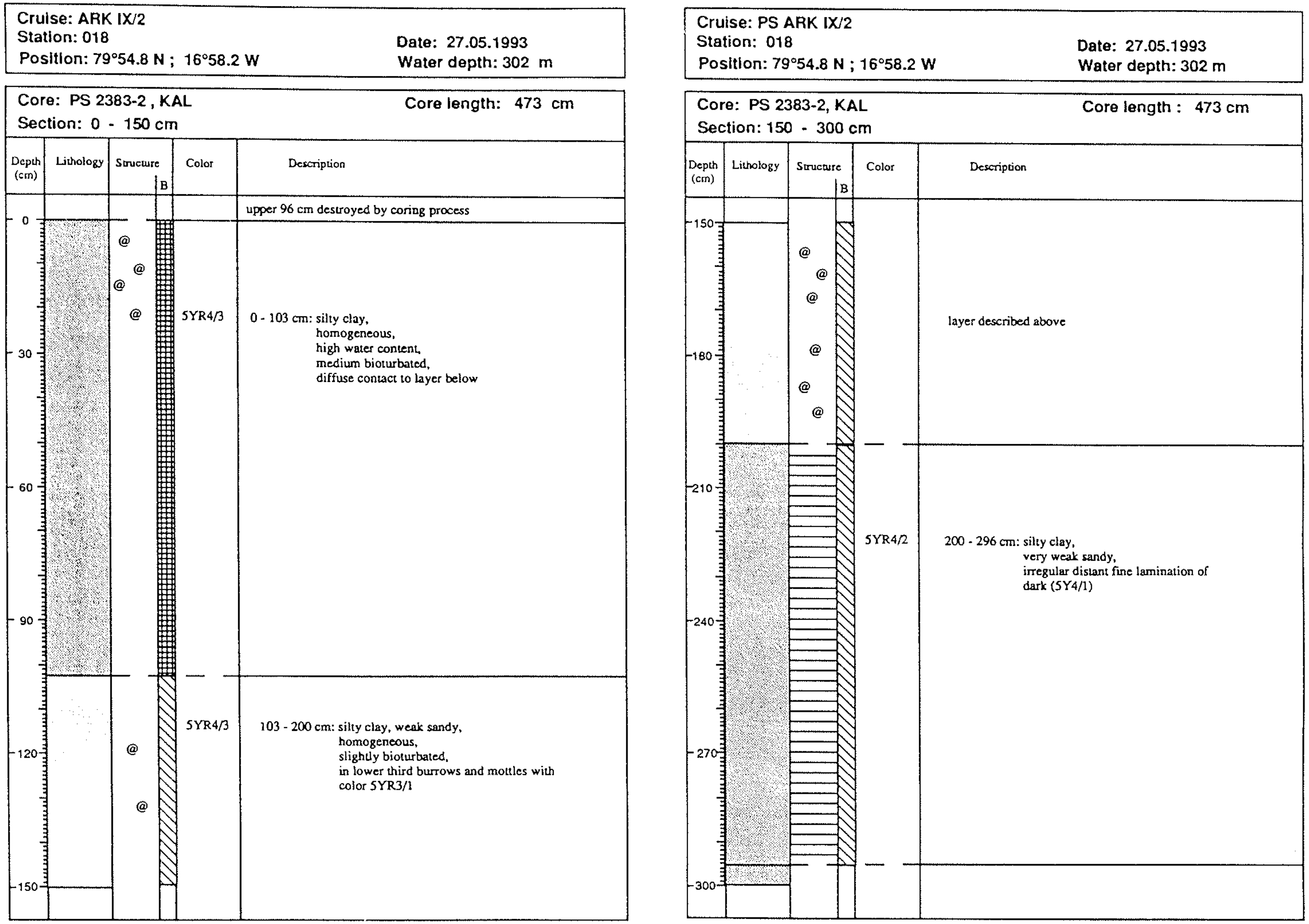
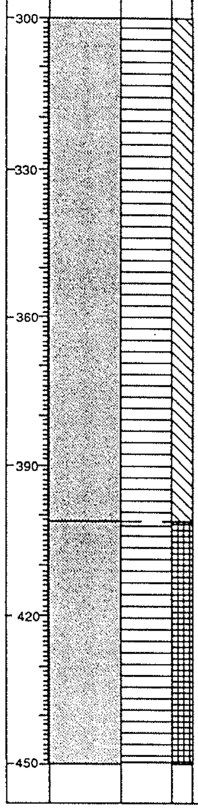


Fig. 10.1. Description of a long sediment core (Kastenlot PS 2383-2) taken north of Belgica Bank.

Cruise: PS ARK IX/2
Station: 018
Position: 79°54.8 N ; 16°58.2 W
Date: 27.05.93
Water depth: 302 m

Core: PS 2383-2, KAL
Section: 300 - 450 cm
Core length: 473 cm

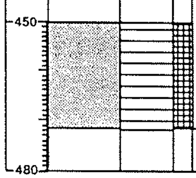
Depth (cm)	Lithology	Structure B	Color	Description
300 - 402			5YR4/3	296 - 402 cm: silty clay, very weak sandy, irregular distant fine lamination of dark (5Y4/1) and yellow reddish layers in a range of several mm rare bioturbated
402 - 450			5YR4/3 to 5YR4/4	402 - 473 cm: very silty clay, weak sandy, nearly the same fine lamination as in the section from 296 - 402 cm medium bioturbated



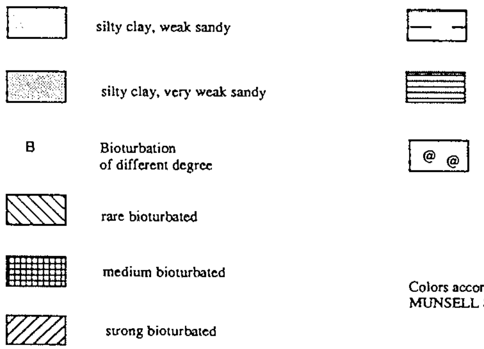
Cruise: PS ARK IX/2
Station: 018
Position: 79°54.8 N ; 16°58.2 W
Date: 27.05.93
Water depth: 302 m

Core: PS 2383-2 , KAL
Section: 450 - 480 cm
Core length: 473 cm

Depth (cm)	Lithology	Structure B	Color	Description
450 - 473			5YR4/3 to 5YR4/4	layer described above
473 - 480				end of core: 473 cm



Legend



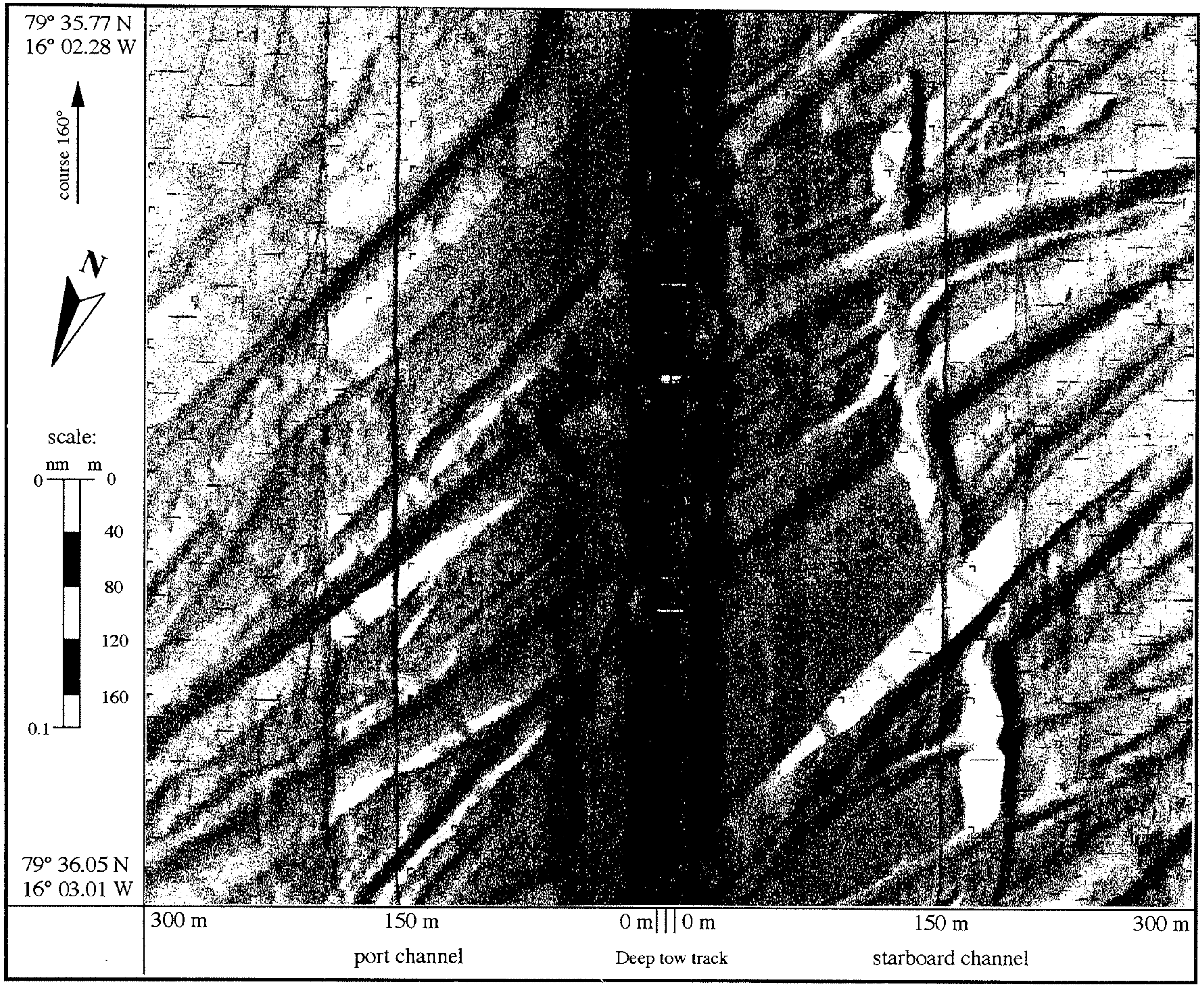


Fig. 10.2. Side scan sonar image north of Belgica Bank (204 m depth)

10.2 Marine Geology

A. Mackensen, C. Kopsch, S. Nam, H. Notholt, M. Weber

The geological sampling program on the third leg of the ARK-IX cruise is both, part of and also the continuation of an ongoing study (Nam et al., 1993; Stein et al., 1993) designed to investigate the east Greenland continental margin response to global climatic changes during the last 250,000 years. Special emphasis is given to the last glacial and interglacial time. As such this program completes the NEW Polynya project by extending the time scale as well as the geographic range of the biological and oceanographic investigations. The geological investigations add information on (1) the fate of the organic matter that was produced in the surface water layer of the polynya, on and within the sediment, and (2) on the pattern of the near-bottom current circulation as reflected in the sediments of the continental shelf and the upper slope during the glacial/interglacial cycles. A suite of sedimentological, micropaleontological and geochemical standard routines will be applied to the samples recovered. The intensive biological sampling and the oceanographic surveys undertaken as part of the NEW project provide us with the unique opportunity to calibrate our paleoenvironmental reconstruction to the Recent analogue.

Since it is recently detected that during peak cold climatic periods atmospheric CO_2 concentration was about 30% below Recent, i.e. interglacial values, one of the tasks in paleoceanographic research has been to understand the global carbon cycle. Atmospheric CO_2 changes during the ice ages should be forced by a redistribution of carbon within the ocean, which is the world's largest easily and readily accessable CO_2 reservoir. Bottom water circulation and biological productivity are two of the mechanisms responsible for the partitioning and the redistribution of carbon within the ocean. These two processes are recorded by the stable isotopic composition of carbon, foraminiferal faunas and by geochemical as well as sedimentological gradients in the sediment.

Materials and methods

Water samples: To follow the fate of the stable carbon isotope composition ($d^{13}C$) from the surface water, the site of primary production, down through the water column onto the surface sediment and into the fossil benthic foraminiferal test, we carried out an intensive water sampling program. Immediately after recovery, all of the water samples taken for carbon analyses were poisoned with a saturated solution of $HgCl_2$, sealed with wax and kept cool until on-shore for determination of the $d^{13}C$ of the total dissolved inorganic carbon. Samples for $d^{18}O$ determination were not poisoned but otherwise treated in the same way.

To determine the distribution of stable carbon and oxygen isotopic composition in the water column, we drew 250 mL and 100 mL water, respectively, from 12 L Niskin sampling bottles at 24 oceanographic CTD stations (Fig. 10.3).

To determine the stable carbon and oxygen isotopic composition of the bottom water within the last 0.40 m above the sea floor, at 14 stations, we drew 250 ml and 100 ml water, respectively, from 12 l sampling bottles of the BWS from 0.05, 0.10, 0.20 and 0.40 m above the ground each (Fig. 10.3). To determine the stable carbon and nitrogen (^{15}N) isotope composition of the particulate organic matter of

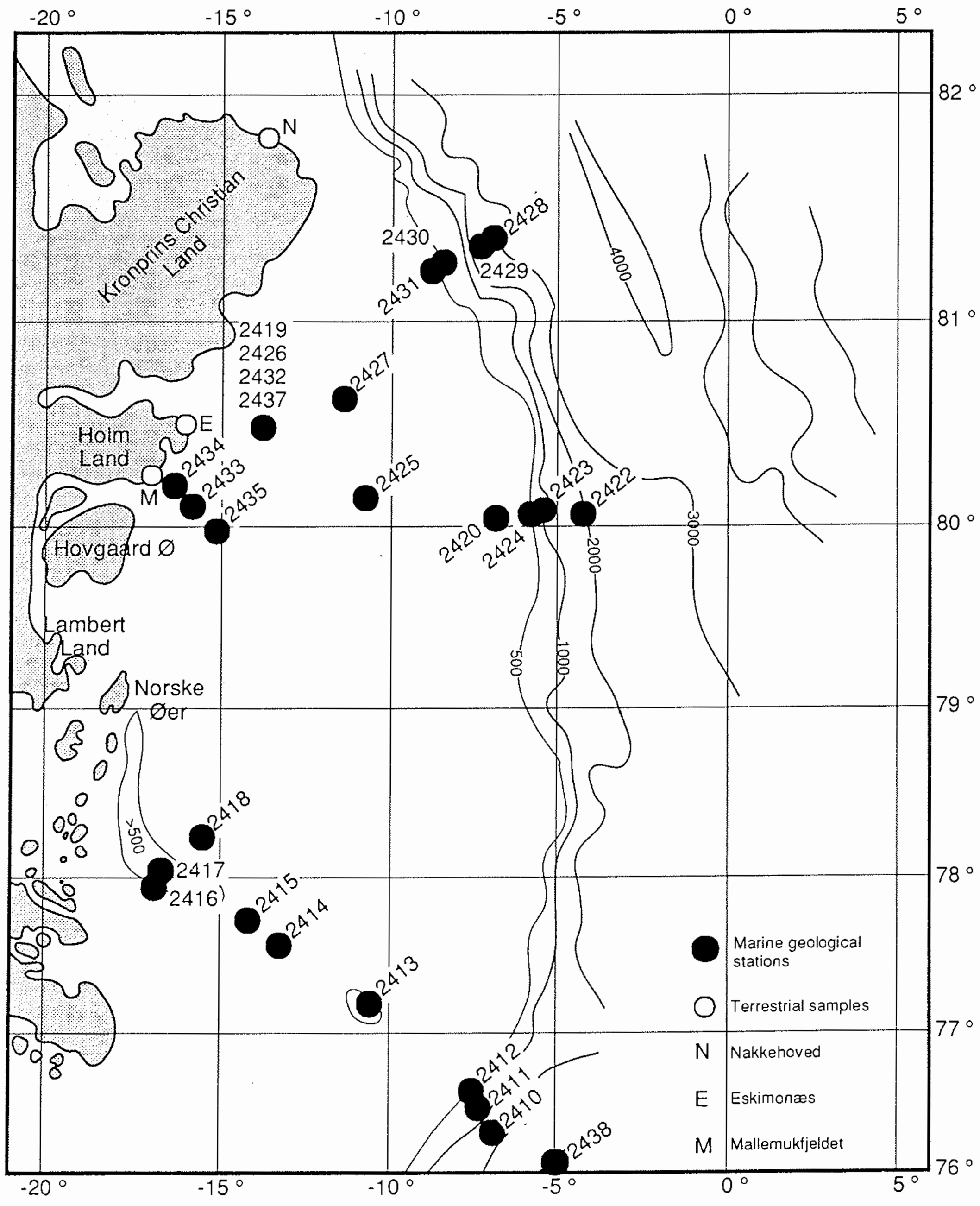


Fig. 10.3. Map with locations of marine and terrestrial geological stations.

the bottom water, between one and two litre of each bottle were filtered through micro fibre filters. The residue was kept frozen until on-shore treatment.

To determine the stable carbon and oxygen isotopic composition of the bottom water directly overlying the sediment, i. e. from the sediment/water interface, at 21 stations, we drew 250 ml and 100 ml water, respectively, from one of the cores of the multiple corer (Fig. 10.3). These samples are of particular importance, since they were taken to figure out by comparison with BWS samples whether pore water is polluted by bottom water during sampling as was suspected by Mackensen et al. (in press), and how the water column in the multiple corer tube integrates the gradients within the benthic nepheloid layer and above it.

Sediment samples: To directly compare sedimentary particulate organic matter ^{13}C and ^{15}N composition with possible terrigenous sources, samples from snow, meltwater run-off, soil and plants were collected from several locations on the East Greenland coastal areas (Fig. 10.3, Table 10.2a-d). The samples are kept frozen until on-shore treatment. These samples are complemented by two additional sample sets currently collected by the Danish Geological Survey on Greenland and the AWI on Spitsbergen, respectively.

Table 10.2a: List of terrestrial organic samples and species from Mallemukfjæll (80° 13,86'N 6° 48,26'W; July 4)

Sample no.	Object	Location
215	Soil	Edge of plateau
215 a	Plant, Cruciferae, Draba alpina	Edge of plateau
217	Soil+Bryophytes	Edge of plateau
225 a	Plant, Cerastium/Stellaria	Slope
225 b	Bryophytes	Slope
225 c	Stone with lichen	Slope
226 a	Plant, Minuartia?	Edge of plateau
230 a	Plant, Salicacae, Salix polaris	Edge of plateau
231 a	Stone with lichen	Plateau, ca. 300 m above sea
231 b	Stone with lichen	Plateau, ca. 300 m above sea
231 c	Stone with lichen	Plateau, ca. 300 m above sea
231 d	Stone with lichen	Plateau, ca. 300 m above sea

Table 10.2b: List of terrestrial organic samples and species from Mallemukfjæll (80° 13,86'N 6° 48,26'W; July 5)

Sample no.	Object	Location
500	Plant, Salicacae, Salix polaris	Edge of plateau
503	Plant, Papaveraceae, Papaver dahlianum	Edge of plateau
503 a	Plant, Cruciferae, Draba alpina	Edge of plateau
503 b	Plant, Salicacae, Salix polaris	Edge of plateau
504	Plant, Cruciferae, Draba alpina	Edge of plateau
505	Plant, Minuartia? spec. indet.	Edge of plateau
506	Plant, Papaveraceae, Papaver dahlianum	Edge of plateau
507	Plant, Salicacae, Salix polaris	Edge of plateau
508	Plant, Saxifragaceae, Saxifraga oppositifolia	Edge of plateau
509	Plant, spec. indet.	Edge of plateau
510	Plant, Saxifragaceae, Saxifraga oppositifolia	Edge of plateau
511	Plant, Cerastium/Stellaria	Edge of plateau
512	Bryophytes	Edge of plateau
513	Sediment	Small stream
514	Bryophytes+Lichen	Edge of plateau
515	Soil	Plateau, ca. 300 m above sea
516	Soil	Plateau, ca. 300 m above sea
517	Sediment	Small stream

Table 10.2c: List of terrestrial organic samples and species from Eskimonæs (80° 26,30'N 15° 47,19'W; July 4)

Sample no.	Object	Location
201	Bryophytes, in water	Beach, Puddle
202	Melting surface water, algae	Beach, Snow
203	Melting water, bottom material	Beach, Snow
204	Bryophytes	Beach
206	Bryophytes+Sediment	Beach, Small stream
208	Sediment, Gravel	Beach
209	Bryophytes	Beach, Edge of snow
211	Melting water, bottom material	Beach, Snow
211 a	Bryophytes	Beach, Edge of snow
212	Snow, Inorganic material	Beach
216	Sediment, Gravel	Beach
227 a	Bryophytes	Beach, By puddle
228 a	Stone with lichen	Beach
229 a	Plant, Papaveraceae, Papaver dahlianum	Beach

Table 10.2d: List of terrestrial organic samples and species from Nakkehoved (81° 43,28'N 13° 13,61'W; July 16)

Sample no.	Object	Location
401	Plant, Potentilla tridentata	Beach
402	Plant, Potentilla, spec. indet.	Beach
403	Plant, Papaveraceae, Papaver, spec. indet.	Beach
404	Plant, Luzula multiflora?	Beach
405	Plant, Cerastium arcticum	Beach
406	Plant, Papaveraceae, Papaver, spec. indet.	Beach
407	Plant, Minuartia, spec. indet.	Beach

During leg ARK IX/3, multiple corers with tubes of 6 cm or 10 cm diameter were used. After sampling the water, sediment was extruded out of usually four of the 6 cm-multiple corer tubes, and out of two of the 10 cm tubes, respectively, cut into slices of 1 cm thickness, stained with Rose Bengal, and stored separately prior to determining its benthic foraminiferal content onshore. Two 6 cm tubes and one 10 cm tube were kept frozen at -27°C. At the onshore laboratory, these samples will be cut into slices of 0.5-1 cm thickness and analysed on their ^{13}C and ^{15}N composition of the sedimentary and fluffy layer organic matter.

Late Quaternary sediments were cored with a gravity corer on three profiles running from the inner polynya area on the continental shelf perpendicular to the continental slope down into the deep sea (Fig. 10.3). All of these stations were complemented by multiple corer and CTD casts to recover an undisturbed surface sediment and to describe the hydrography of the overlying water masses, respectively. Because of time constraints the selection of appropriate sampling positions with the aid of Parasound echosounding was not always possible. Consequently, at three stations on the continental slope, where strong bottom currents generated a lag sediment with gravel and stones or turbidites occur, as well as on some stations on the shelf, where over consolidated diamicton was deposited, we did not succeed to recover long cores. However, generally a recovery of 53% is within the range known from the southern East Greenland continental margin, although the length of the cores is below average (Fig. 10.4). In addition to long gravity cores we prolonged our geological profiles across the slope onto the shelf with up to 1 m cores. These cores were retrieved with a so-called Rumohr corer and will be analysed to obtain further information on Recent and late Holocene sedimentation processes within the polynya area and sediment export down the adjacent upper continental slope.

Preliminary results and further investigations

Cores taken by gravity corer from the continental shelf usually are very short, probably because of the fact that even in the troughs only a thin veneer of soft glaciomarine sediments of probably Holocene age cover firm and compacted diamicton of probably late Pleistocene age, that may be interpreted as till. This interpretation includes that during the last glacial time (oxygen isotope stage 2) grounded ice covered the continental shelf. Cores taken from the continental slope are usually longer and consist of alternating glaciomarine sequences of brownish to light olive grey sandy mud with low to moderate IRD (Ice rafted debris) content and dark grey to dark olive grey sandy mud with high amounts of

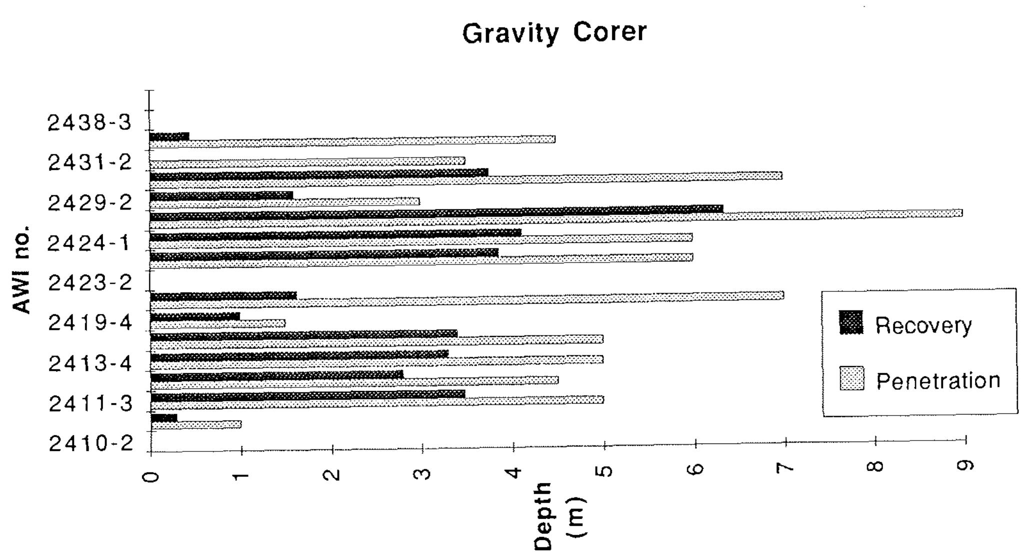


Fig. 10.4. Plot showing penetration and recovery of each gravity corer deployment.

samples these changing lithofacies can be interpreted as reflecting late Quaternary interglacial and glacial periods. Coal particles are found in cores PS2428-3 and PS2430-3 within the dark coloured, probably glacial sequences. It is known that coal is transported by enhanced ice rafting during glacial periods from source areas in Siberia or from Svalbard (Bischof et al., 1990), although local origin from adjacent deposits on Greenland cannot be excluded (C. Hjort, pers. communication, 1993).

Onboard ship, preliminary investigations of splits of surface sediment samples were undertaken to roughly get an idea on their benthic foraminiferal content. Most of the continental shelf samples yield species- and specimen-rich benthic foraminiferal faunas. *Melonis zaandamae, Lobatula lobatula* (the former *Cibicides lobatulus*), *Cassidulina teretis, Islandiella norcrossi* and *Buccella tenerrima* belong to the most common calcareous species. Accessory species include, *Elphidium excavatum, E. arctica* and other elphidiids, as well as *Cassidulina reniforme, Nonion labradoricum* and *Rupertina stabilis.* Including the rich agglutinated fauna (a. o., *Rhabdammina* spp., *Rhizammina* spp., *Cribrostomoides* sp.) a difference in faunal composition between soft-bottom preferring faunas and those living on hard substrates is obvious. This faunal change, of course, is related to food supply and bottom currents. In general, the faunal composition does so far not differ significantly from shallow water faunas known from the Iceland-Faeroe-Ridge and the northern Barents Sea (Mackensen et al., 1985; Mackensen, 1987).

In addition to the analysis of the stable carbon isotopic composition of dissolved inorganic carbon and foraminiferal carbonate, it is planned to measure the ^{13}C and ^{15}N values of sedimentary organic carbon. To interpret longer sediment sequences and their isotopic composition in terms of the origin of the organic material from either marine or terrestrial source areas, it is necessary to analyse Recent processes that cause isotopic fractionation. It is known that extreme isotopic fractionation can occur when organisms grow under harsh environmental conditions such as in the Arctic and Antarctic (Fischer, 1989). This enhanced fractionation can bias the usually different signals between terrestrial and marine organic matter. Therefore one of us (H. Notholt) will determine the isotopic composition of the terrestrial material collected on this cruise and the two associated expeditions on Greenland and Spitsbergen (Table 10.2a-d) and the marine organic material that we collected with the Bottom Water Sampler and the multiple corer.

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11 USCG POLAR SEA - NEWP93 Operational cruise summary
J. Deming

The Polar Sea left Kevlavik on July 18, 1993, transitted to the ice edge at about 79°N 3°W, and entered a relatively ice-free portion of the study area near the mouth of the northern trough. Our first station was occupied at approximately 80°20'N 8°50'W (Fig. 11.1). The first phase of the cruise continued to focus in the northern trough and open polynya region. There we successfully recovered all four of the yearlong current-meter and sediment-trap moorings, including hydrographic sections flanking the mooring locations prior to their recovery. We also occupied the international time-series station for a period of 72 h to assess diurnal and tidal effects there, sampled benthic stations along the axis of the trough, and completed hydrographic transects flanking the mouth of the northern trough (which we had been unable to complete last year due to heavy ice and operational problems). Early in the cruise, we met the Polarstern at the time-series station for transfer of personnel and gear and for an intercalibration of methods on samples from a CTD cast and multi-coring device. The results of this effort should facilitate international data comparisons between participants of the Polar Sea and Polarstern cruises.

The second phase of the cruise involved pelagic and benthic work in the south-western portion of the polynya and in the southern trough. We reached that area by transitting the width of the Belgica Bank along a NE-SW hydrographic transect, punctuated with benthic sampling stations, to assess water movements on the Bank and related chemistry and biology. While working southwest in the polynya, a 60-mi wide piece of the fast-ice ridge or "nose" on the shelf broke free at about 79°30'N 16°W, leaving an 8-mi wide crack in the fast ice that spanned the entire east-west width of the nose from the shelf to the coastline. We took advantage of this rare event and the resulting ice crack to collect pelagic and benthic samples from sites previously unapproachable by ship due to the "permanence" of the fast-ice ridge. During this effort, a major storm with strong

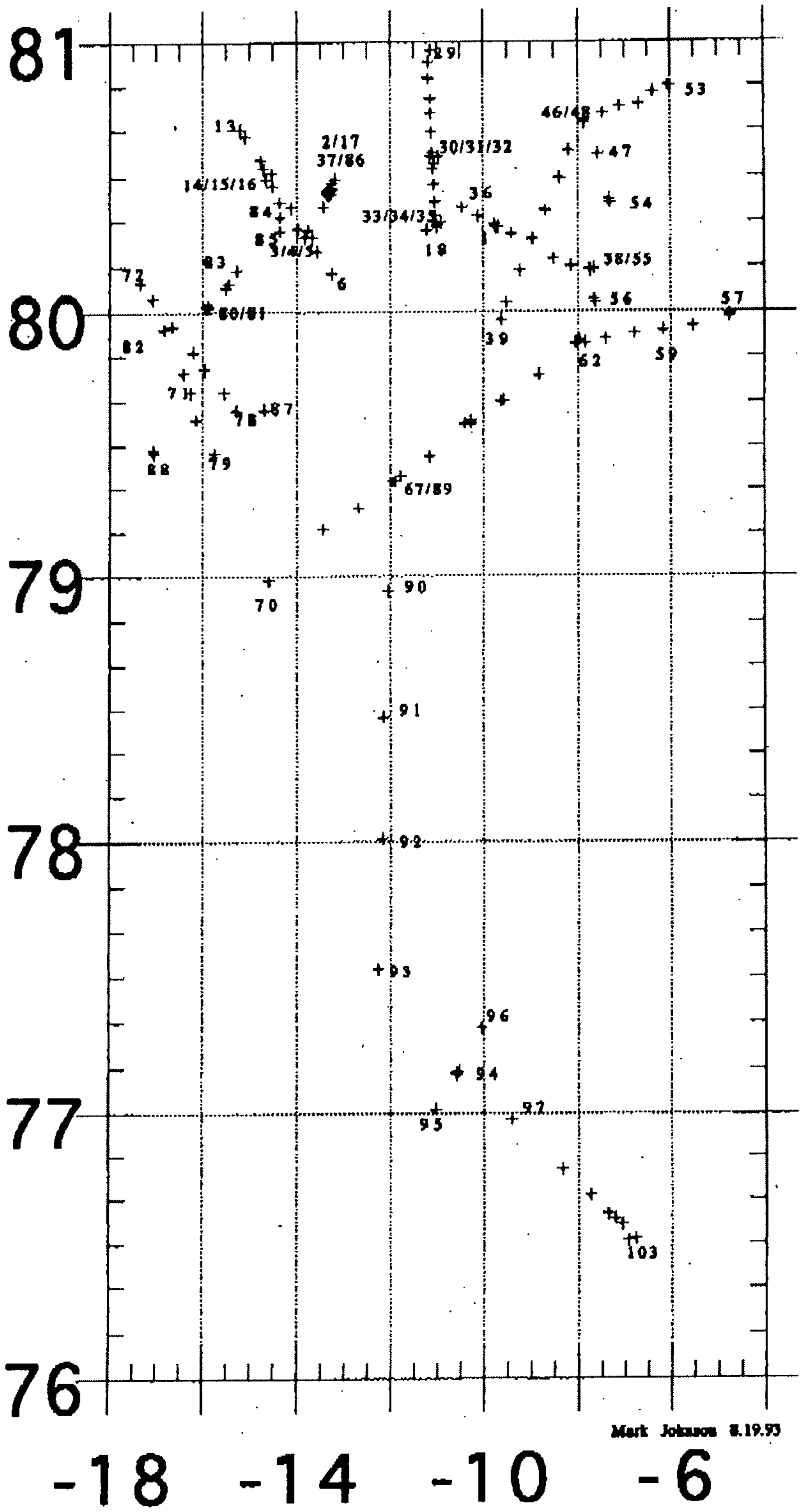

Fig. 11.1. Cruise track of USCG Polar Sea.

throughout the study area, providing us with an opportunity to experience the extraordinary ice-breaking capability of the Polar Sea. After emerging from the fast ice, we completed a final hydrographic and benthic sampling effort in the southern trough of the study area. This entire area was shrouded by fog and low cloud for the duration of our cruise, precluding a picture of the new storm-induced ice distribution from the satellite images. However, the need to break through heavy ice in areas previously ice-free (and vice versa) confirmed the dramatically altered ice cover. We left the study area near the ice edge at about 76°30'N 7°W, and arrived in Kevlavik on August 20.

In total, we occupied 103 stations and completed 180 CTD hydrocasts for chemical determination of nutrients, oxygen, inorganic carbon species (including carbon dioxide), chlorophyll, particulate carbon and nitrogen, biogenic silica, productivity, bacterial and protozoan abundance and algal taxonomy. We recovered 3-4 boxcores from 20 of the stations for analysis of sediments, bacterial abundance and activity, geochemistry, forams, meiofauna and macrofauna. At six stations large-volume pumping systems were deployed for the assay of stable isotopes. At the time-series station, two short-term floating sediment trap arrays and a three-week meteorological buoy were deployed. On five occasions in open water, a remotely operated benthic lander for measuring benthic oxygen demand was deployed successfully. Divers were used for two deployments of a lander in shallow water beyond the reach of the ship. Within the limitations of weather (fog and the major storm near the end of the cruise) and mechanical and safety constraints, we made good use of the US Coast Guard helicopters to validate satellite images, recover ice cores and survey bird and mammal populations. We also conducted two support flights for the Danish NEW-Land project and our international colleagues on Greenland. We considered the cruise a significant operational success for individual and collective research endeavours and look forward to data exchange and analysis with our international colleagues.

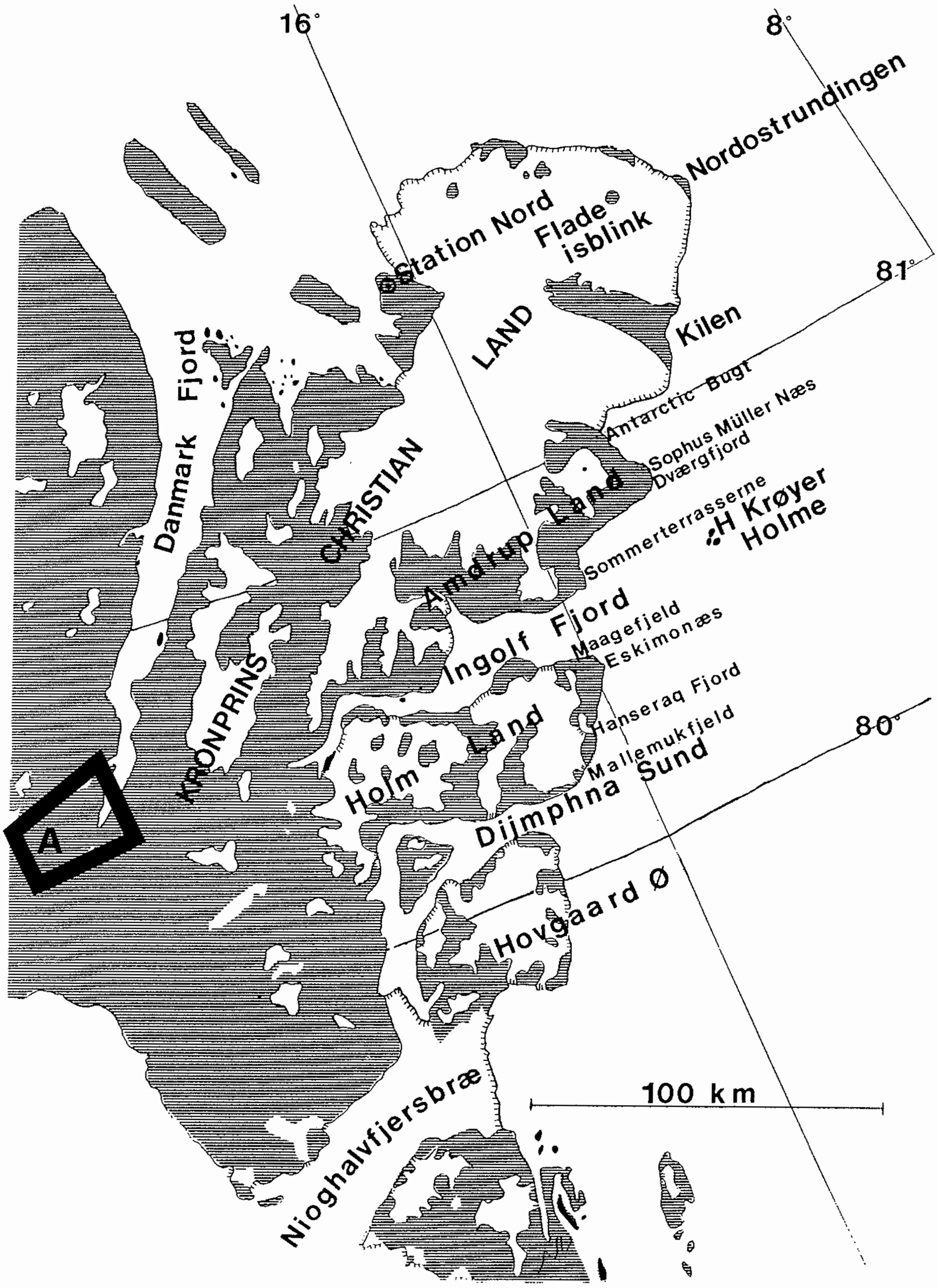

Fig. 12.1. Map of Northeast Greenland.

12 NEWLand

12.1 Marine shallow coastal ecology - with special reference to the plankton development

J.M. Weslawski, J. Wiktor

The goals were to collect data on the marine ecology of the shallow-coastal edge of NEW, with special reference to the time series of plankton development. The study was performed from May 27 to June 17 on the Eskimonæs peninsula.

Methods and preliminary results

Study area: As a base camp the Eskimonæs peninsula was chosen. The Polish hut was erected next to the Swedish camp, at 80°26'330"N 15°47'230"W. The Eskimonæs area is a flat, covered with stones, nearly without vegetation. Snow cover was patchy at the time of arrival, reaching in some places more than 1 m thickness, on other spots barren ground was exposed. The work was performed on the coastal polynya of variable area, from 1 to 15 km^2. Constant sampling point was located 1600 m from the shore line, at 80°27'160"N 15°46'454"W. A list of all sampling activities is presented in Table 12.1.

Bathymetry: Due to the malfunction of alkaline batteries our boat echosonde refused to work in low temperatures. Nevertheless, some information was obtained. The area around Eskimonæs is a shallow water, flat bank, not exceeding 30 m in depth up to 2 miles from the shore, as far as we could reach the ice free water. Bottom is covered by gravel and stones all over the area. On the places deeper than 25 m we found tracks of red mud. The layer of soft sediment was very thin, covering just the surface of stones on the bottom.

Ice conditions: The average ice situation and polynya shape at Eskimonæs is shown in Fig. 12.2. At the time of arrival, the Ingolfs Fjord fast ice edge was running to the NW from the Eskimonæs, and it stayed unchanged for the three weeks. The area was free of drifting ice for the first two days, as long as strong gale from NW was blowing. After the wind changed for SE direction, the dense drift ice appeared and locked all the area. At the peninsula the small coastal polynya remained open all the time. It was variable in shape and area, but generally it started at the fast ice edge and covered 1 to 15 km^2 area. At the edge of the fast ice its thickness did not exceed 1.8 m. Among drifting ice most of unstapled floes were of 1 to 1.5 m thick. Several middle sized icebergs were stranded in the working area, at highest reaching about 12 m above the water level. In crevices among drifting ice the fresh ice was formed, reaching the thickness up to 10 cm after two weeks of freezing. Nine samples from 1.5 m, 10 cm and 2 cm thick ice were collected. Ice was melted in +5°C water and analysed for salinity, later fixed with 4% formaldehyde for phytoplankton and mineral matter analyses.

Hydrological measurements: With the use of a small CTD probe (Sensor Data Bergen S-202) we have conducted the temperature, salinity and depth measurements. All data are stored in PC and are available as ASCII files. At constant sampling point eight vertical series (every third day) were collected as

Table 12.1: List of all sampling activities of the coastal ecology program.

type of work	dates																				
	28.05	29,05	30,05	31,05	1,06	2,06	3,06	4,06	5,06	6,06	7,06	8,06	9,06	10,06	11,06	12,06	13,06	14,06	15,06	16,06	17,06
wildlife observations	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
water level measurements	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
complete vertical station	o	x	o	x	o	o	x	o	x	x	o	o	x	o	o	x	x	x	x	o	x
sediment trap	o	o	o	o	o	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
zooplankton	o	o	x	o	o	o	o	x	o	o	x	o	o	o	x	o	o	o	x	o	x
dredging for zoobentos	o	o	x	x	o	x	o	x	x	o	x	o	o	o	x	x	x	x	o	o	o
STD other than in vertical st.	o	o	x	o	o	x	o	o	x	o	o	o	o	o	o	o	x	x	x	x	x
baited traps	o	o	o	o	o	o	o	o	o	x	o	x	x	x	o	o	o	o	x	o	o
ice sampling	o	o	o	o	o	o	o	o	o	o	x	x	o	o	o	o	x	x	o	o	o
macrophytes account	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	x	o	o	o

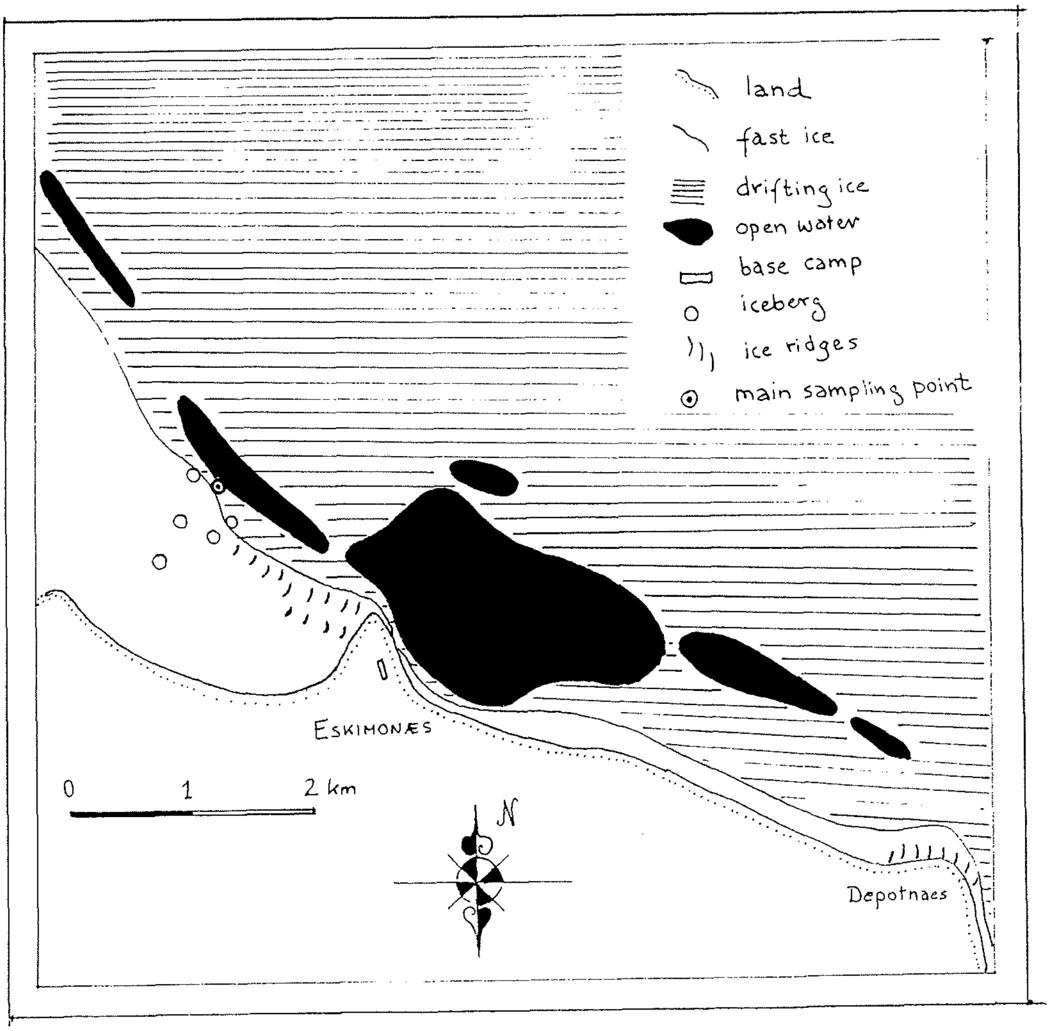

Fig. 12.2. Average ice situation and polynya shape at Eskimonæs.

well as five horizontal cross sections made every fifth day on the small polynya. A number of other hydrological measurements was collected (at icebergs, at land fast ice, at melting ponds on ice etc.). Water transparency was noted with the use of Secchi disk; it ranged from 7 to 12 m.

Water level observations: At the top of the peninsula, the water level measurements were collected with the use of wooden stick marked every 5 cm. 6 to 15 measurements were taken each day (Fig. 12.3). The lowest water level noted was 125 cm, the highest 225 cm.

Nutrients: Two methods for collection of nutrients were applied. One, with the use of vials contaminated with $HgCl_2$. Water samples of 50 ml were stored at temperature 0 to plus 2 degrees for two weeks. Second method was the filtration of 1.8 ml of water on GF/F Whatman filters frozen at -5°C for few days until the transportation to Polarstern. Nutrient samples were collected on constant sampling point from the six standard levels of light attentenuation. Except for eight vertical time series three horizontal profiles were collected. All analyses of the collected material have been made by the German and Canadian teams onboard the ship.

Fig. 12.3

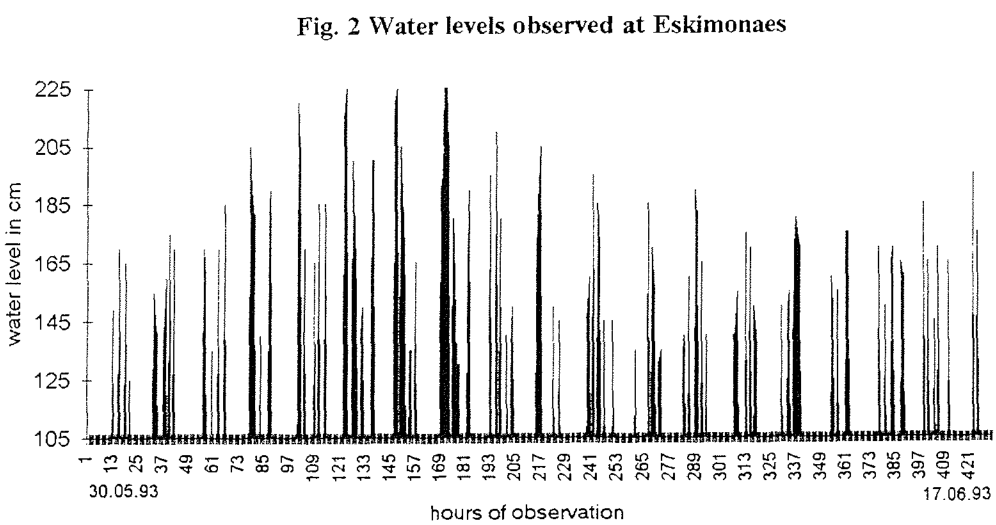

Fig. 12.3. Water level observations near Eskimonæs.

Chlorophyll a: Water samples of 300 to 500 ml were filtered on GF/F Whatman filters and stored frozen at -5°C for few days until the transportation to the ship. Chlorophyll samples have been collected parallel with nutrient sampling.

Particulate organic carbon: Water samples of 200 ml were filtered on pre-combusted GF/F Whatman filters and stored as chlorophyll samples. POC data were collected at the same stations as nutrients and chlorophyll.

Sedimentation: Sediment traps were deployed at the main measuring point, at the depth of 21 m (8 m above the sea bottom). Traps have 6 cm opening diameter and height of 50 cm. Traps have been changed every third day. 1 L water containing the sedimented matter was divided for the POC, chlorophyll, nutrients and phytoplankton analyses, remaining volume was fixed with 4% formaldehyde solution for the mineral matter contents analysis.

Phytoplankton: For the quantitative analyses, water samples of 100 ml were collected and fixed with the Lugol solution. Those samples have been collected from the same water cast as for nutrients and chlorophyll. The qualitative sampling was performed with the use of small net of 25 cm diameter and 20 µm mesh size. Samples were collected vertically from the bottom to the surface and fixed with Lugol solution.

Zooplankton: The WP-2 net with 200 µm mesh size was used for sampling vertically from the bottom to the surface. Samples were preserved with 4% formaldehyde solution. Vertical hauls were collected at constant sampling point every three days (8 samples) and twice in horizontal profile (9 samples).

Benthos: The hard-stony bottom did not permit us to use any of the tube-core quantitative samplers, so the only method was to collect qualitative samples. Triangular dredge of 35x35x35 cm mouth and 1 mm mesh size was used. Thirty one dredgings were performed from the 1 to 30 m depth. Samples were stored in 4% formaldehyde solution. Zoobenthos was dominated by amphipod crustaceans, echinoids and ophiuriids. Baited traps were used to catch the necrophagic animals on the depths of 2, 6, 12 and 29 m, the only catch were numerous lysianassid amphipods. Nearly the whole area investigated was covered with different species of macrophytes. Number of specimens were collected in dredgings and preserved in formaldehyde solution. The account of plant coverage was made on five profiles from the coast to 12 m depth (as the visibility permitted). Fifty squares of 10 m^2 were observed, and in 40% of the investigated area plant cover exceeded 51%.

Wildlife observations: During 21 days of field work, and average 12 hours per day in the field, 16 bird species and 5 sea mammals species were observed. The relative frequency of observations shows Table 12.2.

Other activities: Gizzard content analyzes of 25 common eiders are going to be done in Poland. Droppings of eiders and walrus were collected for additional analyses. First look shows that gastropods (*Margarites)* were common in eiders diet, while shrimps remains were found in walrus excrements.

Table 12.2: Wildlife observations at Eskimonæs between May 27 and June 17, 1993.

Birds	number of days	Remarks
Gavia stellata	4	single
Somateria mollissima	19	flocks of 4 to 24 birds
Somateria spectabilis	1	single
Clangula hyemalis	1	single
Branta bernicla	3	three birds
Stercorarius longicaudatus	2	six birds
Fulmarus glacialis	21	several birds each day
Rissa tridactyla	20	small groups of 3 to 6 birds
Larus sabini (Xema sabini)	1	single
Larus hyperboreus	4	single
Pagophila eburnea	20	few birds every day
Uria lomvia	1	single
Sterna paradisea	6	six birds, two showing nesting behaviour
Cepphus grylle	3	pair and single
Charadrius hiaticula	3	pair
Plectrophenax nivalis	7	few birds
Mammals		
Odobenus rosmarus	20	flocks of 2 to 12 young males (?), resting and feeding in shallow water at the polynya
Ursus maritimus	4	single animals, two adult males
Phoca hispida	5	single, few animals on the fast ice, one in water
Erignathus barbatus	2	single
Monodon monoceros	1	flock of five at the fast ice edge

A data report on the data collected is available from the authors.

12.2 Breeding ecology of cliff-nesting seabirds and their reliance on the NEW polynya

K. Falk, S. Møller

Objectives were to survey breeding populations, collect basic ecological data on phenology, breeding success and foraging behavior of Fulmars (*Fulmarus glacialis*) and Black-legged Kittiwake (*Rissa tridactyla*) in order to assess their use and dependency on the NEW.

Methods

- Surveys of seabirds cliffs along Amdrup Land and Holm Land,
- daily observations (May 15 to August 8) of Fulmar and Kittiwake nests in study plots at Mallemukfjeld (80°11´N 16°38´W) to record colony and site attendance patterns, timing of breeding, and overall breeding success,
- a test of satellite telemetry for mapping of Fulmar foraging range.

Preliminary results

Population census: The breeding Fulmar population in the polynya has never been censused, and only general information on the colonies existed (Hjort et al. 1983). In 1993 it was found that Fulmars bred at 6 cliffs along the polynya, where approx. 2500 'apparently occupied sites' were recorded (Fig.12.4). The Kittiwake was last reported from NEW (Mallemukfjeld) in 1939 (Pedersen 1942), but was not observed there in 1980 (Hjort et al. 1983). In 1993, Kittiwakes occupied about 500 nest sites on Mallemukfjeld - the only colony within the East Greenland National Park. For both species, the actual number of breeding pairs and non-breeding territory-holders remains to be estimated on the basis of detailed observations on a sample of nest sites at Mallemukfjeld.

Fulmar breeding ecology: The Fulmars initiate laying about May 21, indicating that they may be present at the cliffs from about early or mid April, i.e. they probably utilize the opening polynya very early in spring. Hatching takes place from about July 8 and young may be expected to leave the cliff during September, just when NEW is about to close again. Their long breeding season just allows for breeding this far north due to the existence of NEW, but as they are capable of flying long distances, the Fulmars may exploit open water areas outside the pack-ice during parts of the breeding season.

The Fulmars have long brood shifts periods when one bird broods the egg or young while the mate is away on foraging trips to build up reserves to take the next long shift. At Mallemukfjeld the longest brood shifts recorded lasted 13 days, but preliminary estimates suggest a mean shift length of about 6 days. In Alaska, breeding Fulmars attended their young until it was about 16 days old although occasionally young were left periodically at age 6 days (Hatch 1985). At Mallemukfjeld it appeared the rule rather than the exception that young were left unattended for many hours or days when still very small, and loss of unguarded young to the only common predator, the Glaucous Gull (*Larus hyperboreus*) occurred frequently. When the birds have to leave their young early in order to seek food, it may be a sign of constraints on the parents, i.e. to sub-optimal foraging conditions in the polynya in 1993. Analysis of site attendance patterns (more than 20000 records) and breeding success (approx. 290 occupied sites) may add further information as regards the breeding conditions for Fulmars in the NEW.

All-day watches at study plots revealed that the number of Fulmars at the cliffs (colony attendance) did not change significantly during a day in the arctic summer. But colony attendance varied during the study period, with highest numbers present during late laying season in early June (Fig. 12.5). Five Fulmars were equipped with satellite transmitters, and by end of July about 1000 location data have been obtained via the ARGOS satellite receiving system, but no analysis has yet taken place.

Kittiwake breeding ecology: The Kittiwakes occupied the nesting area continuously from May 25 onwards. Laying was initiated about 9 June and hatching started about July 5. Breeding conditions appeared favorable for the Kittiwakes as they had high average breeding success. Very few eggs were taken by the Glaucous Gulls, but depredation of hatched young was more common. It is

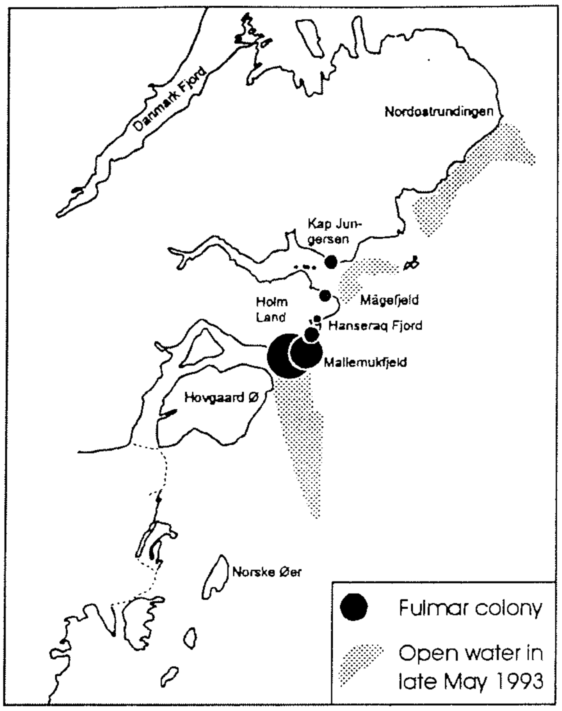

Fig. 12.4. Fulmar colonies near the Northeast Water, 1993.

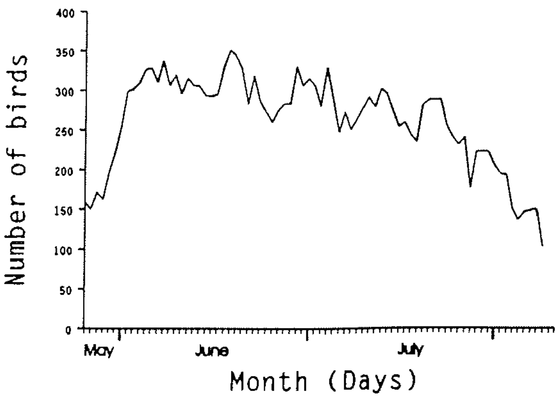

Fig. 12.5. Changes in numbers of fulmars in selected study plots during the breeding season, 1993.

very unlikely that other Kittiwake breeding sites than Mallemukfjeld should occur within the Polynya, and all Kittiwakes observed in the polynya area may represent either foraging birds from this colony, or non-breeding individuals with no attachment to any particular colony.

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12.3 Prebreeding convergation of Common Eiders *(Somateria mollissima)* and King Eiders (*S. spectabilis*) in the NEW and onset of breeding

M. Elander, M. Ericson

We were deployed at Eskimonæs on May 15 by a ski-equipped Twin Otter Iceland. A base-camp was established in the permanent hut, belonging to the dogsledge-patrol Sirius. An aerial survey of the coastal waters between Mallemukfjeld on Holm Land in the south to Antarctic Bugt by Amdrup Land in the north, was made on May 15 and May 16. Heavy drift-ice covered most of the shallow areas along Holm Land, leaving only minor openings off Mallemukfjeld and Hanseraq Fjord. Larger open water areas were only found at the mouth of Ingolf Fjord and north of Amdrup Land. These, however, were rapidly covered with thin new ice during spells of calm weather. No concentrations of eiders were seen and the only ducks observed during these surveys were a pair of Common Eiders off Hanseraq Fjord and a flock of 6 at Eskimonæs.

During the following two weeks, small numbers of Common Eiders and up to 6 pairs of King Eiders were observed around Eskimonæs. Between May 23-25, several flocks of up to 30 Common Eiders were passing, mainly towards the north and this was interpreted as a weak northward migration.

On May 27, the areas between Hovgaards Ø and Eskimonæs were again thoroughly surveyed. The ice-edge off Dijmphna Sund was checked from a helicopter flying at a suitably low altitude and the waters off Holm Land were surveyed from Polarstern when cruising along the coast. Supplementary observations were made from a Zodiak on May 25. At this time there were sizeable shore leads, mainly south of Hanseraq Fjord, but not one single eider was observed.

During aerial reconnaissance by helicopter on May 30, between Ingolfs Fjord and Kilen, a large and extremely concentrated congregation of Common Eiders and King Eiders was discovered off the southernmost tip of Kilen. A quick estimate revealed at least 2000 birds. On June 2 the flock was counted more accurately from the shore and found to contain 2500 Common Eiders and 1000 King Eiders, with an overall sex ratio of roughly 50/50. Besides the main concentration, less than 100 eiders were encountered along the coast of Kilen. The main activities among both Common Eiders and King Eiders were foraging a few hundred meters off the coast, followed by resting/inactivity and courtship display on or along the ice-edge. Copulation was first observed on June 6. On June 4 a limited number of Common Eiders and King Eiders (both sexes) were collected for gizzard analysis and and checks for environmental pollutants. On June 6 the major flock had started to disperse and on June 15 only 200-300 eiders remained, and an additional 100 along the rest of the Kilen coast. This coincided well with the arrival of King Eiders to their breeding territories in e.g. Danmarkfjord, where 30 pairs were observed on June 15. Up to 6 pairs of King Eiders were seen at Eskimonæs in mid-June. On June 15, flocks of altogether 25 pairs of Common Eiders were seen at Sophus Müllers Næs on Amdrup Land and another 5 pairs at Sommerterrasserne also on Amdrup Land. Up to 25 pairs of Common Eiders gathered along the coast at Eskimonæs in mid-June and signs of breeding initiation were noted from June 21 and onwards. The first nest, with a clutch of 4, was found on July 1. No observations were at this time made around the breeding localities on Henrik Krøyers Holme.

The flock of Common Eiders at Eskimonæs started to increase at the end of June, probably due to arrival of postbreeding males and failed breeders from nearby areas and the sex ratio changed in favour of males. On June 29 the flock consisted of 100 males and 45 females and during a survey of the coast of Holms Land from a Zodiak on July 3, 103 males and 27 females in 6 flocks were counted.

Many brooding females were encountered on Henrik Krøyers Holme on July 4 and 5, where more than 50 nests were found, without putting any special efforts into locating nests. No King Eiders were seen here.
We left the area on July 9 and observations were continued by a new team starting July 11.

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12.4 The bird fauna of eastern Holm Land and Amdrup Land, and the Henrik Krøyer Holme
C. Hjort

Besides the special studies on pre-breeding convergations of Common Eiders *Somateria mollissima* and King Eiders *Somateria spectabilis* (Elander & Eriksson, this volume) and on the breeding biology of Fulmars *Fulmarus glacialis* and Kittiwakes *Rissa tridactyla* (Falk & Möller, this volume), a general survey of the bird fauna along the coasts facing the NEW was carried out by the participants in the above mentioned ornithological projects and by the present author, and with inputs from several of the other NEWLand scientists.

The eastern and southern, polynya facing parts of Holm Land (for geographical names see map in Elander & Eriksson, this volume), with its extensive coastal forelands in the east, were covered from mid-May to the end of July. The central parts of the Amdrup Land coastal foreland (ca. 10 km to the north and south of Dvaergfjorden) were covered from the last days of July until mid-August. The Henrik Krøyer Holme islands off that coast were visited twice, on July 4-6 and on July 30. The coastal area on Kilen, furthest to the north, were surveyed during the first week of June. The work was carried out on foot and with Zodiac, and with the help of helicopters from the Geological Survey of Greenland, Polarstern and Polar Sea.

Except for Kilen, where the bird fauna is now rather well known (Hjort et al. 1983, 1987, 1988), only very scattered information on the birds of this region - gathered by geologists and others with a part-time interest in ornithology (Manniche 1910, Pedersen 1942, Hjort et al. 1983) was available before the NEW/NEWLand expeditions in 1993. Except for the existence of bird cliffs at Mallemukfjeld, Hanseraq Fjord and Maagefjeld on Holm Land, and at Kap Jungersen on Amdrup Land (Falk & Möller, this volume), and the ocurrence here of King Eiders in early spring, little substantial knowledge was available.

Not unexpectedly it turned out that, except for the colonies of Fulmars and Kittiwakes and the outstanding bird life on the offshore Henrik Krøyer Holme islands, the breeding bird fauna of these polar desert areas (Bay & Fredskild, this volume) is very poor. The clearly most common breeding bird along the mainland coasts is the Common Eider, with often several pairs/km. The second most common bird there is the Arctic Tern *Sterna paradisaea*, with scattered pairs or small colonies on most promotories, but with the largest colony encountered (at the entrance to Hanseraq Fjord) holding only 15-20 pairs. Away from the coast, on the wide forlands, the only breeders except for Common Eiders (which often put their nests several km inland, but always bring their young down to the coast soon after hatching) were Sanderlings *Calidris alba*, Brent Geese *Branta bernicla hrota* and Red-throated Divers *Gavia stellata*. Warning Sanderlings, or broods, were regularly encountered, especially on Amdrup Land, but there seemed to be less than 1 pair km^{-2}. Brent Goose breeding was proven on Amdrup Land (4 pairs in the surveyed area around Dvaergfjorden) and suspected on Holm Land (1 pair at Hanseraq Fjord). This means that the in 1985 rediscovered Northeast Greenland population of this species, then found breeding rather commonly in the isolated, mostly fox-free area Kilen (Hjort et al. 1987), also has a scattered population (probably <0.25 pairs km^{-2}) along other parts of these bleak polar desert coasts (see also Håkansson et al. 1981). Our observations from Amdrup Land indicate that they were more or less entirely dependent on Arctic Poppies *Papaver radicatum* for food. As to the Red-throated Divers they only put their nests at some shallow foreland lakes, but forage in the sea.

The Henrik Krøyer Holme, three low islands some 15 km off the Amdrup Land coast, turned out - at least during this seemingly fox free year of 1993, to be an extremely good breeding area for birds. Some 300 pairs of Ivory Gulls *Pagophila eburnea* now bred there, a minimum of 50 pairs of Sabine´s Gull *Xema sabini*, one pair of Ross´s Gull *Rhodostethia rosea* and possibly 2 pairs of Gray Phalaropes *Phalaropus fulicaria*. This, besides an unknown number of Arctic Tern and Common Eider pairs, probably more than 100 pairs each, makes this archipelago a strong candidate for special protection status. It is also frequented by many Walruses *Odobenus rosmarus*, Ringed Seals *Phoca hispida*, Bearded Seals *Erignatus barbatus* and Polar Bears *Ursus maritimus.*

Sea bird movements along the coasts were regularly monitored. The dominating species were Fulmars, Kittiwakes and Ivory Gulls, with maximum of 20 birds h^{-1} of each species passing - usually much less.

In all 32 species of birds were encountered in the coastal areas during the NEWLand work. Of these 11 were proven breeders - Red-throated Diver, Fulmar, Brent Goose, Common Eider, Sanderling, Kittiwake, Ivory Gull, Sabine´s Gull, Ross´s Gull, Glaucous Gull and Arctic Tern.

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12.5 Observations on the birds in the inland areas

T.B. Berg, C.M. Kapel

During the inland mammal survey (Kapel and Berg, 12.6) associated to the NEWLand project the following observations were made on birds in the head of Danmark Fjord June 8 to July 10, 1993. In each of the following locations the same route was toured several times (Fig. 12.6):
"Sandslot Foreland": The East coast along Danmark Fjord has a large relative vigorous area from sea level to about 180 m above sea level. The West coast follows the glacial stream and is bounded to the north of a big delta. The observations were primarily made on the East coast.
"Holbæk Foreland": The East coast along the glacial delta has a relative large vigorous area from sea level to about 130 m above sea level. The observations were only made on the East coast.
"Campanula Valley": A long slender valley with a narrow vigorous area along the river. The central and south part of the valley contains a lush grass plain.

The grass plain on "Sandslot Foreland" and "Holbæk Foreland" were used as foraging area for a flock of 39 Pink-footed geese (*Anser branchyrhynchus*) from June 26 and to our departure on July 10. The delta was used by a flock of 7 Red-troated Divers (*Gavia stellata*) and 52 King Eiders (*Somateria spectabilis*). One nest of the Red-troated Diver with 1 egg was found in a small lake in Campanula Valley on July 8. On June 15, a flock of 26 pair of King Eiders showing mating behaviour were seen in the delta and on June 16 the flock had dispersed (see also Elander & Eriksson this volume). At the grass plain in the middle of Campanula Valley nest with 3 eggs was found on July 8. Ptarmigan (*Lagopus mutus*) was not uncommon in the areas, one pair was seen mating On June 13. Lemming were very abundant in the inland (Kapel & Berg this volume) and as a result 2 eggs were often observed in nests of Long-tailed Skua (*Stercorarius longicaudus*). 6 nests out of 8 found between June 14 and July 8 had 2 eggs each. The first egg hatched before July 7. Snow Bunting (*Plectrophenax nivalis*) min. 4 pairs, total min. 17 individuals.

Waders were found as pairs and in greater flocks up to 50-70 individuals with mixed species foraging at the same location in the Campanula Valley. Ringed Plover (*Charadrius histicula*) min. 8 pairs, total min. 31 individuals. One nest with 4 eggs was found June 30. Knot (*Calidris canutus*) min. 8 pairs, total min 35 individuals. Sanderling (*Calidris alba*) min. 1 pair, total 16 individuals. Dunlin (*Calidris alpina*), only observed in Campanula Valley. Min. 4 pairs, total min. 34 individuals. Turnstone (*Arenaria interpres*) was mainly distributed in Campanula Valley. Min. 3 pairs, total 52 individuals. Glaucous Gull (*Larus hyperboreus*) and Arctic Tern (*Sterna paradisaea*) were scarce 4 and 3 individuals, respectively.

In total, 12 species of birds were seen in the head of Danmark Fjord from June 8 to July 10. Of these, 6 were proven breeders: Red-troated Diver, King Eider, Ptarmigan, Ringed Plover, Long-tailed Skua and Snow Bunting. Following birds were showing territorial and/or brooding behaviour: Sanderling, Dunlin and Turnstone.

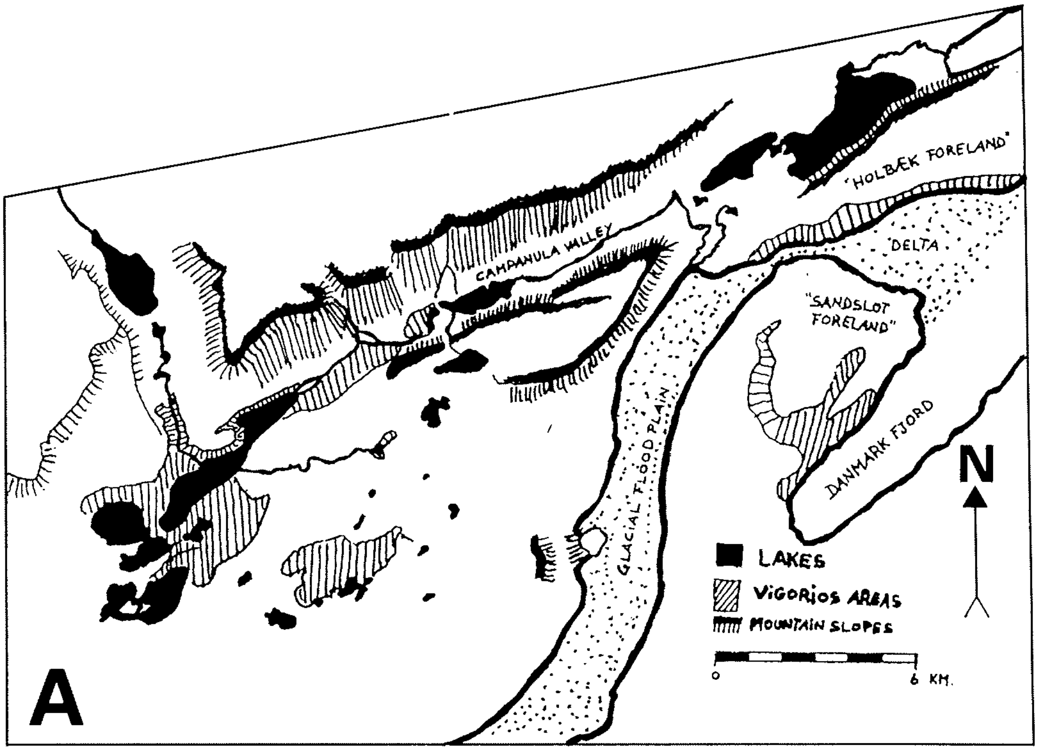

Fig. 12.6. Area of the inland mammal and bird program. For large scale position see Fig. 12.1 (A).

12.6 Summarized observations of mammals

C. M. Kapel, T. B. Berg

During the field work within the NEWLand project and other projects in the same area the following observations of mammals were made on the localities 1-11 (Fig. 12.7). Observations other than of living animals are not included in the scheme.

Polar bear (*Ursus maritimus*): On the coastal stations (Fig. 1: 1,2,4) polar bears were observed more frequently in the middle of the field period. In this period they were seen daily at Eskimonæs. None were seen at the inland stations. During the cruise of 'Polarstern' 21 bears were tagged (Born & Thomassen, this vol.). Females with offspring were most frequently observed near the coast. Two skeletons found up in the mountain slopes inland from Sophus Müllers Næs could indicate that hibernation might take place there.

Ringed seal (*Phoca hispida*): The most common seal in the region, although newer as common as in the waters farther south. Max. ca. 10 were seen at the same time on the ice on the Ingolf Fjord. Observations during recognizance flights suggest the highest density near the coast and fjords.

Bearded seal (*Erignathus barbatus*): A few observations on the ice near Eskimonæs. Not uncommon on Henrik Krøyer Holme and along the Amdrup Land coast.

Walrus (*Odobenus rosmarus*): Smaller groups of 2-10 animals were seen daily on each of the costal stations. The only really large number of animals were observed in the waters close to Kilen in the middle of June. Up to 30 were seen south of Dværg Fjord in early August.

Narwhal (*Monodon monoceros*): Groups of 5-10 animals were observed near Eskimonæs in June, close to Kap Jungersen on Amdrup Land July 15 (Edgar Håkonson, pers. comm.) and larger flocks were seen near Mallemukfjeld and the 79-Fjorden in July. The majority of the observations were made in ice filled waters, whereas only few whales were seen in the open waters.

Mink whale (*Balaenoptera acutorostrata*): One was observed in the waters near Eskimonæs on May 17. The species was determined by the characteristic shape of the fin and blow.

Wolf (*Canis lupus*): One adult male was observed once at Danmark Fjord. In the same period single individuals were observed at Centrum Sø and on Lambert Land. Observations of groups of two animals were done respectively at Skallingen Sø and at Kap Moltke. Faeces was often found at Danmarks Fjord and once on Amdrup Land. North of the research area, in Citronens Fjord, a group of 4 wolves were following snow scooters from a mineral company.

Arctic fox (*Alopex lagopus*): During the attempts to trap foxes routes of approximately 30 km were toured each day at Eskimonæs (May 15-June 10) and near Danmark Fjord (June 10-July 15). During these periods no live or dead foxes

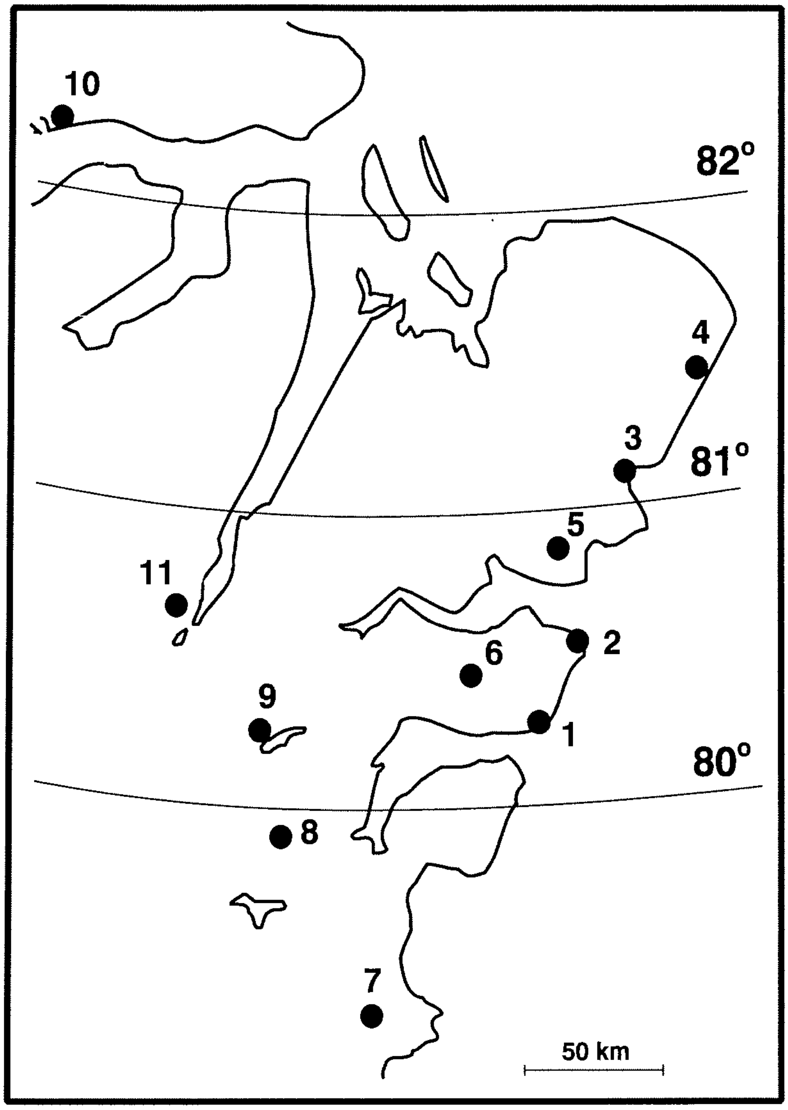

Fig. 12.7. Field stations from which mammal observations were received.

Table 12.3: Mammal observations during the NEWLand study 1993.

Locality	Mallemuk fjeld	Eskimonæs	Sophus Müllers Næs	Kilen	Amdrup Land (Inland)	Holm Land (Inland)	Lambert Land (#)	Skalling Sø (##)	Centrum Sø (##)	Kap Moltke	Danmark Fjord
No. on Fig. 12.7	1	2	3	4	5	6	7	8	9	10	11
Period	15.5-8.8	15.5-28.7	28.6-13.8	2.6-6.7	15.7-25.7	15.7-15.8	5-27.7.	5-27.7	5-27.7	1.6-15.8	8.6-15.7
Polar bear	**	***		**							
Ringed seal	* (sp)	***	***								
Bearded seal		**	**								
Walrus	**	***	***	**							
Narwhal	**	**		*							
Minke whale		*									
Wolf							*	**	•	**	*
Fox					**	*	*	*			
Ermine							*		**		*
Muskox							***		***	***	***
Arctic hare	*						*	*			
Lemming	*	*	*	*	***		***	***	***	***	***

Additional observations kindly supplied by: * Single observation; #: Friderichsen & Escher, Greenland Geological Survey.**: Few observations (<10); ##: A.K. Higgins, Greenland Geological Survey.***: Frequent or numerous observations (>10)
_: E. Knuth, Peary Land Foundation.

were seen and no observations were made on tracks, faeces, bones, or others. After the snow had melted a more than one year old skull was found. One dead fox was collected near Kap Moltke 200 km north of Danmark fjord. In the period July 15-July 28, observations of an active den with one adult and two younger light phase foxes and at least 3 cubs were made on interior Amdrup Land. One adult dark phase fox were seen on Holm Land. Old faeces were found in a predated Eider nest at Eskimonæs in late July.

Ermine (*Mustela erminea*): One was observed in the inland near Danmark Fjord and another on interior Lambert Land. Two observations were done at Centrum Sø. A nest was found on Amdrup Land.

Muskoxen (*Ovibos moschatus*): Fresh faeces were found several times and a herd of 12 animals (2 yearlings, 3 calves) were observed near Danmark Fjord. On interior Amdrup Land a herd of 15 animals (4 calves) were observed. In the interior on Lambert Land a herd of 28 animals were seen. Fresh tracks from 2 animals were observed at Sophus Müllers Næs. At Kap Moltke a herd of 15 animals were observed in July.

Arctic hare (*Lepus arcticus*): Single tracks of hare were observed on nearly all localities although direct observations of animals were only made near Mallemukfjeld, on Lambert Land, and at Skallingen Sø.

Lemming (*Discrostonyx torquatus groenlandicus*): On all localities lemmings were observed, but only near Danmarks Fjord and in the interior on Amdrup Land they were numerous. Observations at Sophus Müllers Næs revealed only few animals and winter nests. At Eskimonæs the maximum number of holes in the snow observed on the daily 30 km reconnaissance tours were 10, to be compared with 218 in the inland near Danmark Fjord. In the latter area at least 3 different cohorts were observed in the period June 8 - July 15. A total of 30 animals were caught by hand and preserved for further examination.

12.7 Botany

C. Bay, B. Fredskild

Botanical terrestrial investigations focusing on the vegetation history and the present vegetation have been carried out mainly at two localities. The Sophus Müllers Næs locality is at the coast bordering the polynya, while the Amdrup Land locality in the central part of Amdrup Land is not under influence of the open water conditions prevailing by the outer coast. In addition, three localities were visited during stays of a few hours; one in the polynya (Henrik Krøyer Holme), one by the coast of the polynya (Eskimonæsset), and one in the sheltered inland (Holm Land).

Vegetation history: A lake on Amdrup Land was cored to register the vegetation history and climatic development during the Holocene. Under 5.8 m of water no less than 103 cm of slightly clayey gyttja with mosses were taken. So far, this is the longest core of organic sediments in North Greenland - north of 78°N and high arctic Canada. The core is being pollen-analyzed and ^{14}C dated. At the outer coast all lakes were too shallow to allow for undisturbed sedimention. Here, the only accumulation of organic material were some peaty layers on the lee side of boulders serving as "bird-stones". The 20-30 cm thick deposits at three boulders were sampled for later investigation.

Present vegetation: The present vegetation has been analysed with respect to floristic composition, diversity, degree of cover, and biomass and was classified according to the classification used in northern Greenland (Bay 1992). Six vegetation types were recognized at the Amdrup Land locality. They comprize sedge dominated fen with a high species diversity, hummocky *Salix arctica* dominated snow bed, mossy snow bed, open *Salix arctica*-vegetation, *Phippsia algida*-vegetation on solifluction soil, and windexposed polar barrens. The vegetation bordering the polynya is much poorer with respect to species diversity, cover, and biomass, and five vegetation types were defined. The cover is generally less than 1%. Only a *Saxifraga oppositifolia* - dominated snow bed - with a very limited distribution has a degree of cover exceeding 4% and a biomas of 11 g/m^2. Of the 73 species of vascular plants recorded on Amdrup Land only 23 occur by the polynya. Here, the vegetation was devoid of woody species, of fens with *Eriophorum* ssp. and *Carex* stans, and of species classified as inland species, only occurring in the interior part of North Greenland.

Judging from the preliminary results only areas less than 5-10 km from the coast are under influence of the local climate by the polynya. The low summer temperatures here limit the conditions for plant growth, resulting in an impoverished vegetation with a very low species diversity, cover, and biomass. Most of the landscape is barren and generally the plant cover is less than 1%. The area is classified as polar desert according to Alexandrova (1988). Comparing the polynya locality to other outer coastal localities in North Greenland that have a much richer flora and a higher productivity of the vegetation, it appears that the polar desert areas bordering the polynya are among the least vegetated areas in high arctic Greenland. A new delimitation of the polar desert zone of Greenland is proposed, reducing the size of the original zone to only comprize the most coastal part of North Greenland north of 80°N.

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12.8 The Archaeology of Holm Land, Amdrup Land, and Henrik Krøyers Holme

C. Andreasen, H. Lange

The archaeological activities were concentrated along the coasts of Amdrup Land and Holm Land incl. a short visit to Henrik Krøyer Holme. The primary aim was to make an assessment of the prehistoric resource-exploitation and if possible within a cultural and chronological frame. Providing a reasonable amount of sites and preserved organic material (bones) it should be possible to make assumptions regarding presence/absence of vital animals (for people) in the polynya during the last 4000 years. The data collected consist of maps of the sites and the individual ruins at these as well as a large amount of bones and some artefacts from the sites and the individual features.

Using Peary Land as a reference the cultural history of the region has three phases:

I.	Independence I	: 2400 - 2000 BC (4400 - 4000 BP)
II.	Independence II	: 700/600 - 400 BC (2700/2600 - 2400 BP)
III.	Thule-culture	: 1100? - 1700 AD? (800? - 300? BP)

Data from Peary Land and the area south of the 1993-research area indicates however, that the time-gap between Independence I and II might be lesser. The cultural history in the research area was little known before 1993: only a few Thule-sites and indications on paleo-eskimo sites were known.

The Survey

Holm Land was surveyed from the northern face of Mågefjeldet in Ingolfsfjord to Hanseraq Fjord in the south. Within this area 31 sites were found with a total of several hundred ruins. Most sites were lying along the coast facing the polynya. The most important areas are at Mågefjeldet and around Eskimonæs. All three phases seem to be present.

Amdrup Land was surveyed from Antarctica Bugt to the bay south of Dværgfjorden. Within this area 12 sites were found of which especially the north-east corner of Amdrup Land (Kødgravene) and two sites at each side of Dværgfjorden are important. The sites were mainly situated at the capes with a few along the coastline between these. In this area all three phases seem to be present, too.

Henrik Krøyer Holme was surveyed in a few hours at three of the islands. Paleo-eskimo sites were present although not in any substantial number and their specific cultural affiliation is presently unknown. Thule culture winterhouses were found at the long island and the small one south of it.

Results

As only few diagnostic artefacts were found in the ruins the main method in the field for dating the objects was to date them according to their level above the sea assuming that the sites would be situated as close to the shore-line as possible and that the land had continued its displacement. This seems to be a valid method in Peary Land but need to be proven by ^{14}C-datings in this area.

Independence I is probably present at several sites but the features associated with this period are either very vaguely defined ruins with almost no bones, or well defined structures (stone-rings) but with no datable architectural elements or objects. In a few ruins diagnostic artefacts (burin-spalls) were found but those ruins were found both at a high level and at the Independence II-level. The main reason to attribute these features to the earliest phase is thus that most were found at old high-elevated beach-terraces and the general impression of stronger weathering than the younger ruins.

Independence II is present with an overwhelming amount of ruins along the whole coast. Middens with bones were often found thus providing a large collection of bones as well as some artefacts. The dominant bones are: seal *Phoca sp.* (probably Ringed Seal *Phoca hispida* as well as Bearded Seal *Erignatus barbatus*) and Walrus *Odobenus rosmarus.* Besides this Polar Bear *Ursus maritimus*, Narwhale (?) *Monodon monoceros*, and birds *Aves* sp. were present. Musk-ox *Ovibus moschatus* and Caribou *Rangifer tarandus* might be present with a few bones, but they were obviously not an essential part of the diet in this area. Among the artefacts the most important objects are harpoon-heads for hunting marine mammals, especially walrus. The harpoon-heads would in Canada be dated at ca. 1000 - 900 BC (3000 - 2900 BP) thus indicating the presence of a much earlier Independence II-phase that hitherto known and consequently decreasing the present time-gap between Independence I and II.

Thule culture were found at many sites where both summer-tentrings, winter-houses and a large number of big meat-caches were seen. Winter-houses were found at 6 sites, incl. Henrik Krøyer Holme, while tent-rings were more numerous, although still far less than Independence II. The most important sites are: around Eskimonæs, Sophus Müller Næs, Kødgravene, Antarctica Bugt and Henrik Krøyer Holme. The sites are, with one exception, very close to the coast-line. No real midden-accumulations were found, instead the bones were spread all over the sites, mainly: whale-ribs and -vertebrae as well as bones from walrus, narwhale, polar bear, seals, and beards. Besides this some dog-crania, a few bones of musk ox were collected and a large number of artefacts were collected: parts of sledges, snow-knifes, some harpoon-heads, parts of harpoon-shafts etc.

The overall impression of the settlement-pattern and ressource-exploitation is one of general continuity through 4000 years regarding preference of settlement-area and the marine mammal species hunted. ^{14}C-dating of as many ruins as possible at different levels should clarify to what extent we still have a chronological discontinuity. There are still no indications of a habitation period between Independence II and the Thule-culture.

The data acquired during this summer are numerous and requires further analysis. The amount of sites and ruins is somewhat astonishing and the collection of bones and from the paleo-eskimo sites is the largest from East Greenland. When analyzed it will provide an important list of species present as well as it offers possibilities for an assessment of hunting-seasons. Hopefully these data together with the paleo-botanical data will help clarify whether the polynya has been consistently present thorugh the last 4.000 years.

12.9 Weichselian and Holocene glacial and marine history of the coastal forelands along the NEW

C. Hjort

Primary objectives of the NEWLand programme were the climatic history of the NEW, especially during the Holocene, and the history of the polynya's utilization by man - seen as an exponent of changes in biological production. In this context an archaeology project (Andreassen & Lange, this volume) and a botany/paleovegetation project (Bay & Fredskild, this volume) were carried out.

These were complemented by a study of the glacial and marine history of the coastal forelands on Holm Land and Amdrup Land (for geographical names see map in Elander & Eriksson, this volume), were especially a knowledge of the isostatically/eustatically induced shoreline displacement is important for interpreting human settlement patterns in time and space.

The glacial and marine history of the ice-free enclave Kilen in the northernmost part of the polynya area have been studied in 1980 and 1985 (Hjort 1981, 1988, Hjort & Feyling-Hanssen 1987, Feyling-Hanssen 1990). Among other things it was then suggested that the present configuration of the independent Flade Isblink icecap - at the very northeastern corner of Greenland - was largely an effect of precipitation and temperature distribution linked with the Northeast Water polynya (Hjort 1988). Holm Land has, however, in a glacial- and marine history context, only been briefly visited - and the Quaternary of Amdrup Land was totally unknown before 1993.

The work within this project during the NEWLand expedition was basically concerned with:
- moraines from earlier (probably mainly Weichselian and early Holocene) fjord- and piedmont glaciers which infringed on or protruded onto the forelands. The oldest of them were, either at their time of formation or later, inundated and abraded by the sea.
- delimiting the altitude of the marine limit - it was found to be c. 80 m a.s.l. (cf. Hjort 1981, 1988).
- collecting material (mollusc shells and seaweed, whalebones and driftwood) from elevated marine sediments and beach ridges at different altitudes, and bones from paleo- and neoeskimo sites, to produce a ^{14}C-dated shoreline displacement curve for the area.

These objectives were all reasonably well satisfied and there now exists enough dating material to produce a shoreline displacement curve covering both eastern Holm Land and Amdrup Land. There are also shells from marine sediments up close to the marine limit which, hopefully, should approximately date the original deglaciation and subsequent marine inundation of the coastal forelands at the end of the last (Weichselian) glaciation.

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13 STATION LIST

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
001	22.05.	15.05	72°21'	10°43'E	2147	BO
		15.25	72°21'	10°43'E	2147	
002	23.05.	15.23	75°00'	03°00'	3690	GWS / CTD / MN / CTD / BO / ROV
		22.35	74°58'	03°07'	3387	RMT
003	25.05.	00.08	78°59'	03°57'	2014	CTD / BO
		02.00	78°58'	04°01'	1988	
004	25.05.	05.14	79°07'	05°41'	991	CTD / BO
		06.35	79°08'	05°39'	1080	
005	25.05.	09.18	79°11'	06°15'	487	GKS / CTD / BO / SD / CTD / MN
		11.56	79°10'	06°22'	421	
006	25.05.	12.58	79°10'	07°06'	249	CTD / BO / BO
		13.56	79°10'	07°11'	246	
007	25.05.	15.57	79°11'	08°19'	195	CTD / BO / BO
		16.45	79°11'	08°19'	198	
008	25.05.	20.25	79°14'	09°37'	138	CTD / BO / BO / CTD / SD / MN / ROV
		22.18	79°13'	09°38'	142	
009	26.05.	01.32	79°16'	10°52'	224	CTD / BO / BO
		02.24	79°16'	10°52'	231	
010	26.05.	08.15	79°19'	12°17'	196	CTD / BO / CTD / SD
		09.28	79°19'	12°18'	197	
011	26.05.	14.07	79°22'	13°33'	143	CTD / PLA / BO / SD / BO / WS / MN
		15.37	79°22'	13°33'	145	R-Lot
012	26.05.	18.28	79°24'	14°58'	49	CTD / BO / BO / R-Lot
		19.15	79°24'	14°57'	53	
013	26.05.	20.40	79°25'	15°37'	43	CTD / BO / R-Lot / ADCP
		21.28	79°25'	15°37'	43	
014	26.05.	22.14	79°31'	15°48'	127	CTD / SD / BO / BO / R-Lot / BO
		23.30	79°31'	15°47'	127	
015	27.05.	00.14	79°36'	16°02'	189	CTD / SD / BO / BO / GWS / CTD
		02.11	79°36'	16°00'	191	R-Lot / SD / ADCP / HN
016	27.05.	03.03	79°42'	16°16'	303	CTD / BO / BO / R-Lot
		04.23	79°42'	16°16'	294	

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
017	27.05.	06.55	80°00'	17°06'	123	CTD / BO / BO / MN / R-Lot / ADCP
		08.25	80°00'	17°05'	123	
018	27.05.	11.19	79°55'	16°59'	311	CTD / BWS / 3xGKG / MUC / R-Lot
		21.11	79°56'	16°54'	267	KAL / EBS / ROV / RMT
019	28.05.	01.21	80°22'	15°41'	73	CTD / BO / BO / R-Lot
		02.10	80°22'	15°40'	77	
020	28.05.	10.42	80°20'	15°18'	227	CTD / BO / RF / R-Lot / ADCP
		12.24	80°20'	15°18'	225	
021	28.05.	15.52	80°20'	14°50'	319	CTD / WS / BO / BO / CTD / MN / R-Lot
		17.51	80°20'	14°50'	308	
022	28.05.	20.15	80°13'	14°16'	265	CTD / BO / R-Lot / Ice sampling
		21.40	80°13'	14°16'	263	
023	28.05.	23.35	80°05'	14°40'	207	CTD / BO / BO / MN / R-Lot
	29.05.	01.04	80°04'	14°41'	211	
024	29.05.	02.46	79°56'	14°14'	79	CTD / BO / BO / WS / R-Lot
		03.37	79°56'	14°15'	91	
025	29.05.	07.24	80°10'	12°55'	83	CTD / BO / BO / R-Lot
		08.16	80°10'	12°54'	83	
026	29.05.	10.11	80°20'	13°21'	267	CTD / BO / R-Lot
		11.17	80°20'	13°21'	263	
027	29.05.	12.37	80°23'	13°32'	285	CTD / ROV / SD / BO / BO / CTD / MN
		17.37	80°23'	13°35'	285	R-Lot
028	29.05.	19.18	80°28'	13°44'	329	CTD / BO / BO / R-Lot / CTD
		20.28	80°28'	13°43'	328	
029	29.05.	22.31	80°32'	14°01'	233	CTD / BO / BO / R-Lot
		23.39	80°32'	14°01'	238	
030	30.05.	06.06	80°27'	13°43'	329	CTD / FOT / CTD / BWS / 3xGKG
		20.16	80°25'	13°49'	325	MUC / ROV / CTD / ADCP / EBS
031	30.05.	22.17	80°30'	12°57'	285	CTD / Sediment trap deployed
	31.05	00.03	80°30'	12°56'	287	
032	01.06.	05.18	80°37'	11°19'	249	CTD / FOT / BWS / R-Lot / ROV
		12.36	80°35'	11°18'	245	3xGKG / MUC / CTD
033	03.06.	06.05	81°00'	10°03'	45	CTD / WS / BO / BO / CTD / EBS
		08.13	81°01'	10°14'	43	

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
034	03.06.	08.50	81°07'	10°28'	49	CTD / BO / BO / R-Lot / ADCP / RMT
		10.19	81°06'	10°31'	49	
035	03.06.	11.11	81°10'	10°59'	67	CTD / SD / BO / BO / RF / CTD / FOT
		13.23	81°10'	10°59'	57	WP
036	03.06.	14.25	81°15'	11°30'	35	CTD / BO / WS / SD / BO / CTD / ROV
		17.50	81°13'	11°30'	39	EBS
037	03.06.	19.07	81°10'	11°55'	31	CTD / WP / BO / BO
		19.41	81°10'	11°55'	31	
038	03.06.	20.47	81°05'	12°29'	63	CTD / BO / SD / BO / RMT
		23.02	81°04'	12°34'	85	Sediment trap deployed
039	04.06.	00.08	81°00'	12°56'	31	CTD / SD / WP / BO / BO / EBS
		01.09	81°00'	12°55'	41	
040	04.06.	02.31	80°53'	13°04'	37	CTD / BO / SD / BO / RF
		03.17	80°53'	13°03'	39	
041	04.06.	04.40	80°50'	13°59'	159	CTD / SD / BO / BO / WP / KWS / RMT
		06.57	80°50'	13°40'	105	
042	04.06.	09.50	80°57'	11°03'	65	Grid / RMT / CTD / ADCP / BWS / FOT
		20.32	81°00'	10°57'	47	ROV / BWS / 3xGKG / MUC / AGT
		23.42	81°03'	12°18'	101	Sediment trap recovered
043	05.06.	01.33	81°15'	11°30'	37	CTD / BO / SD / BO
		02.02	81°15'	11°30'	35	
044	05.06.	02.53	81°10'	11°30'	39	CTD / BO / BO / WP / RMT
		04.21	81°09'	11°32'	43	
045	05.06.	05.49	81°04'	11°32'	61	CTD / BO / BO / ADCP / RMT
		07.31	81°01'	11°39'	71	
046	05.06.	08.00	81°00'	11°31'	95	CTD / BO / SD / BO / CTD / WP / R-Lot
		10.05	81°00'	11°37'	89	ADCP
047	05.06.	11.08	80°55'	11°30'	259	CTD / BO / BO / R-Lot / ADCP/ CTD
		13.39	80°56'	11°43'	235	RMT
048	05.06.	14.28	80°50'	11°35'	291	CTD / WP / SD / BO / BO / R-Lot
		17.15	80°50'	11°33'	280	BWS / ADCP
049	05.06.	19.27	80°45'	11°33'	137	CTD / BO / BO / R-Lot / ADCP/ FOT
		22.00	80°45'	11°37'	123	Ice sampling
050	06.06.	10.17	80°43'	11°18'	123	R-Lot

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
051	06.06.	12.18	80°44'	11°15'	121	CTD / BO / BO / WP / R-Lot
		13.32	80°44'	11°13'	129	
052	06.06.	17.56	80°48'	12°30'	163	CTD / WP / SD / BO / BO
		19.00	80°47'	12°31'	163	
053	06.06.	20.11	80°44'	13°20'	155	CTD / WP / SD / BO / BO / RMT
		21.44	80°44'	13°24'	149	
054	06.06.	22.26	80°44'	13°43'	213	CTD / WP / SD / BO / BO / FOT / ROV
	07.06.	02.36	80°45'	13°43'	151	2xEBS
055	07.06.	03.18	80°48'	14°01'	195	CTD / WP / BO / BO / CTD / RMT
		05.41	80°49'	13°55'	169	
056	07.06.	07.16	80°52'	14°02'	105	CTD / BO / BO / WP / FOT / ROV
		11.21	80°52'	14°01'	105	BWS
057	07.06.	13.07	80°39'	13°31'	177	CTD / WP / BO / BO / RMT / AGT
		15.32	80°41'	13°32'	235	
058	07.06.	17.28	80°32'	13°35'	261	CTD / WP / BO / BO
		18.52	80°32'	13°32'	259	
059	07.06.	19.53	80°27'	13°41'	321	CTD / ADCP / FOT / ROV / CTD / BWS
	08.06.	03.05	80°30'	13°41'	289	3xGKG / MUC / EBS
060	08.06.	10.20	80°17'	13°39'	247	Start ice camp
		15.07	80°18'	13°35'	249	CTD / ADCP / CTD / R-Lot / FOT / BWS
						ROV / 2xGKG / MUC / CTD / 7xBO
						3xGKG / 8xBO / CTD / ROV / EBS
	09.06.	15.39	80°19'	13°02'	222	End ice camp
061	09.06.	19.24	80°30'	14°07'	295	CTD / BO / BO / ADCP / R-Lot / R-Lot
	10.06.	02.14	80°31'	14°06'	248	FOT / MN / ROV / BWS / GKG / EBS
062	10.06.	11.27	80°11'	16°33'	157	CTD / BO / BO
		12.16	80°11'	16°33'	159	
063	10.06.	13.16	80°07'	16°09'	205	CTD / BO / BO / RMT
		15.00	80°06'	16°02'	174	
064	10.06	15.34	80°03'	15°50'	408	CTD / BO / BO / WP
		17.45	80°03'	15°49'	401	
065	10.06	18.52	79°57'	15°30'	262	CTD / BO / BO
		19.51	79°57'	15°29'	266	
066	10.06	20.43	79°53'	15°12'	193	CTD / BO / SD / BO /WP
		21.44	79°53'	15°11'	187	

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
067	10.06	22.59	79°49'	14°48'	84	CTD / BO / BO
		23.35	79°49'	14°48'	84	
068	11.06.	03.39	79°45'	14°26'	77	CTD / BO / BO / WP
		04.14	79°45'	14°26'	82	
069	11.06.	10.40	79°23'	14°58'	47	CTD / BO / BO / FOT
		11.35	79°23'	14°59'	47	
070	11.06.	12.39	79°25'	15°37'	35	CTD / HN / BO / BO
		13.04	79°25'	15°38'	37	
071	11.06.	13.54	79°31'	15°48'	117	CTD / BO / BO / RMT
		15.19	79°32'	15°51'	129	
072	11.06.	15.57	79°36'	16°01'	188	CTD / BO / BO / WP
		17.09	79°36'	16°01'	191	
073	11.06.	18.00	79°42'	16°16'	305	CTD / BO / BO / R-Lot
		19.38	79°42'	16°15'	299	
074	11.06.	20.33	79°48'	16°34'	243	CTD / BO / BO / WP / R-Lot
		22.17	79°48'	16°34'	243	Sediment trap deployed
075	11.06.	23.17	79°54'	16°58'	301	CTD / BO / BO
	12.06.	00.18	79°55'	16°57'	276	
076	12.06.	01.11	80°00'	17°06'	115	CTD / BO / BO / RMT
		02.36	80°00'	16°58'	107	
077	12.06.	04.14	80°05'	15°44'	403	BO / BO / R-Lot / BWS / FOT / ROV
		13.13	80°05'	15°44'	417	3xGKG / MUC / CTD / BO / ADCP
						ROV / EBS
078	12.06.	16.11	79°43'	16°19'	311	Side Scan Sonar Test
		20.42	79°51'	16°24'	251	Sediment trap recovered
079	13.06	00.33	80°12'	13°50'	140	FOT / ROV / 2xGKG
		03.19	80°12'	13°49'	138	
080	13.06	04.13	80°13'	13°54'	201	BO / BO / MN / ADCp / R-Lot / FOT
		08.23	80°14'	13°49'	210	BWS / CTD / MUC / BWS
081	13.06	16.32	81°01'	09°34'	77	CTD / BO / BO
		17.07	81°01'	09°34'	75	
082	13.06	18.14	80°57'	09°45'	45	CTD / BO / BO / SD / R-Lot / ADCP
		18.57	80°57'	09°44'	43	
083	13.06	20.18	80°50'	09°29'	50	CTD / BO / BO / EBS
		21.16	80°50'	09°27'	49	

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
084	13.06	23.10	80°41'	09°19'	39	CTD / BO / BO / WP / ADCP
		23.55	80°41'	09°19'	31	
085	14.06.	00.41	80°36'	09°04'	241	CTD
		06.05	80°35'	09°22'	265	CTD / BO / BO / CTD / MN / R-Lot
		11.48	80°35'	09°18'	263	ADCP / FOT / BO / WP / BWS / CTD EBS
086	14.06.	19.24	81°15'	11°30'	35	CTD / BO / BO / WP / FOT
		20.13	81°15'	11°32'	33	
087	14.06.	20.57	81°10'	11°29'	73	CTD / BO / BO
		21.20	81°10'	11°28'	45	
088	14.06.	22.15	81°04'	11°28'	59	CTD / BO / BO / GKS / RMT
		23.38	81°04'	11°24'	57	
089	15.06.	00.54	81°00'	11°31'	97	CTD / BO / BO / FOT / CTD / AGT
		02.44	81°00'	11°33'	87	
090	15.06.	03.33	80°55'	11°27'	191	CTD / BO / BO / WP
		04.49	80°55'	11°32'	249	
091	15.06.	07.43	80°50'	11°31'	277	CTD / BO / BO / FOT / RMT
		10.16	80°50'	11°40'	287	
092	15.06.	11.02	80°45'	11°29'	133	CTD / BO / BO / WP
		12.27	80°45'	11°28'	143	
093	15.06.	14.17	80°40'	11°37'	240	CTD / BO / BO / SD / WP / CTD
		16.02	80°40'	11°36'	237	
094	15.06.	21.00	80°36'	11°30'	252	Ice camp start
	16.06.	09.03	80°35'	11°16'	247	CTD / 3xBO
	17.06.	08.32	80°31'	10°59'	277	CTD
		11.45	80°32'	10°54'	259	Ice camp end
095	17.06.	16.50	80°27'	13°41'	319	CTD / BO / BO / CTD / ADCP / BWS
		23.55	80°27'	13°23'	305	ROV / 3xGKG / EBS
096	18.06.	04.10	80.03'	15°50'	417	ADCP calibration
		06.46	80°03'	15°50'	417	
097	18.06.	09.08	79°42'	16°17'	323	Side Scan Sonar
		18.24	79°35'	15°42'	107	
098	19.06.	02.24	78°56'	13°36'	165	CTD / BO / BO
		03.06	78°56'	13°36'	165	
099	19.06.	12.53	78°54'	12°05'	261	CTD / BO / WP / ADCP / R-Lot / FOT
		16.28	78°55'	12°04'	265	ROV

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
100	20.06.	06.05	78°46'	09°50'	418	CTD / BO / BO / ADCP / R-Lot / FOT
		11.45	78°44'	09°55'	426	3xGKG / KAL
101	20.06.	16.54	78°41'	08°21'	187	CTD / BO / BO / ADCP / R-Lot
		18.09	78°41'	08°21'	187	
102	20.06.	21.12	78°39'	06°58'	220	CTD / BO / SD / BO / BO / ADCP
		23.13	78°38'	06°59'	219	R-LOT / EBS
103	21.06.	01.06	78°36'	05°48'	313	CTD / BO / BO / ADCP / R-Lot
		02.40	78°35'	05°52'	307	
104	21.06.	11.15	78°22'	04°37'	920	CTD / BO / SD / BO
		12.56	78°22'	04°40'	803	
105	21.06.	15.27	78°15'	04°11'	2021	CTD / BO / BO / MN
		18.39	78°14'	04°17'	1922	
106	22.06.	08.45	75°00'	03°00'	3689	CTD / BO
		10.42	75°00'	02°59'	3690	

ARK IX/3

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
108	27.06	14.03	75°00'	03°00'	3689	CTD / MN / SD / HN / HN / BO / CTD
		23.05	74°58'	03°03'	3686	MN / CTD / RMT
109	28.06	09.30	76°19'	06°50'	1842	CTD / HN / HN / CTD / SD / BO / BO
		17.18	76°18'	06°52'	1679	RF / SL / SL
110	28.06	19.23	76°31'	07°14'	1058	CTD / MN / HN / BO / BO / RF / CTD
	29.06	02.28	76°29'	07°15'	1103	MUC / SL
111	29.06	04.08	76°35'	07°31'	476	CTD / MN / BO / BO / MUC / SL
		07.38	76°35'	07°27'	571	
112	29.06	10.50	76°44'	08°18'	351	CTD / BO / start ice camp / BO / RF
		12.15	76°44'	08°16'	350	
113	29.06	15.50	76°52'	09°00'	365	Start ice camp
		16.18	76°52'	09°00'	366	CTD / BO / BO
		17.53	76°52'	09°00'	365	End ice camp
114	29.06	21.20	77°02'	09°37'	397	CTD / MN / SD / BO
		23.22	77°02'	09°36'	394	
115	30.06	03.33	77°10'	10°29'	476	CTD / BO / BO / WP / CTD / BWS
		14.50	77°11'	10°27'	474	CTD / ROV / 3xGKG / MUC / MUC
						SL / EBS / AGT

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
116	30.06	20.02	77°18'	11°20'	486	CTD / HN / BO / BO
		21.06	77°20'	11°20'	490	
117	01.07	00.32	77°26'	12°10'	442	CTD / MN / SD / BO / BO / RF
		02.56	77°26'	12°12'	440	
118	01.07	09.05	77°33'	13°06'	341	CTD / HN / BO / BO / RF / R-Lot
		10.53	77°33'	13°08'	339	
119	01.07	14.34	77°44'	13°59'	361	CTD / HN / 2xBO / SD / CTD / BWS
	02.07	02.00	77°43'	14°10'	372	CTD / RF / BWS / SL / 3xGKG / MUC
						EBS / AGT / ROV
120	02.07	03.53	77°49'	14°45'	434	CTD/ MN / BO / BO / RF
		06.04	77°49'	14°47'	440	
121	02.07	08.20	77°55'	15°40'	485	CTD / HN / BO / SD / BO / CTD
		10.14	77°55'	15°41'	485	
122	02.07	15.08	77°56'	16°48'	402	CTD / R-Lot
		15.54	77°56'	16°48'	404	
123	02.07	20.24	78°01'	16°36'	501	CTD / MN / BO / BO / R-Lot
		20.54	78°01'	16°36'	502	Start ice camp
		22.27	78°01'	16°36'	507	
		23.10	78°01'	16°36'	502	End ice camp
124	03.07	03.14	78°05'	16°11'	481	CTD
		03.50	78°05'	16°11'	483	
125	03.07	05.50	78°10'	15°45'	371	CTD / BO / BO
		07.16	78°10'	15°46'	371	
126	03.07	08.38	78°14'	15°24'	210	CTD / BO / BO / R-Lot
		09.47	78°14'	15°25'	210	
127	03.07	22.05	79°25'	15°37'	35	CTD / SD / HN / BO / BO / ROV / RMT
	04.07	01.13	79°26'	15°32'	35	
128	04.07	02.04	79°31'	15°48'	115	CTD / BO / BO / ROV
		04.57	79°32'	15°43'	101	
129	04.07	05.48	79°36'	16°01'	193	BO / BO / CTD / RMT
		07.06	79°36'	16°01'	187	
130	04.07	08.02	79°41'	16°16'	303	CTD / BO / HN / SD / BO / CTD
		09.45	79°41'	16°15'	303	
131	04.07	10.47	79°48'	16°36'	247	CTD / BO / RMT
		12.25	79°49'	16°35'	171	

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
132	04.07	13.12	79°54'	16°56'	261	CTD / BO / BO
		14.43	79°54'	16°54'	243	
133	04.07	15.28	80°00'	17°06'	101	CTD / APN / BO / RMT
		16.49	80°00'	17°02'	149	
134	04.07	17.45	80°02'	16°23'	175	CTD / HN / BO / CTD / MN / CTD
		19.52	80°02'	16°24'	201	
135	04.07	20.56	80°08'	15°44'	372	CTD / BO / CTD / RMT
		22.57	80°09'	15°42'	362	
136	04.07	23.53	80°15'	15°05'	369	CTD / BO / SD / BO / CTD / MN / SD
	05.07	02.30	80°15'	15°06'	378	
137	05.07	04.36	80°21'	14°22'	337	CTD / BO / BO / CTD / RMT
		07.24	80°24'	14°13'	317	
138	05.07	09.04	80°27'	13°41'	319	CTD / SD / 3xBO / MN / CTD / BWS
		18.49	80°30'	13°26'	287	CTD / RF / MUC / SL / 5xGKG / R-Lot
						MUC / EBS / AGT
139	05.07	20.11	80°32'	12°31'	289	CTD / BO / HN
		22.20	80°32'	12°32'	293	
140	06.07	00.12	80°33'	11°36'	251	Start ice camp
		10.10	80°33'	11°15'	262	CTD / HN / BO / CTD / RF / ROV / RF
						CTD
	07.07	13.30	80°31'	10°34'	276	End ice camp
141	07.07	16.34	80°28'	11°14'	295	CTD / BO / BO / MUN / CTD
		18.44	80°28'	11°07'	293	
142	07.07	20.50	80°22'	10°03'	321	CTD / SD / BO / BO / HN / CTD
		22.25	80°21'	10°03'	327	
143	08.07	00.55	80°16'	08°54'	329	CTD / BO / BO / CTD / MN / CTD
		03.07	80°16'	08°47'	301	
144	08.07	04.48	80°10'	07°45'	297	CTD / BO / BO / CTD / RMT
		06.35	80°09'	07°35'	291	
145	08.07	08.45	80°04'	06°40'	314	CTD / BO / SD / HN / BO / RF / MN
						CTD / BWS / CTD / MUC / 4xGKG
		20.55	80°01'	06°45'	308	ROV / 2xEBS / AGT / ROV
146	09.07	00.10	80°02'	05°43'	473	CTD / HN / BO / BO / RF / MN
		02.50	80°00'	05°45'	441	
147	09.07	07.34	80°04'	04°12'	1991	CTD / HN / BO / BO / RF / MN / MUC
		13.15	80°02'	04°14'	1927	SL

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
148	09.07	17.03	80°05'	05°23'	923	CTD / BO / BO / RF / MN / SL / MUC
		22.55	80°02'	05°27'	820	SL
149	10.07	00.21	80°03'	05°44'	451	CTD / SL / MUC
		02.46	80°02'	05°46'	407	
150	10.07	05.15	80°03'	06°45'	294	CTD / BO / BO
		06.10	80°03'	06°44'	301	
151	10.07	07.41	80°03'	07°43'	275	CTD / BO / BO
		08.44	80°03'	07°42'	284	
152	10.07	10.25	80°03'	08°45'	257	CTD / BO / BO
		11.50	80°03'	08°46'	257	
153	10.07	14.35	80°03'	09°44'	104	CTD / BO / BO
		15.27	80°03'	09°45'	104	
154	10.07	18.07	80°03'	10°42'	143	CTD / BO / BO
		18.52	80°03'	10°41'	139	
155	10.07	19.55	80°09'	10°43'	179	CTD / BO / HN / BO / RF / CTD / BWS
	11.07	03.11	80°08'	10°47'	192	CTD / MUC / 3xGKG / ROV / EBS / AGP
156	11.07	07.51	80°17'	11°33'	163	CTD / BO / HN / BO / RF /
		09.09	80°17'	11°32'	178	
157	11.07	10.20	80°22'	11°58'	281	CTD / BO / BO / RMT
		11.45	80°22'	11°59'	282	
158	11.07	12.25	80°26'	12°20'	268	CTD / HN / BO / BO
		13.23	80°26'	12°20'	265	
159	11.07	14.11	80°30'	12°41'	290	CTD / BO / BO / RMT
		15.48	80°30'	12°38'	282	
160	11.07	16.40	80°35'	13°02'	291	CTD / BO / BO
		17.55	80°36'	13°00'	296	
161	11.07	18.39	80°40'	13°22'	214	CTD / BO / SD / BO / RMT
		20.35	80°40'	13°27'	207	
162	11.07	21.46	80°44'	13°45'	226	CTD / BO / BO
		23.06	80°44'	13°45'	223	
163	12.07	00.30	80°48'	14°04'	51	CTD / HN / BO / BO / RF / ROV / RMT
		03.42	80°48'	13°58'	178	
165	12.07	07.16	80°27'	13°40'	319	CTD / BO / BO / CTD / BWS / CTD
		13.35	80°28'	13°37'	314	BWS / MUC / 3xGKG / EBS

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
166	12.07	15.44	80°27'	15°26'	187	CTD / HN / BO / BO / RF / CTD / RMT
		18.06	80°28'	15°23'	221	
167	12.07	19.13	80°23'	15°05'	221	CTD / BO / BO
		20.05	80°23'	15°05'	222	
168	12.07	20.50	80°19'	14°43'	367	CTD / BO / BO / CTD / RMT
		22.40	80°19'	14°37'	367	
169	12.07	23.21	80°14'	14°21'	291	CTD / BO / BO
	13.07	00.21	80°14'	14°20'	280	
170	13.07	01.05	80°10'	14°00'	141	CTD / BO / SD / BO / RMT
		02.38	80°09'	13°59'	142	
171	13.07	03.15	80°06'	13°40'	209	CTD / HN / BO / BO
		04.28	80°06'	13°39'	204	
172	13.07	05.09	80°02'	13°19'	87	CTD / BO / ROV / RMT
		08.05	80°01'	13°14'	81	
173	13.07	08.50	79°56'	12°59'	99	CTD / BO / HN / BO / RF
		09.52	79°56'	12°58'	99	
174	13.07	11.40	79°53'	12°44'	153	ROV
		12.42	79°53'	12°43'	149	Start ice sampling
		12.54	79°53'	12°43'	148	
		14.01	79°53'	12°43'	150	End ice sampling
175	13.07	15.42	79°48'	12°24'	250	CTD / HN / BO / BO
		16.57	79°49'	12°24'	253	
176	13.07	18.19	79°44'	12°03'	240	CTD / BO / BO
		19.33	79°44'	12°00'	233	
177	13.07	21.30	79°39'	11°48'	280	CTD / HN / BO / BO / MN / 3x GKG
	14.07	00.23	79°39'	11°45'	313	
178	14.07	05.05	79°52'	12°37'	149	CTD / BO / BO / RF
		06.18	79°53'	12°36'	149	
179	14.07	13.30	80°37'	11°19'	249	CTD / HN / BO / SD / CTD / BWS / CTD
		18.06	80°36'	11°17'	250	MUC / 3xGKG / EBS
180	14.07	20.14	80°31'	10°00'	254	CTD / BO / BO / HN / RMT
		21.49	80°32'	10°02'	265	
181	14.07	22.30	80°35'	10°24'	289	CTD / BO / BO
		23.28	80°35'	10°22'	293	
182	15.07	00.30	80°39'	10°49'	219	CTD / BO / BO / CTD / RF / RMT
		03.03	80°39'	10°53'	253	

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
183	15.07	03.50	80°44'	11°12'	225	CTD / BO / BO / CTD
		05.08	80°44'	11°10'	114	
184	15.07	06.15	80°48'	11°36'	207	CTD / BO / BO / RF
		07.48	80°48'	11°34'	220	
185	15.07	08.50	80°52'	12°01'	145	CTD / BO / BO
		09.51	80°52'	11°59'	157	
186	15.07	11.03	80°57'	12°28'	59	CTD / BO / HN / BO / CTD / RMT
		12.44	80°56'	12°31'	87	
187	15.07	13.43	81°00'	12°48'	47	CTD / HN / BO
		14.08	81°00'	12°49'	47	
188	15.07	17.18	81°15'	11°30'	31	CTD / BO / RMT
		18.19	81°14'	11°34'	35	
189	15.07	19.19	81°10'	10°59'	63	CTD / BO / BO / CTD / ROV
		22.06	81°11'	10°57'	57	
190	16.07	00.14	81°05'	10°30'	45	CTD / BO / ROV
		01.56	81°05'	10°31'	43	
191	16.07	03.02	81°00'	10°10'	41	CTD / HN / BO / RMT
		03.50	80°59'	10°14'	37	
192	16.07	04.43	80°57'	09°45'	43	CTD / BO / BO / CTD
		05.41	80°57'	09°47'	43	
193	16.07	07.47	81°12'	09°11'	99	CTD / BO
		08.23	81°12'	09°10'	105	
194	16.07	09.14	81°16'	09°36'	109	CTD / RMT / BO / SD
		09.47	81°16'	09°36'	115	
195	16.07	11.06	81°20'	10°00'	123	CTD / HN / BO / SD
		11.39	81°20'	10°00'	117	
196	16.07	12.37	81°24'	10°26'	119	CTD / BO / BO / SD
		13.06	81°24'	10°26'	121	
197	16.07	14.02	81°28'	10°51'	91	CTD / BO / SD / BO / HN / RF / CTD
		16.18	81°27'	10°53'	69	RMT
198	16.07	17.27	81°32'	11°15'	137	CTD / BO
		17.57	81°32'	11°15'	133	
199	16.07	18.47	81°36'	11°40'	101	CTD / BO
		19.38	81°36'	11°39'	93	

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
200	16.07	20.36	81°40'	12°05'	141	CTD / BO / MN
		21.03	81°40'	12°04'	147	
201	16.07	22.00	81°44'	12°30'	171	CTD / BO / BO / HN / CTD / RMT
		23.35	81°43'	12°26'	149	
202	17.07	00.41	81°46'	12°10'	175	CTD / BO
		01.25	81°47'	12°12'	183	
203	17.07	02.41	81°49'	12°51'	185	CTD / BO
		03.30	81°49'	12°54'	185	
204	17.07	04.59	81°45'	11°25'	197	CTD / BO
		05.50	81°45'	11°26'	191	
205	17.07	07.57	81°41'	11°00'	191	CTD / BO
		08.28	81°41'	11°00'	183	
206	17.07	09.48	81°37'	10°34'	231	CTD / HN / BO / BO / RF / HN / HN
		12.12	81°37'	10°26'	255	CTD / RMT
207	17.07	13.25	81°33'	10°09'	185	CTD / BO
		14.06	81°33'	10°09'	187	
208	17.07	16.07	81°29'	09°44'	217	CTD / BO
		17.01	81°29'	09°43'	215	
209	17.07	18.13	81°24'	09°25'	205	CTD
		18.43	81°24'	09°25'	205	
210	17.07	19.45	81°20'	09°00'	455	CTD / HN / BO / SD
		20.27	81°20'	08°59'	461	
211	17.07	21.47	81°17'	08°32'	982	CTD / HN / BO
		23.17	81°17'	08°32'	976	
212	18.07	00.00	81°14'	08°50'	387	CTD
		00.23	81°14'	08°50'	382	
213	18.07	05.05	81°23'	06°45'	2767	CTD / MUC / SL
		10.36	81°22'	06°51'	2770	
214	18.07	11.45	81°21'	07°17'	2117	CTD / HN / SL / MUC / MUC
		17.02	81°20'	07°16'	1723	
215	18.07	20.20	81°15'	08°24'	1005	CTD / MN / MUC / SL
		23.44	81°16'	08°22'	1051	
216	19.07	01.26	81°14'	08°44'	503	CTD / MN / SL / SL / MUC / EBS
		05.39	81°12'	08°43'	364	

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
217	19.07	13.44	80°27'	13°40'	322	CTD / HN / BO / BO / CTD / BWS
		19.33	80°27'	13°32'	315	CTD / MUC / 3xGKG / EBS
218	20.07	01.08	79°53'	11°00'	174	CTD / HN / BO / BO / MN / 4xGKG
		03.14	79°54'	10°56'	157	
219	20.07	04.24	80°00'	11°00'	105	CTD / BO / BO / RF / CTD
		05.49	80°00'	11°01'	103	
220	20.07	07.34	80°07'	11°01'	143	CTD / BO / BO
		08.40	80°07'	11°02'	134	
221	20.07	10.20	80°14'	10°59'	156	CTD / HN / BO / SD / BO / CTD
		11.44	80°14'	11°01'	157	
222	20.07	12.37	80°21'	11°00'	287	CTD / HN / BO / BO / RMT
		14.33	80°22'	11°04'	329	
223	20.07	15.18	80°28'	11°01'	293	mooring recovery
		15.54	80°28'	11°01'	293	
		16.33	80°27'	11°01'	285	CTD / BO / CTD
		18.00	80°27'	10°56'	289	
		18.45	80°28'	11°02'	289	
		21.30	80°28'	11°02'	289	
224	20.07	22.40	80°35'	11°00'	254	CTD / BO / BO
		23.37	80°35'	10°59'	258	
225	21.07	00.33	80°42'	11°00'	118	CTD / HN / SD / BO / BO / RMT
		02.00	80°42'	11°07'	128	
226	21.07	02.53	80°49'	11°00'	226	CTD / HN / BO / SD / BO / RF / CTD
		04.55	80°49'	10°53'	201	
227	21.07	06.01	80°56'	11°00'	80	CTD / HN / BO / BO / RMT
		07.20	80°55'	11°03'	120	
228	21.07	08.28	81°03'	11°00'	53	CTD / HN / SD / BO / BO
		08.59	81°03'	11°02'	55	
229	21.07	10.03	81°10'	10°58'	58	CTD / HN / BO / BO / RF / CTD / RMT
		11.41	81°10'	11°01'	60	
230	21.07	12.27	81°12'	11°20'	51	ROV
		13.44	81°12'	11°17'	55	
231	22.07	00.05	80°05'	15°45'	399	CTD / HN / BO / BO / MUC / 3xGKG
		05.24	80°03'	15°47'	405	EBS / AGT
232	22.07	06.37	80°11'	16°15'	230	CTD / BO / BO / MN / ROV / BWS
		14.14	80°10'	16°20'	209	MUC / 4xGKG / EBS / RMT

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
233	22.07	15.43	80°01'	16°23'	223	CTD / BO / BO
		17.48	80°01'	16°22'	226	
234	22.07	17.28	79°57'	15°05'	171	CTD / BO / BO / ROV / BWS / MUC
	23.07	00.18	79°56'	15°02'	162	3xGKG / EBS / RMT / AGT
235	23.07	01.26	79°50'	14°29'	86	CTD / BO / HN / BO / RMT
		02.34	79°50'	14°32'	78	
236	23.07	04.21	79°44'	13°57'	120	CTD / BO / BO / RF / MN
		05.38	79°44'	13°55'	118	
237	23.07	08.10	79°37'	13°27'	187	CTD / HN / BO / BO / RF
		09.35	79°37'	13°27'	199	
238	23.07	12.07	79°31'	12°57'	211	CTD / BO / BO / RF / MN / 3xGKG
		15.33	79°31'	13°00'	225	rubber boat
239	23.07	21.23	79°11'	15°08'	39	ROV
		23.32	79°11'	15°13'	40	
240	24.07	01.14	79°23'	14°58'	46	CTD / HN / HN / BO / BO / ROV / RMT
		04.11	79°24'	15°02'	54	
241	24.07	04.49	79°24'	15°18'	34	CTD
		04.56	79°24'	15°18'	34	
242	24.07	05.33	79°25'	15°37'	35	CTD / BO / BO / ROV
		08.15	79°25'	15°37'	31	
243	24.07	09.01	79°28'	15°43'	90	CTD
		09.13	79°28'	15°43'	90	
244	24.07	09.50	79°31'	15°48'	111	CTD / HN / BO / RMT
		11.03	79°32'	15°49'	122	
245	24.07	11.25	79°33'	15°54'	141	CTD
		11.45	79°33'	15°54'	141	
246	24.07	12.21	79°36'	16°00'	189	CTD / HN / BO / BO
		13.37	79°36'	16°02'	189	
247	24.07	14.07	79°39'	16°09'	253	CTD
		15.25	79°39'	16°09'	258	
248	24.07	14.54	79°41'	16°17'	294	CTD / HN / BO / BO / RMT
		16.41	79°42'	16°20'	314	
249	24.07	17.10	79°45'	16°24'	219	CTD
		17.24	79°45'	16°24'	220	

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
250	24.07	17.54	79°48'	16°34'	244	CTD / BO / BO
		18.46	79°48'	16°33'	251	
251	24.07	19.19	79°51'	16°46'	90	CTD
		19.30	79°51'	16°46'	90	
252	24.07	19.56	79°54'	16°56'	260	CTD / HN / BO / RMT
		21.00	79°55'	16°58'	285	
253	24.07	21.19	79°57'	17°01'	196	CTD
		21.29	79°57'	17°01'	196	
254	24.07	21.53	80°00'	17°06'	94	CTD / HN / BO / BO / RMT
		23.00	80°01'	17°01'	143	
255	25.07	06.06	80°25'	14°10'	344	mooring recovery
		06.09	80°25'	14°10'	344	
256	25.07	08.50	80°31'	12°55'	283	mooring recovery
		09.30	80°30'	12°54'	283	
257	25.07	19.47	80°30'	13°13'	305	CTD / SD
		20.29	80°30'	13°11'	293	
258	26.07	04.23	80°27'	13°40'	327	CTD / BWS / MUC / MUC / 3xGKG
		08.48	80°27'	13°37'	320	EBS
259	26.07	10.57	80°28'	11°02'	290	mooring recovery
		15.20	80°28'	11°01'	297	
		15.53	80°28'	11°16'	204	CTD / BO / BO
		16.53	80°28'	11°15'	303	
260	26.07	18.20	80°22'	10°05'	326	CTD / BO / BO / RMT
		20.02	80°21'	09°59'	332	
261	26.07	21.18	80°16'	08°54'	301	CTD / HN / BO / BO / MN
		22.50	80°16'	08°49'	303	
262	27.07	00.22	80°10'	07°46'	294	CTD / HN / BO / SD / BO / RMT
		02.15	80°09'	07°42'	296	
263	27.07	04.23	80°03'	06°39'	305	CTD / BO / BO / RF / MN
		06.27	80°04'	06°34'	312	
264	27.07	08.15	79°54'	06°08'	302	CTD / MN / BO / SD / BO / RMT
		10.59	79°54'	05°58'	299	3xGKG

Station No.	Date 1993	Time (UTC)	Lat. N	Long. W	Depth (m)	Gear
265	27.07	12.47	79°44'	05°42'	305	CTD / HN / BO / BO
		13.53	79°43'	05°41'	299	
266	27.07	16.00	79°30'	05°41'	409	CTD / BO / MN
		17.52	79°30'	05°46'	338	
267	27.07	20.30	79°15'	05°23'	1072	CTD / HN / BO / BO
		22.00	79°15'	05°22'	1084	
268	28.07	05.20	79°00'	03°12'	2354	mooring recovery
		06.33	79°00'	03°12'	2354	
		07.58	79°00'	03°12'	2359	mooring deployment
		09.46	79°00'	03°12'	2365	
269	28.07	13.10	79°00'	04°40'	1545	mooring deployment
		14.24	78°59'	04°39'	1550	
270	28.07	18.35	79°00'	06°04'	520	mooring deployment
		19.19	79°00'	06°01'	537	
271	29.07	09.28	78°47'	10°47'	345	3xGKG / BO / BO / MN / CTD / MN
		12.18	78°48'	10°47'	350	
272	29.07	15.14	78°45'	10°00'	418	CTD / BO / BO
		16.17	78°45'	10°00'	420	
273	29.07	18.49	78°45'	08°39'	164	CTD / BO / MN / 2xGKG
		20.25	78°45'	08°58'	158	
274	30.07	06.20	79°00'	06°06'	339	mooring recovery
		07.20	79°00'	06°06'	339	
275	30.07	08.15	79°00'	06°06'	330	mooring recovered
		11.21	79°00'	06°13'	330	
276	30.07	18.23	78°25'	04°04'		mooring recovery
		19.36	78°25'	04°04'		
277	31.07	05.20	78°30'	03°21'	2354	mooring recovery
		06.39	78°30'	03°21'	2354	
278	01.08	08.05	76°00'	05°00'	3245	CTD / MUC / HN / SL / SL
		14.22	76°01'	05°00'	3254	
279	01.08	23.45	75°00'	03°00'	3679	CTD / HN / CTD / MN / BO / BO / CTD
	02.08	07.45	75°02'	03°05'	3677	CTD

Abbreviations

ADCP	**a**coustic **d**oubler **c**urrent **p**rofiler
AGT	**Ag**assiz **t**rawl
APN	**Ap**stein-**n**et
BO	**Bo**ngo-net
BWS	**B**ottom-**w**ater-**s**ampler
CTD	**CTD** probe
EBS	**E**pi**b**enthic-**s**ledge
FOT	**Fot**oschlitten (still camera system)
GKG	**G**roß**k**asten**g**reifer (giant box corer)
GKS	**G**las**k**ugel**s**chöpfer (glass bottle sampler)
HN	**H**and **n**et
KAL	**Ka**stenl**ot** (box corer)
MN	**M**ulti**n**et
MUC	**Mu**ltiple **c**orer
PLA	**Pla**nkton net
R-Lot	**R**umohr-**Lot**
RF	**RF** net
RMT	**R**ectangular **m**idwater **t**rawl
ROV	**R**emotely **o**perated **v**ehicle
SD	**S**ecchi-**d**isc
SL	**S**chwere**l**ot (gravity corer)
WP	**WP**2-net
WS	**W**asser**s**chöpfer (water cast)

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Hirche, Hans-Jürgen	AWI
Hollmann, Beate	AWI
Köhler, Herbert	DWD
Köhn, Brigitte	AWI
König, Thomas	DLR
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Michel, Andreas	AWI
Nielsen, Torkel Gissel	MBLR
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MBLR Marine Biological Laboratory Roskilde
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MGM McGill University Montreal, Department of Meteorology,
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MUN Memorial University of Newfoundland,
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PMELNOAA Pacific Marine
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SOW University of Washington
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16 SHIP'S CREW

	ARK IX/2	ARK IX/3
Master	H. Jonas	E. Greve
Ch. Mate	M. Müller	I. Varding
Naut. Offc.	U. Grundmann	M. Bürger
Naut. Offc.	M. Rodewald	S. Schwarze
Naut. Offc.	M. Block	M. Block
Doctor	Dr. Schuster	Dr. A. Schröder
Ch. Eng.	V. Schulz	D. Knoop
2. Eng.	G. Erreth	W. Delff
2. Eng.	R. Fengler	H. Folta
2. Eng.	O. Ziemann	W. Simon
Electrician	H. Maslack	R. Erdmann
Electronician	U. Lembke	K.J. Hoops
Electronician	H. Muhle	M. Fröb
Electronician	A. Greitemann-Hacke	A. Piskorzynski
Electronician	J. Roschinsky	R. Rabenhorst
Radio Offc.	K.H. Wanger	E. Müller
Radio Offc.	H. Geiger	J. Butz
Cook	E. Kubicka	W. Köwing
Cook Mate	H. Hüneke	M. Kästner
Cook Mate	H. Wübber	F. Roggatz
1. Steward	G. Scheel	D. Peschke
Stewardess	S. Hoffmann	V. Daute
Stewardess	M. Hoppe	A. Hopp
Stewardess		U. Baumgartl
2. Steward	C.-C. Yang	A. Neves
2. Steward	K.Y. Yu	K.Y. Yu
2. Steward	A. Neves	C.-C. Yang
2. Steward	J. Tu	Ch. Chang
Laundry	Ch. Chang	
Boatswain	R. Zulauf	W. Hopp
Carpenter	K. Marowsky	P. Kassubeck
Carpenter	P. Kassubeck	
Decks Crew	J. Soage Curra	E. Arias Iglesias
	M. Winkler	A. Suarez Paisal
	S. Pousada Martinez	R. Ponte Dourado
	H. Thiele	J. Novo Loveira
	M. Schmidt	B. Pereira Portela
	B. Iglesias Bermudez	A. Prol Otero
	S. Moser	A. Thiele
		M. Meis Torres
Store Keeper	K. Müller	B. Barth
Motormen	M. Lesch	G. Fritz
Motormen	U. Husung	F. Buchas
Motormen	E. Heurich	S. Reimann
Motormen	G. Dufner	G. Jordan
Motormen	E. Carstens	A. Padur