The Russian-German TRANSDRIFT IX Expedition 2003: Cruise Report and First Results

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Content

1. Process Studies on Permafrost Dynamics in the Laptev Sea – An Introduction

Permafrost of a thickness of up to 1000 m is an important feature of the seafloor of the Laptev Sea and of the landscape of the adjoining central part of Northern Siberia. By way of numerous studies carried out in the hinterland of the Laptev Sea, terrestrial permafrost, its distribution and its stability boundaries have been thoroughly investigated. Our knowledge of the submarine permafrost of the Laptev Sea, however, is only based on the results of Russian exploratory drillings off the Novosibirskiye Islands (NSI) during the 1960s and 1970s and of the scientific Russian-German expedition TRANSDRIFT VIII (2000), during which pilot drilling was carried out in the central Laptev Sea.

The submarine permafrost was formed under subaerial conditions during the last glacial and subsequently underwent submersion due to the postglacial sea-level rise and nowadays due to shoreline erosion. Therefore its present state is highly transient. The submarine permafrost regime is largely determined by heat and mass transport processes that control the response rate to the new warm and salty boundary conditions. A considerable amount of organic carbon is stored in the upper permafrost layer and gas hydrates are expected to be found within and beneath the submarine permafrost. Large increases of CO_2 and CH_4 emissions are associated with degradation of permafrost. Thawing of permafrost could release large quantities of greenhouse gases into the atmosphere, thus further increasing global warming. Even though the submarine permafrost is of importance for the global climate system, the knowledge on its recent dynamics is still limited.

During the past decade a large-scale change in the arctic atmospheric circulation took place causing different oceanographic boundary conditions, indicated by, e.g., decrease in ice coverage, increase in riverine input and in air temperatures and increased inflow of Atlantic water masses into the Arctic Ocean and the Laptev Sea. These changing boundary conditions probably influence the stability of the submarine permafrost. Since in permafrost regions geochemical processes are largely governed by microbiological processes, the role of micro-organisms is of major interest in studying the dynamics of biogeochemical cycles in permafrost regions. In particular methane formation/oxidation and formation of carbon dioxide are regarded as microbial key processes in frozen sediments.

The aim of the joint Russian-German project “Process Studies of Permafrost Dynamics in the Laptev Sea” is to investigate by way of an interdisciplinary approach to which extent exchange processes and interaction between atmosphere, hydrosphere and seafloor cause the degradation of submarine permafrost. On the basis of the scientific results of the predecessor Russian-German projects carried out in the Laptev Sea this joint project focuses on the processes taking place during the submersion of terrestrial permafrost, on recent processes under "stable conditions" as well as on aggradation/degradation processes and their causes.

The Russian-German project “Process Studies of Permafrost Dynamics in the Laptev Sea” is funded by the German Federal Ministry of Education and Research (FKZ 03G0589A) and the Ministry of Industry, Science and Technology of the Russian Federation. The TRANSDRIFT IX expedition was the first marine expedition within the framework of the project mainly focusing on the investigations of the recent factors affecting the stability of submarine permafrost in the Laptev Sea and of the quantification of microbial processes and of their impact on the regulation of biogeochemical cycles in submarine permafrost. It started in Tiksi on August 29 and ended in Tiksi harbor on September 4 2003. The expedition was financially supported by the Alfred Wegener Institute for Polar and Marine Research.

The expedition would not have been possible without the support of numerous colleagues, authorities, and institutions in Russia and Germany. We would especially like to thank for the support and advice of Prof. L. Timokhov (AARI, Russia), Dr. S. Priamikov (AARI, Russia), Dr. H. Kassens (GEOMAR, Germany) and Dr. K. Volkmann-Lark (GEOMAR, Germany) as well as the directors of the hydrographic bases in Arkhangelsk and Tiksi. The expedition was financially supported by the Alfred Wegener Institute for Polar and Marine Research.

We wish to thank the ship’s master, Captain Yuri Lekarev, and his crew of RV “IVAN KIREYEV” for their extraordinary contribution to the success of our work. The quick deployment of the two seafloor observatories within 3 days after leaving the harbor of Tiksi was only possible due to the professional and dedicated help of this team.

2. The TRANSDRIFT IX Expedition: Process studies on submarine permafrost dynamics in the Laptev Sea

The TRANSDRIFT IX expedition was carried out aboard RV “IVAN KIREYEV” within the framework of the Russian-German project “Laptev Sea System” and was funded by the German Federal Ministry of Education and Research and the Alfred Wegener Institute for Polar and Marine Research (AWI, Germany). The cruise took place at the same time as the expeditions “Mamontovy Klyk 2003” and “Samoylov 2003”. The research program during the expedition focused on recent processes influencing the stability of the submarine permafrost and on bacterially influenced processes of its biogeochemical cycles. Multidisciplinary experiments were performed comprising:

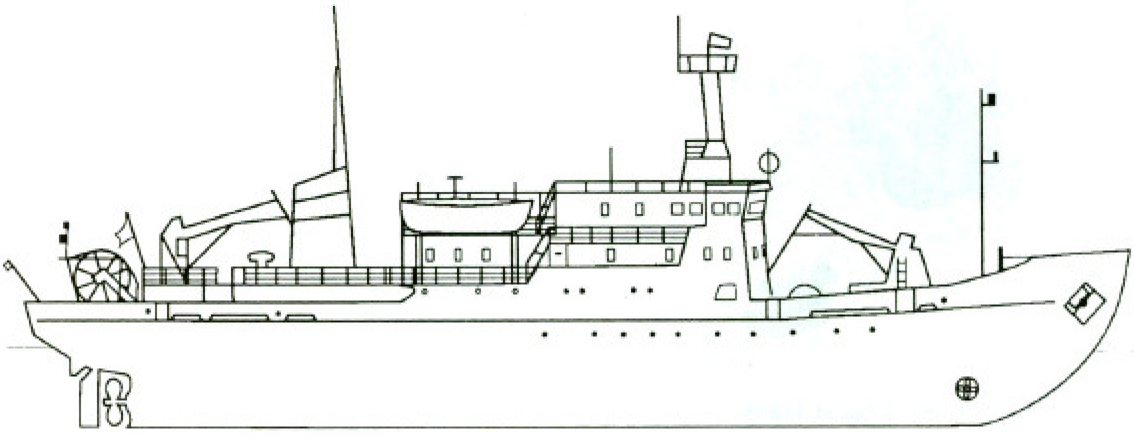
measurements of physical and chemical parameters of the water column and of sediments

sedimentological investigations of sediments and suspended particulate matter

micro-biological studies in the water column and on sediments

One of the major tasks was the investigation of the complex interaction between atmosphere, water column and seafloor/submarine permafrost. Therefore two seafloor observatories were deployed for a period of one year to monitor seasonal variability in surface-sediment temperature and in oceanographic parameters within the water column. They will be recovered during the TRANSDRIFT X expedition in 2004. This somewhat extensive working program for this comparably short period of ship time could be carried out due to fairly calm weather conditions. South-easterly to south-westerly winds prevailed with an average wind speed of 6.1 m/s. The air temperature varied from 2 to 6°C with a mean of 4°C.

RV “IVAN KIREYEV” was constructed in Finland in 1977 and belongs to the Hydrographic Department of Arkhangelsk (Figure 1). It is especially equipped for carrying out oceanographic investigations at high latitudes (class 3 ice capability).



Characteristics	Value
Year of construction	1977
Length over all (max.), m	68
Breadth (max), m	12.4
Draft at load, m	5
Register tons, tons; gross net	1267 380
Displacement at load, tons	1639
Cruising speed, knots	10
Power of main engine, kW	1470
Total crew (max.), persons	55
Tonnage, tons	609

Figure 1: General view and major technical characteristics of RV “IVAN KIREYEV”.

3. Motivation: Deployment of two seafloor observatories

The main task during the TRANDRIFT IX expedition was to deploy two seafloor observatories to study the seasonal variability in temperature and salinity distribution within the water column, interacting processes in the transition zone water column/sediment and in the current system, and the transport processes for the period of one year. One of the seafloor observatories was deployed in the nearshore area north of the Lena Delta to characterize processes in an onshore/offshore environment and within the frontal zone of the Lena River (LENA 03; Figure 2).

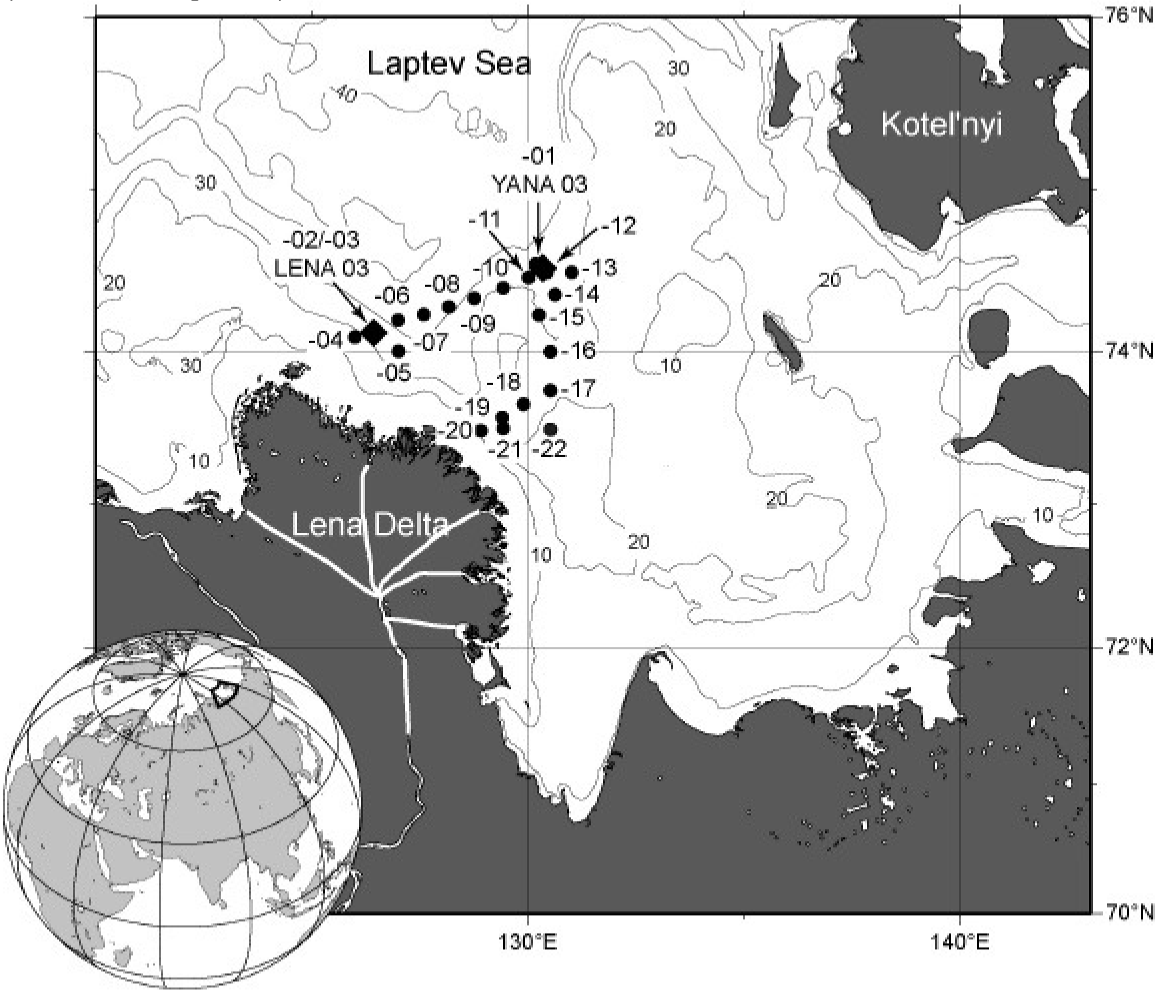


Figure 2: Bathymetric map of the eastern Laptev Sea shelf and the locations of the stations during the TRANSDRIFT IX expedition (IK03). Solid circles indicate short-term, solid squares long-term stations.

To study changes in the hydrodynamic system and its interaction with the seafloor, the second seafloor observatory was deployed in the mid-shelf area (YANA 03; Figure 2).

The seafloor observatories (Figure 3) are each equipped with 4 sediment thermometers (ANTARES, Germany), 1 Acoustic Doppler Current Profiler (ADCP, WH-Sentinel 300 kHz, RD-Instruments, USA), 2 Conductivity

Temperature Depth meters (CTDs, XR-420 CTD+2, RBR, Canada) in combination with turbidity meters (SEAPOINT), and 1 Conductivity Temperature meter (CT, XR-420 CT, RBR; FIGURE; observatories). Conductivity and temperature meters are deployed at defined water depths (LENA 03: 2, 10, and 15 m above seafloor; YANA 03: 2, 10, and 20 m above seafloor) along a sensor string to detect fluctuations in temperature and salinity within the water column. The sediment thermometers record the temperature from the sediment surface up to a depth of 70 cm to determine the heat flux between the water column and the seafloor. The bottom-moored upwards-looking broadband ADCPs monitor the current speed and direction of the entire water column to reconstruct the origin of warmer bottom waters. ADCP measurements at both stations will be carried out at intervals of 1 minute and averaged over 30 minutes in different depth cells.

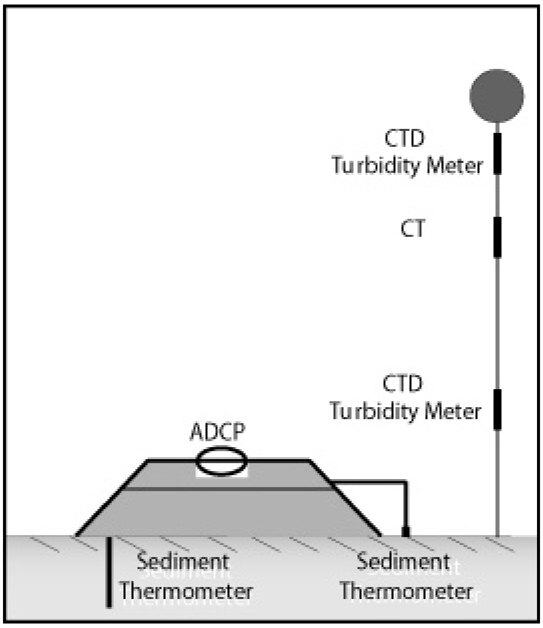


Figure 3: Seafloor observatories to monitor seasonal variability in salinity, temperature, turbidity, ice coverage, currents, and in bottom-sediment temperature.

4. Recent stability factors of submarine permafrost

After submergence submarine permafrost degrades, thawing from the seabed downwards by the influx of salt and heat as a result of the new oceanographic boundary conditions, even in the presence of negative mean seafloor temperatures (e.g. Osterkamp et al., 1989; Gosink & Baker, 1990). Both the transport of heat and the transport of salt are important for the dynamics of the submarine permafrost and, depending upon conditions, either or both may control the response rate to the oceanographic boundary conditions. Changes in temperature and salinity distribution within the water column are of major importance as they directly influence the energetic balance of the submarine permafrost (Vigdorchik, 1980; Gosink & Baker, 1990; Hutter & Straughan, 1999). Therefore process studies on the interaction between atmosphere, water column and seafloor/submarine permafrost were and still are carried out to characterize the stability factors of the submarine permafrost.

4.1 Working program

To investigate the influence of interactions between seafloor, water column, and atmosphere on the stability of the submarine permafrost, relevant parameters in the water column and of surface bottom sediments were determined along a grid of 22 long and short-term stations on the eastern Laptev Sea shelf (Figure 2). 3 long-term stations (at least 18 hours) were located in the adjacency of the seafloor observatories to calibrate the one-year records after recovering them during TRANSDRIFT X expedition in 2004. Measurements with a Conductivity Temperature Depth meter (CTD; SBE 19, Sea-Bird) in combination with a turbidity meter (SEAPOINT) have been carried out to obtain data on the distribution of temperature, salinity, and suspended particulate matter (SPM) within the water column. Water samples of about two liters each were collected with Niskin bottles from defined water depths. These water samples have been filtered through pre-weighed HVLP filters by MILLIPORE (0.45 microns) to obtain SPM concentration. All turbidity meter measurements were correlated with corresponding filtered water samples. A strong correlation was observed ($r = 0.801$; $p = 0.01$; $n = 84$). Due to the linear relation between turbidity meter measurements and filtered water samples optical backscatter signals could be translated into SPM concentrations ($SPM_{optical}$). Complementary surface bottom-sediments were sampled with a small sediment grab to determine surface temperatures (depth: 0 – 10 cm), pore-water salinity, and grain size parameters. The long-term stations and the seafloor observatories were connected by a SW-NE transect of short-term stations for a better spatial representation. Additionally two transects of short-term stations crossing the river front of the River Lena have been carried out.

4.2 Preliminary results

A total of 52 CTD casts and 113 water samples were obtained during the expedition. Along the SW-NE transect a stratified water column was observed with the pycnocline situated in a depth between 5 and 10 m (Figure 4). The surface waters were characterized by temperatures of >5°C and salinities <10, influenced by the freshwater input of the Lena River. Near the seafloor the temperature were <-1°C and salinities >30. Highest SPM concentrations were mainly observed nearest to the Lena Delta with the maxima close to the seafloor. This maximum represents the bottom-nepheloid layer, a layer of increased SPM concentration. The material discharged by the Lena River settles quickly and forms the bottom nepheloid layer. Crossing the hydrological front of the Lena River a layer of increased temperature can be observed in a depth between 7 and 12 m showing the temperature signal of the surface water but with significantly increased salinity (Figure 4). This distribution might be explained by sinking of the surface water along isohalines.

The temperature of bottom surface sediments varied between –1.47°C and –0.53°C in water depths of 21 to 33 m. The temperature measurements were in the lower range of measurements carried out during TRANSDRIFT I-V expeditions (Kassens & Karpiy, 1994; Kassens & Dmitrenko, 1995; Kassens et al., 1997). Temperature measurements were limited to silty/clayey sediments due to the sampling technique. Even though the surface temperature of the bottom surface sediments is below 0°C and partly close to the freezing point of the surrounding seawater the sediments are not frozen. This can probably be explained by its pore water salinity which will be determined at the Otto Schmidt Laboratory in St. Petersburg.

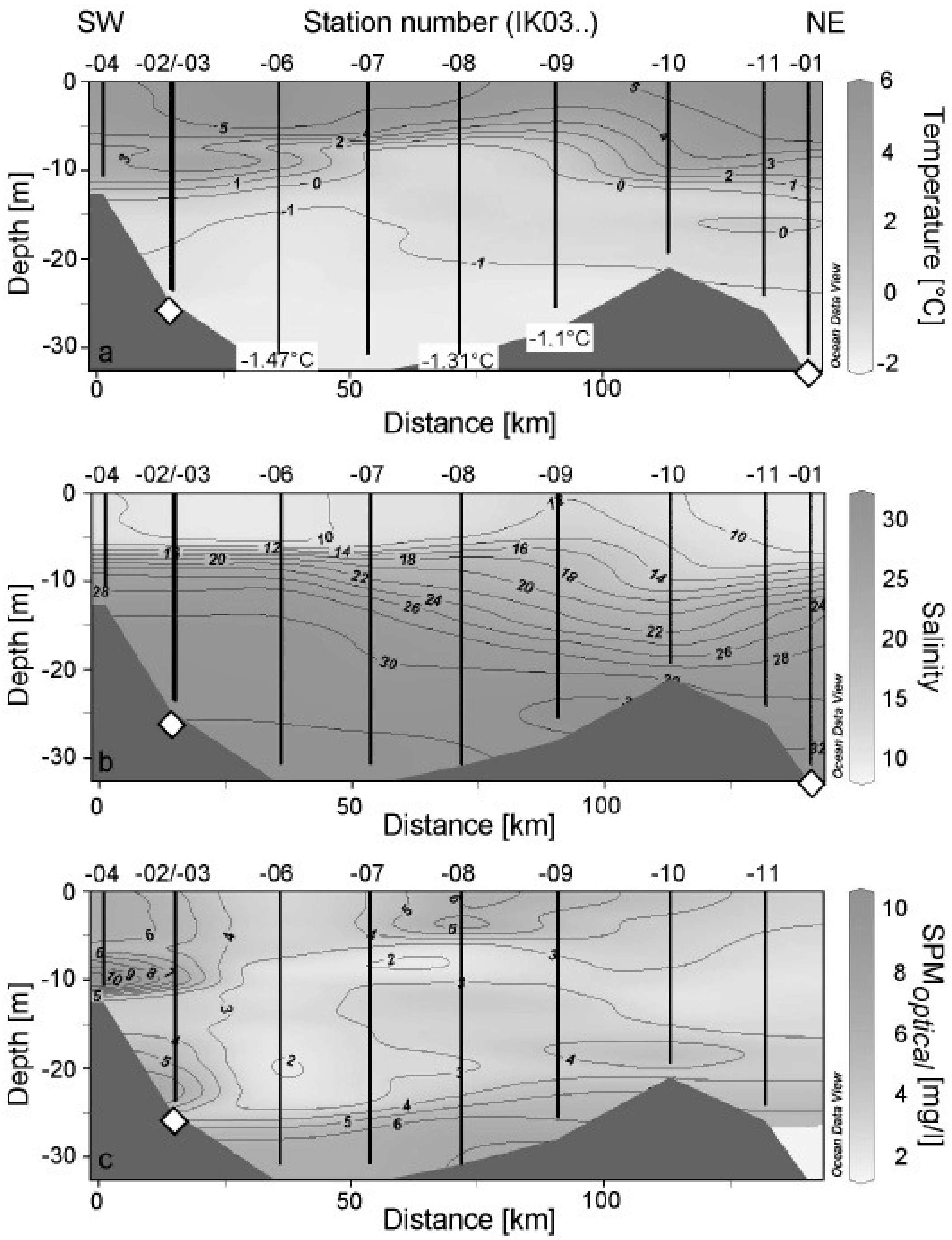


Figure 4: (a) Water and surface bottom sediment temperature [℃], (b) salinity, and (c) SPM [mg/l] distribution along a SW-NE transect. SPM has been derived from turbidity meter measurements. White squares indicate the position of the seafloor observatories.

5. Hydrochemical structure of the water column

In the Laptev Sea the strong variability of meteorological, oceanographical, and biological conditions, results in a complex water column structure (Pivovarov et al., accepted). During the different seasons water masses with different properties are formed in the same region. A small spatial distribution and a short life span are characteristic for these shallow water masses. In general, the water column can be subdivided vertically into surface, intermediate and bottom structural zones. Transport processes and biogeochemical cycling of dissolved and particulate matter differ from each other in these structural zones.

The surface structural zone (SSZ) is the most active area, where energy and material is transformed by interactions between sea, ice, and atmosphere. The thickness of the SSZ in the well-stratified seas is usually 5-10 m and changes seasonally. In the Laptev Sea two different regions can be distinguished due to their physical and chemical properties: i.) river plumes, which occupy the southern and eastern regions of the Laptev Sea and ii.) arctic basin surface waters, which influence the northwestern part of the sea. Especially the silicate concentration of surface waters is considered to be a good chemical tracer of the river plume. The 10 μmol l^{-1} silicate isoline is accepted to be a boundary of the river plume that is also characterized by low salinity (less than 25), low oxygen saturation (95 – 100 %), and high concentrations of suspended matter (0.5-0.8 mg l^{-1} at the outer shelf and up to 70 mg l^{-1} near the Lena River Delta).

The intermediate structural zone (ISZ) in the shallow arctic seas consists of the halocline, a layer up to 20 m of thickness with strong salinity gradients. It has a multi-layered structure itself and consists of water masses of various origins. Data of summer oceanographic surveys have shown that the water masses of the ISZ, formed in winter, in spring, and in summer can be distinguished by their chemical properties and temperature.

Low temperatures (-1.2 ÷ -1.5 °C), extremely low oxygen saturation (30-50%), and high nutrient concentrations are characteristic for the bottom structural zone. The intensive influx of riverine organic matter and limited ventilation are the reasons for the oxygen deficit. In winter the fast ice prevents gas exchange with the atmosphere, in summer the halocline insulates the bottom water masses from the surface waters.

5.1 Working program

To investigate the structure of the water column and to track dynamic processes in the coastal Arctic Ocean, the chlorinity and the distribution of silicon, phosphorus, and inorganic nitrogen compounds will be determined. Vertical profiles (5 m sampling interval) from the surface down to the seafloor were taken along a grid of 22 stations (Figure 2). Water samples were taken with a 2-liter plastic water sampler (PWS). From the PWS about 130 sub-samples were taken and stored frozen in high-density polyethylene bottles. Analysis will be carried out in the Otto Schmidt Laboratory for Polar and Marine Sciences (OSL) in St. Petersburg. Chlorinity will be determined by means of ion chromatography (Metrohm 761 Compact IC). The determination of nutrients is based on automated continuous flow-analysis (Skalar San plus).

6. Diversity of nitrifying bacteria in submarine permafrost

The main scientific objectives of this study are the quantification and understanding of bacterially influenced processes of the biogeochemical cycles in permafrost. This extreme habitat causes highly specific adaptations of bacterial life and shows a high diversity. Knowledge of bacteria from permafrost is important for the ecological understanding because of their extreme adaptations to low temperatures and varying salinities. The enrichment and cultivation of bacteria from low temperatures is also of interest for biotechnology, such as waste-water treatment.

The comparison of submarine and terrestrial permafrost habitats and their dynamics in the case of a possible climate change are of particular interest. Therefore samples will be taken from various environments (nearshore and mid-shelf area) and shall be analyzed using physiological and molecular microbiological techniques.

6.1 Working program

During the TRANDRIFT IX expedition the major task was the sterile sampling of submarine permafrost to determine the microbial nitrogen cycle. Sampling was focused on the diversity of nitrifying bacteria, which will be examined with several microbiological techniques (Figure 5). 11 sterile sediment samples were taken from aerobic habitats and prepared for transport at *in situ* temperatures. Various samples were taken from the water column at various depths and filtered (0,2 µm cellulose/acetate; Schleicher & Schüll, Germany). In addition, specialized polycarbonate filters (Nuclepore-edge, Whatman) were used for microscopy and FISH (Fluorescence *In Situ* Hybridisation).

In order to get an idea of the cell quantity, MPN (Most-Propable-Number) technique was used. Physiological and molecular-biological characterization of the cultures will be performed at the Department for Microbiology (University of Hamburg).

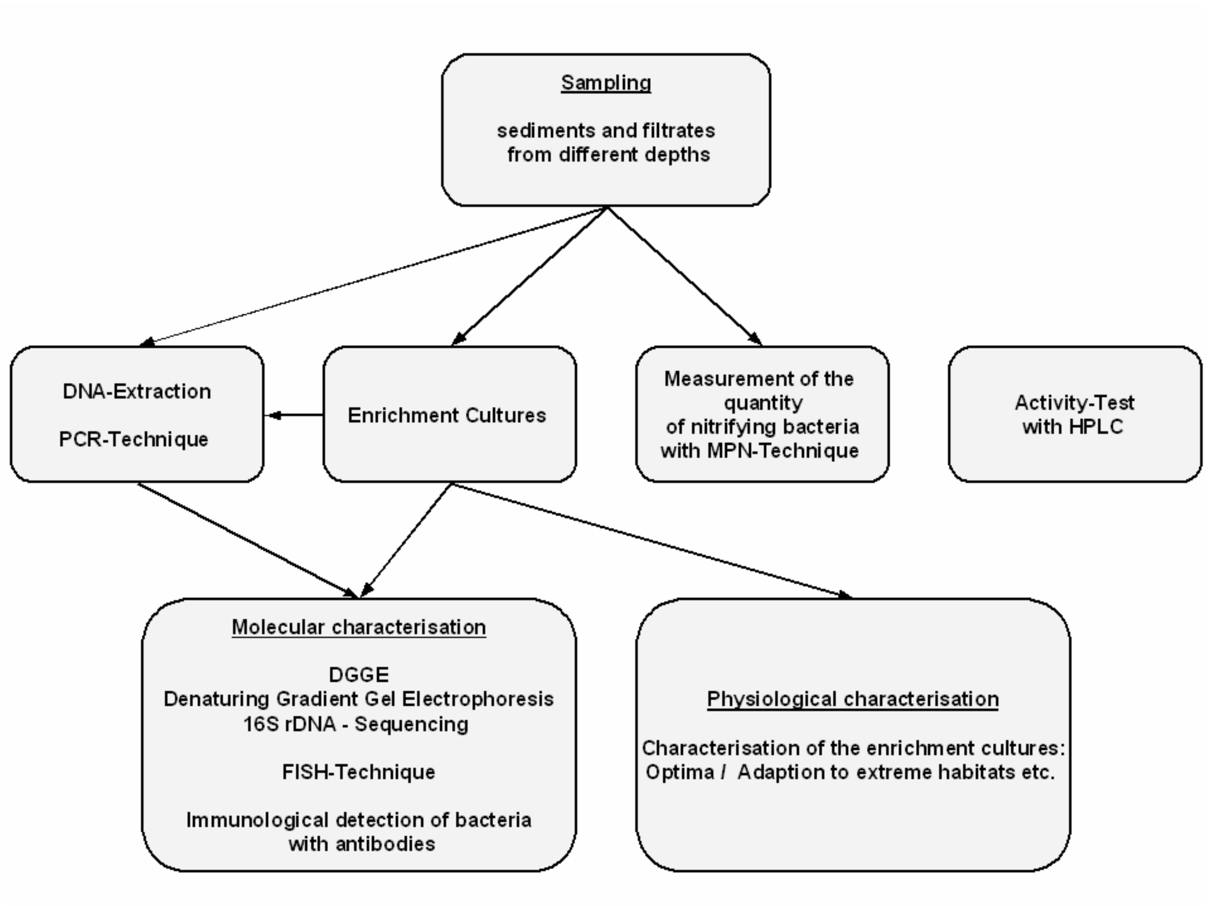


Figure 5: Flow-chart of planned sample treatment.

6.2 Preliminary Results

Due to the adapted transport conditions at *in situ* temperatures, several enrichment cultures and plates could be obtained (Table 1). Ammonia and nitrite oxidizing cultures obviously are psychrophilic (temperatures beneath 5°C). So there are hints for high diversity and adaption potentials for nitrifiers, revealed by various growth optima.

DNA extraction and amplification of 16S rDNA fragments from the hypervariable V3 region were performed successfully for all samples and several enrichment cultures. Molecular-biological techniques like TGGE (Temperature Gradient Gel Electrophoresis) will provide the means for a detailed phylogenetic analysis. With these approaches interesting and new bacteria could be detected at the beginning of the enrichment process.

Activity tests and further physiological examinations like electron microscopy and methods for enrichment etc. will be performed.

The amount of ammonia, nitrite and nitrate in the sediments will be quantified by HPLC (High Performance Liquid Chromatography) and IC (Ion Chromatography). Furthermore the detection of the nitrifiers will be performed by FISH (Fluorescence *in-situ* Hybridization) and immunological techniques based on specific binding of antibodies to key enzymes.

Table 1: Enrichment cultures from sediment (NIOX Nitrite oxidizing bacteria/ AMOX Ammonia oxidizing bacteria, + = culture grows)

	Station	**Sample N.**	**Cultures at [°C]**	**DNA Extraction**	**NIOX 70% Sea water**	**NIOX 100% Sea water**	**AMOX 70% Sea water**	**AMOX 100% Sea water**
IK-03	01	1S	4, 10, 17	+		+		
	01	2S	4, 10, 17	+		+		+
	04	3S	4, 10, 17	+	+			
	06	4S	4, 10, 17	+		+		
	11	5S	4, 10, 17	+	+		+	
	09	6S	4, 10, 17	+		+		+
	02	7S	4, 10, 17	+	+		+	
	04	8S	4, 10, 17	+		+	+	+
	18	9S	4, 10, 17	+		+		+
	01	10S	4, 10, 17	+		+	+	+
	09	11S	4, 10, 17	+		+		+

Shipboard scientific party

Name	Institute	Profession	Nationality
Alawi, Mashal	University of Hamburg	Biologist	German
Churun, Vladimir	AARI	Oceanographer	Russian
Gukov, Aleksandr	LDR	Geographer	Russian
Hölemann, Jens	AWI	Marine Geologist	German
Novikhin, Andrey	AARI	Hydrochemist	Russian
Wegner, Carolyn	GEOMAR	Geologist	German

Participating institutions

AARI	State Research Center – Arctic and Antarctic Research Institute, 199397 St. Petersburg, Ul. Beringa, 38, Russia
AWI	Alfred Wegener Institute for Polar and Marine Research, Columbusstr., 27568 Bremerhaven, Germany
GEOMAR	GEOMAR Research Center for Marine Geosciences, Wischhofstr. 1-3, 24148 Kiel, Germany
LDR	Lena Delta Reserve, 678400 Tiksi, Ul. Akademika Federova, 28, Russia
University of Hamburg	University of Hamburg, Faculty of Biology, Biocenter Klein Flottbek Ohnhorststr. 18, 22609 Hamburg, Germany

Appendix: Station list of the TRANSDRIFT IX (IK03) expedition

Station	Date	Time (GMT)	Latitude [°N]	Longitude [°E]	Water depth [m]	activity
IK03-01	**08/29/2003**	**12:00**	**74° 33.03'**	**130° 10.19'**	**33**	**Begin of station**
IK03-01-A	08/29/2003	12:30-12:40	74° 33.03'	130° 10.19'	33	CTD TM
IK03-01-A	08/29/2003	12:45-13:35	74° 33.03'	130° 10.19'	Surface, 5, 10, 15, 20, 25, 30	WS HCh MB
IK03-01-B	08/29/2003	13:45-13:55	74° 33.03'	130° 10.19'	33	CTD TM
IK03-01-P1	08/29/2003	14:00-14:30	74° 33.03'	130° 10.19'	5-0, 10-0, 20-0	PN
IK03-01-VV1	08/29/2003	14:30-15:00	74° 33.03'	130° 10.19'	33	VV
IK03-01-P2	08/29/2003	23:30-00:00	74° 33.03'	130° 10.19'	5-0, 10-0, 20-0	PN
IK03-01-C	08/30/2003	00:00-00:15	74° 33.03'	130° 10.19'	33	CTD TM
IK03-01-C	08/30/2003	00:15-00:55	74° 33.03'	130° 10.19'	Surface, 5, 10, 15, 20, 25, 30	WS HCh MB
IK03-01-D	08/30/2003	01:00-01:15	74° 33.03'	130° 10.19'	33	CTD TM
IK03-01-VV2	08/30/2003	01:15-01:45	74° 33.03'	130° 10.19'	33	VV
IK03-01-E	08/30/2003	03:15-03:25	74° 33.03'	130° 10.19'	33	CTD TM
IK03-01-VV3	08/30/2003	03:30-04:00	74° 33.03'	130° 10.19'	33	VV
YANA 03	**08/30/2003**	**05:33-05:46**	**74° 31.6'**	**130° 19.1'**	**28.5**	**Deployment of seafloor observatory**
IK03-02	**08/30/2003**	**12:00**	**74° 07.03'**	**126° 25.4'**	**25**	**Begin of station**
IK03-02-A	08/30/2003	12:30-12:45	74° 07.03'	126° 25.4'	25	CTD TM
IK03-02-P1	08/30/2003	23:15-23:45	74° 07.03'	126° 25.4'	5-0, 10-0, 20-0	PN
IK03-02-B	08/30/2003	23:45-00:20	74° 07.03'	126° 25.4'	Surface, 5, 10, 15, 20	WS HCh MB
IK03-02-B	08/31/2003	00:30-00:45	74° 07.03'	126° 25.4'	25	CTD TM
IK03-02-VV1	08/31/2003	00:45-01:10	74° 07.03'	126° 25.4'	25	VV
IK03-02-C	08/31/2003	01:15-01:30	74° 07.03'	126° 25.4'	25	CTD TM
IK03-02-D	08/31/2003	03:30-03:45	74° 07.03'	126° 25.4'	25	CTD TM
IK03-02-D	08/31/2003	03:45-04:15	74° 07.03'	126° 25.4'	Surface, 5, 10, 15, 20	WS HCh MB
IK03-02-E	08/31/2003	04:15-04:30	74° 07.03'	126° 25.4'	25	CTD TM

Appendix: Continuation

Station	Date	Time (GMT)	Latitude [°N]	Longitude [°E]	Water depth [m]	activity
IK03-02-F	08/31/2003	05:15-05:30	74° 07.03'	126° 25.4'	25	CTD TM
IK03-02-G	08/31/2003	06:15-06:30	74° 07.03'	126° 25.4'	25	CTD TM
LENA 03	**08/31/2003**	**07:30-07:34**	**74° 07.2'**	**126° 25.3'**	**25.4**	**Deployment of seafloor observatory**
IK03-03	**08/31/2003**	**08:00**	**74° 06.91'**	**126° 27.04'**	**25**	**Begin of station**
IK03-03-A	08/31/2003	08:00-08:15	74° 06.91'	126° 27.04'	25	CTD TM
IK03-03-A	08/31/2003	08:15-08:50	74° 06.91'	126° 27.04'	Surface, 5, 10, 15, 20, 22	WS HCh MB
IK03-03-B	08/31/2003	09:00-09:10	74° 06.91'	126° 27.04'	25	CTD TM
IK03-03-C	08/31/2003	10:00-10:10	74° 06.91'	126° 27.04'	25	CTD TM
IK03-03-VV1	08/31/2003	10:10-10:40	74° 06.91'	126° 27.04'	25	VV
IK03-03-D	08/31/2003	11:00-11:10	74° 06.91'	126° 27.04'	25	CTD TM
IK03-03-E	08/31/2003	12:00-12:10	74° 06.91'	126° 27.04'	25	CTD TM
IK03-03-F	08/31/2003	13:00-13:10	74° 06.91'	126° 27.04'	25	CTD TM
IK03-03-G	08/31/2003	14:00-14:09	74° 06.91'	126° 27.04'	25	CTD TM
IK03-03-H	08/31/2003	15:09-15:14	74° 06.91'	126° 27.04'	25	CTD TM
IK03-03-I	08/31/2003	16:00-16:06	74° 06.91'	126° 27.04'	25	CTD TM
IK03-03-J	08/31/2003	22:00-22:10	74° 06.91'	126° 27.04'	25	CTD TM
IK03-04	**08/31/2003**	**23:45**	**74° 05.55'**	**125° 59.53'**	**12.6**	**Begin of station**
IK03-04-A	08/31/2003	23:50-00:00	74° 05.55'	125° 59.53'	12.6	CTD TM
IK03-04-A	09/01/2003	00:00-00:20	74° 05.55'	125° 59.53'	Surface, 5, 8, 10	WS HCh MB
IK03-04-P1	09/01/2003	00:00-00:20	74° 05.55'	125° 59.53'	5-0,10-0	PN
IK03-04-VV1	09/01/2003	00:30-01:00	74° 06.05'	125° 56.85'	13	VV
IK03-04-B	09/01/2003	01:25-01:35	74° 06.72'	125° 53.7'	13	CTD TM
IK03-05	09/01/2003	03:55	74° 00.06'	127° 00.13'	25	Begin of station
IK03-05-A	09/01/2003	04:15-04:25	74° 00.06'	127° 00.13'	25	CTD TM
IK03-05-P1	09/01/2003	04:15-04:25	74° 00.06'	127° 00.13'	5-0, 10-0, 20-0	PN

Appendix: Continuation

Station	Date	Time (GMT)	Latitude [°N]	Longitude [°E]	Water depth [m]	activity
IK03-05-A	09/01/2003	04:30-04:50	74° 00.06'	127° 00.13'	Surface, 5, 10, 15, 20, 24	WS HCh MB
IK03-05-VV1	09/01/2003	04:50-05:05	74° 01.08'	127° 02.16'	26	VV
IK03-05-B	09/01/2003	05:05-05:15	74° 01.08'	127° 02.16'	26	CTD TM
IK03-06	**09/01/2003**	**06:35**	**74° 11.97'**	**127° 00.06'**	**33**	**Begin of station**
IK03-06-A	09/01/2003	06:40-06:50	74° 11.97'	127° 00.06'	34	CTD TM
IK03-06-A	09/01/2003	06:55-07:35	74° 11.97'	127° 00.06'	Surface, 5, 10, 15, 20, 25, 30	WS HCh MB
IK03-06-VV1	09/01/2003	07:40-08:00	74° 11.97'	127° 00.06'	34	VV
IK03-06-B	09/01/2003	08:00-08:10	74° 11.96'	127° 02.05'	34	CTD TM
IK03-07	**09/01/2003**	**09:10**	**74° 14.10'**	**127° 35.18'**	**33**	**Begin of station**
IK03-07-A	09/01/2003	09:15-09:25	74° 14.10'	127° 35.18'	33	CTD TM
IK03-07-P1	09/01/2003	09:15-09:25	74° 14.10'	127° 35.18'	5-0, 10-0, 20-0	PN
IK03-07-A	09/01/2003	09:25-09:50	74° 14.10'	127° 35.18'	Surface, 5, 10, 15, 20, 25, 30, 35	WS HCh MB
IK03-07-VV1	09/01/2003	09:50-10:10	74° 14.17'	127° 34.95'	33	VV
IK03-07-B	09/01/2003	10:10-10:20	74° 14.21'	127° 34.00'	33	CTD TM
IK03-08	**09/01/2003**	**11:20**	**74° 17.00'**	**128° 09.75'**	**29**	**Begin of station**
IK03-08-A	09/01/2003	11:25-11:35	74° 17.00'	128° 09.75'	29	CTD TM
IK03-08-P1	09/01/2003	11:25-11:40	74° 17.00'	128° 09.75'	5-0, 10-0, 20-0	PN
IK03-08-A	09/01/2003	11:45-12:15	74° 17.09'	128° 09.28'	Surface, 5, 10, 15, 20, 25	WS HCh MB
IK03-08-VV1	09/01/2003	12:15-12:30	74° 17.09'	128° 09.28'	29	VV
IK03-08-B	09/01/2003	12:30-12:40	74° 17.09'	128° 09.28'	29	CTD TM
IK03-09	**09/01/2003**	**14:05**	**74° 20.13'**	**128° 45.15'**	**28**	**Begin of station**
IK03-09-A	09/01/2003	14:10-14:20	74° 20.13'	128° 45.15'	28	CTD TM
IK03-09-P1	09/01/2003	14:10-14:20	74° 20.13'	128° 45.15'	5-0, 10-0, 20-0	PN
IK03-09-A	09/01/2003	14:20-14:40	74° 20.13'	128° 45.15'	Surface, 5, 10, 15, 20, 25, 28	WS HCh MB

Appendix: Continuation

Station	Date	Time (GMT)	Latitude [°N]	Longitude [°E]	Water depth [m]	activity
IK03-09-VV1	09/01/2003	14:40-15:10	74° 21.13'	128° 47.26'	28	VV
IK03-09-B	09/01/2003	15:15-15:30	74° 22.03'	128° 49.67'	28	CTD TM
IK03-10	**09/01/2003**	**16:40**	**74° 24.03'**	**129° 25.2'**	**21**	**Begin of station**
IK03-10-A	09/01/2003	16:45-16:55	74° 24.03'	129° 25.2'	21	CTD TM
IK03-10-P1	09/01/2003	16:45-16:55	74° 24.03'	129° 25.2'	5-0, 10-0	PN
IK03-10-A	09/01/2003	16:55-17:15	74° 24.03'	129° 25.2'	Surface, 5, 10, 15, 18	WS HCh MB
IK03-10-B	09/01/2003	17:15-17:25	74° 24.35'	129° 27.22'	21	CTD TM
IK03-11	**09/01/2003**	**18:45**	**74° 28'**	**130°**	**26**	**Begin of station**
IK03-11-A	09/01/2003	18:50-19:00	74° 28'	130°	26	CTD TM
IK03-11-P1	09/01/2003	18:55-19:05	74° 28'	130°	5-0, 10-0, 20-0	PN
IK03-11-A	09/01/2003	19:10-19:30	74° 28'	130°	Surface, 5, 10, 15, 20, 25	WS HCh MB
IK03-11-VV1	09/01/2003	19:30-19:40	74° 28'	130°	26	VV
IK03-11-B	09/01/2003	19:40-20:00	74° 28'	130°	26	CTD TM
IK03-12	**09/01/2003**	**20:45**	**74° 29.9'**	**130° 25.3'**	**26**	**Begin of station**
IK03-12-A	09/01/2003	20:45-20:55	74° 29.9'	130° 25.3'	26	CTD TM
IK03-12-A	09/01/2003	21:00-21:20	74° 29.9'	130° 25.3'	Surface, 5, 10, 15, 20, 25	WS HCh MB
IK03-12-B	09/01/2003	21:20-21:30	74° 29.9'	130° 25.3'	26	CTD TM
IK03-13	**09/01/2003**	**22:30**	**74° 3'**	**131°**	**30**	**Begin of station**
IK03-13-A	09/01/2003	22:30-22:40	74° 3'	131°	30	CTD TM
IK03-13-P1	09/01/2003	23:00-23:10	74° 3'	131°	5-0, 10-0, 20-0	PN
IK03-13-A	09/01/2003	23:00-23:10	74° 3'	131°	Surface, 5, 10, 15, 20, 28	WS HCh MB
IK03-13-VV1	09/01/2003	23:15-23:40	74° 3'	131°	30	VV
IK03-13-B	09/01/2003	23:40-23:50	74° 3'	131°	30	CTD TM
IK03-14	**09/02/2003**	**01:05**	**74° 21.5'**	**130° 36.5'**	**23**	**Begin of station**
IK03-14-A	09/02/2003	01:10-01:20	74° 21.5'	130° 36.5'	23	CTD TM
IK03-14-P1	09/02/2003	01:15-01:25	74° 21.5'	130° 36.5'	5-0, 10-0, 20-0	PN
IK03-14-A	09/02/2003	01:30-01:50	74° 21.5'	130° 36.5'	Surface, 5, 10, 15, 20	WS HCh MB

Appendix: Continuation

Station	Date	Time (GMT)	Latitude [°N]	Longitude [°E]	Water depth [m]	activity
IK03-14-B	09/02/2003	01:50-02:00	74° 21.5'	130° 36.5'	23	CTD TM
IK03-14-VV1	09/02/2003	02:00-02:20	74° 21.5'	130° 36.5'	23	VV
IK03-15	**09/02/2003**	**03:25**	**74° 14'**	**130° 15'**	**21**	**Begin of station**
IK03-15	09/02/2003	03:30-03:40	74° 14'	130° 15'	21	CTD TM
IK03-15	09/02/2003	03:40-03:45	74° 14'	130° 15'	Surface, 5, 10, 15, 20	WS HCh MB
IK03-16	**09/02/2003**	**05:30**	**74°**	**130° 30'**	**26**	**Begin of station**
IK03-16	09/02/2003	05:30-05:40	74°	130° 30'	26	CTD TM
IK03-16	09/02/2003	05:45-06:05	74°	130° 30'	Surface, 5, 10, 15, 20, 25	WS HCh MB
IK03-16-VV1	09/02/2003	06:05-06:25	74°	130° 30'	26	VV
IK03-17	**09/02/2003**	**07:45**	**74° 44.99'**	**130° 29.95'**	**25**	**Begin of station**
IK03-17	09/02/2003	07:50-08:00	74° 44.99'	130° 29.95'	25	CTD TM
IK03-17	09/02/2003	08:00-08:20	74° 44.99'	130° 29.95'	Surface, 5, 10, 15, 20, 22	WS HCh MB
IK03-17-VV1	09/02/2003	08:25-08:50	74° 44.99'	130° 29.95'	25	VV
IK03-18	**09/02/2003**	**10:50**	**73° 39.58'**	**129° 52.78'**	**15**	**Begin of station**
IK03-18	09/02/2003	10:55-11:00	73° 39.58'	129° 52.78'	15	CTD TM
IK03-18	09/02/2003	11:00-11:20	73° 39.58'	129° 52.78'	Surface, 5, 10, 12	WS HCh MB
IK03-18-VV1	09/02/2003	11:20-11:40	73° 39.58'	129° 52.78'	15	VV
IK03-19	**09/02/2003**	**13:00**	**73° 34.53'**	**129° 24.83'**	**21**	**Begin of station**
IK03-19	09/02/2003	13:05-13:15	73° 34.53'	129° 24.83'	21	CTD TM
IK03-19	09/02/2003	13:15-13:30	73° 34.53'	129° 24.83'	Surface, 5, 10, 15, 18	WS HCh MB
IK03-19-VV1	09/02/2003	13:30-13:40	73° 34.53'	129° 24.83'	21	VV
IK03-20	**09/02/2003**	**14:55**	**73° 29.6'**	**128° 54.9'**	**12.5**	**Begin of station**
IK03-20	09/02/2003	14:55-15:05	73° 29.6'	128° 54.9'	12.5	WS HCh MB
IK03-20-P1	09/02/2003	15:00-15:15	73° 29.6'	128° 54.9'	5-0, 10-0	PN
IK03-20-VV1	09/02/2003	15:15-15:35	73° 29.6'	128° 54.9'	12.5	VV

Appendix: Continuation

Station	Date	Time (GMT)	Latitude [°N]	Longitude [°E]	Water depth [m]	activity
IK03-21	**09/02/2003**	**16:45**	**73° 30.05'**	**129° 25.4'**	**15.5**	**Begin of station**
IK03-21	09/02/2003	16:50-17:00	73° 30.05'	129° 25.4'	15.5	CTD TM
IK03-21-P1	09/02/2003	16:50-17:00	73° 30.05'	129° 25.4'	5-0, 10-0	PN
IK03-21	09/02/2003	17:00-17:15	73° 30.05'	129° 25.4'	Surface, 5, 10, 14	WS HCh MB
IK03-21-VV1	09/02/2003	17:15-17:45	73° 30.05'	129° 25.4'	15.5	VV
IK03-22	**09/02/2003**	**19:55**	**73° 30'**	**130° 30.2'**	**26**	**Begin of station**
IK03-22	09/02/2003	19:55-20:05	73° 30'	130° 30.2'	26	CTD TM
IK03-22-P1	09/02/2003	19:55-20:05	73° 30'	130° 30.2'	5-0, 10-0, 20-0	PN
IK03-22	09/02/2003	20:10-20:35	73° 30'	130° 30.2'	Surface, 5, 10, 15, 20, 22	WS HCh MB
IK03-22-VV1	09/02/2003	20:35-20:55	73° 30'	130° 30.2'	26	VV

Abbreviations

CTD **C**onductivity **T**emperature **D**epth Meter
HCh **H**ydro**ch**emical sampling (Silicate, Phosphate, Nitrate, Nitrite, Ammonia, Chlorinity)
MB **M**icro**b**iological measurements
PN **P**hytoplankton **n**et
TM **T**urbidity **M**eter
WS **W**ater **s**amples for determination of suspended particulate matter concentration
VV **V**an **V**een Greifer/Snapper

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