Preliminary Report
of
the R/V Hakuho Maru Cruise KH-97-2

Subarctic North Pacific
and
Bering Sea Ecosystem Expedition

(July 9 - September 8, 1997)

Ocean Research Institute
University of Tokyo

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by
the Scientific Members of the Expedition

edited by
Kouichi KAWAGUCHI

1998

Contents

Secondary and higher production processes

Biogeochemical processes

Air-sea interaction

Introduction

The KH-97-2 cruise of R/V Hakuho Maru was conducted under the title "Studies on the biological and biogeochemical processes of the ecosystems in the subarctic Pacific Ocean and Bering Sea" from July 9 to September 8, 1997. A total of 42 scientists and supporting staff from 18 organizations in Japan, Korea and Brazil participated in this cruise.

The subarctic Pacific Ocean and Bering Sea are known not only as one of the most productive waters in the world, supporting a great amount of fisheries resources, but also as key waters controlling the air-sea flux of green house-effect gasses such as CO_2. During this cruise we tried to characterise these productive waters, as ecosystems having the above-mentioned structures and functions, from biological, chemical, physical and geological perspectives.

Studies on the biological processes included the primary and lower biological production processes in the epipelagic zone, the interactions among epi-, mesopelagic and benthic animals and their biological production processes.

The chemical process study focused on the characterization and flux determination of the sinking, suspended and dissolved organic and inorganic materials which are related to biological processes.

Furthermore, studies on the air-sea flux of green house-effect gasses and the characterization of marine aerosols were also included in the chemical studies. The physical oceanographical work is mostly related to the measurement of environmental factors in the ecosystems such as light and temperature fields and profiles.

Sampling by various types of plankton nets and water samplers was undertaken to collect marine organisms ranging from bacteria to micronekton. Chemical analysis of the sea water samples, culture experiments on bacteria and plankton, measurement of physical oceanographic factors by CTD and vertical flux of sinking particles by sediment traps, core sampling of deep-sea sediments by a multiple-core sampler, and continuous aerosol sampling were also carried out by scientists from various fields.

Most of the community structure and biological process-oriented

studies were conducted at 4 stations located at the centers of the western subarctic gyre, Alaskan gyre, Central subarctic waters (along 180° long.) and Bering Sea.

The main subjects of the comprehensive studies at the 4 stations were as follows.

(1) Comparative studies on the community structures and biological production processes in the western and eastern subarctic Pacific Ocean and Bering Sea
(2) Structures and functions of communities of primary and higher producers (from bacteria to micronekton)
(3) Structure of the marine food web in the epi- and mesopelagic zones and related biogeochemical processes
(4) Interaction between epipelagic and mesopelagic ecosystems
(5) Effect of air-sea interactions on the flux of green house-effect gasses
(6) Vertical transport of sinking, suspended and dissolved organic and inorganic materials
(7) Characterization of aerosol and radioactive substances in the air
(8) Chemical and paleoenvironmental studies based on deep-sea marine sediment cores

Studies on the ecosystems as biological production fields were made in relation to the international cooperative projects Japanese GLOBEC (Global Ocean Ecosystem Change), GLOBEC under the PICES (North Pacific Marine Science Organization) and JGOFS (Joint Global Ocean Flux Study) programs.

On behalf of all the scientists and staff aboard this cruise, I would like to express my special gratitude to the captain, Yutaka Tanaka, the officers and the crew of R/V Hakuho Maru for their skillful assistance in the severe conditions of the subarctic.

Ms. Kimie Ishimaru of the Plankton Division, ORI greatly helped us in the editing of this report.

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Chief Scientist (1st Leg)

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- FF,HU: Faculty of Fisheries, Hokkaido University
- GSEES,HU: Graduate School of Environmental Earth Science, Hokkaido University
- MAG,HU: Marine and Atmospheric Geochemistry, Hokkaido University
- ILTS,HU: Institute of Low Temperature Science, Hokkaido University
- CSSE,MIT: Computer Science and Systems Engineering, Muroran Institute of Technology

- SA,TU: School of Agriculture, Tohoku University
- ICR,KU: Institute for Chemical Research, Kyoto University
- DLES,SU: Department of Life and Earth Sciences, Shizuoka University
- IHAS,NU: Institute for Hydrospheric-Atmospheric Sciences, Nagoya University
- FB,MU: Faculty of Bioresources, Mie University
- SES,USP: School of Environmental Science, University of Shiga Prefecture
- DMST,HTU: Department of Marine Science and Technology, Hokkaido Tokai University
- FS,SUT: Faculty of Science, Science University of Tokyo
- IPCR: Institute of Physical and Chemical Research
- NK: Nippon Kaiyo Co., Ltd.

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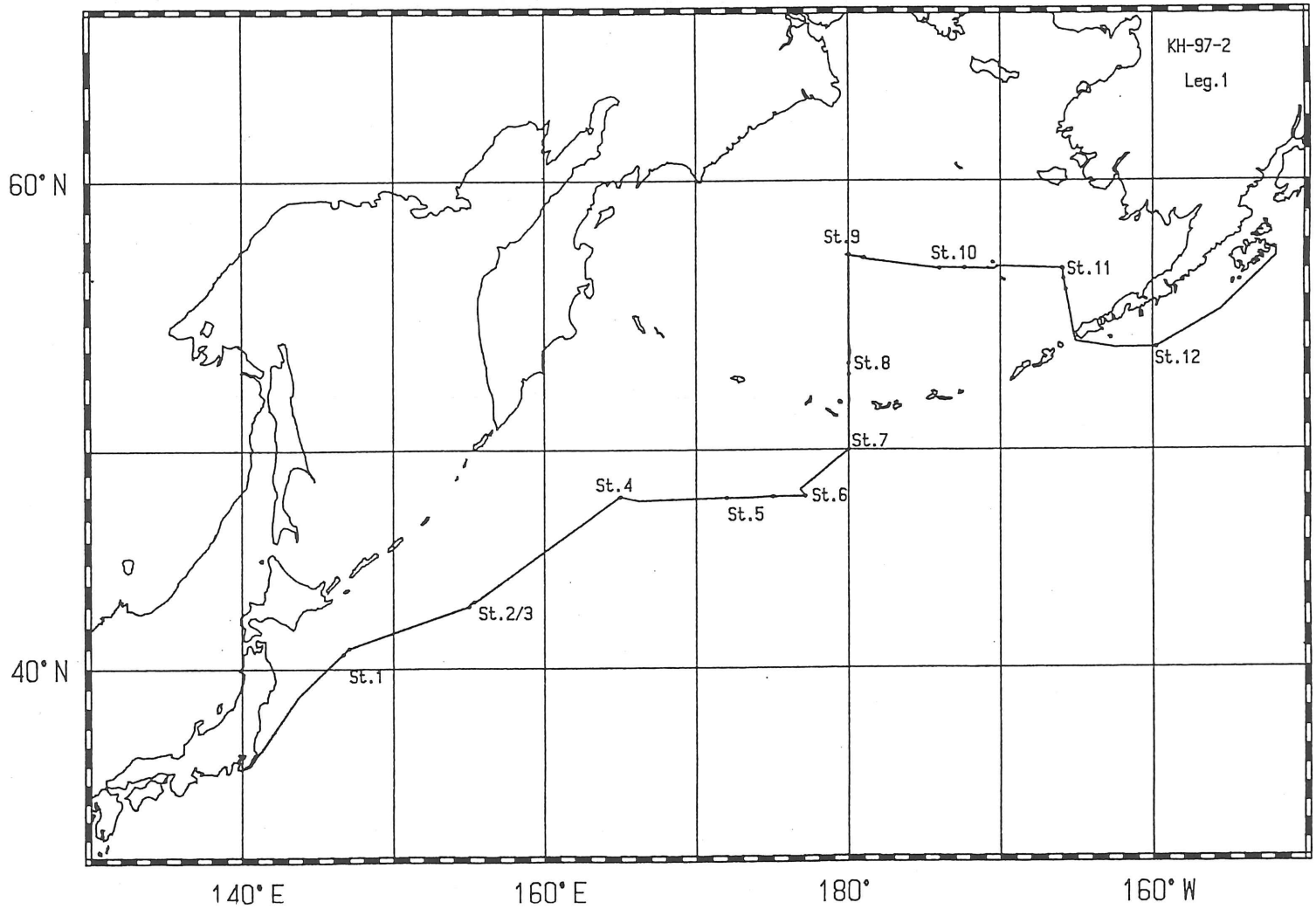
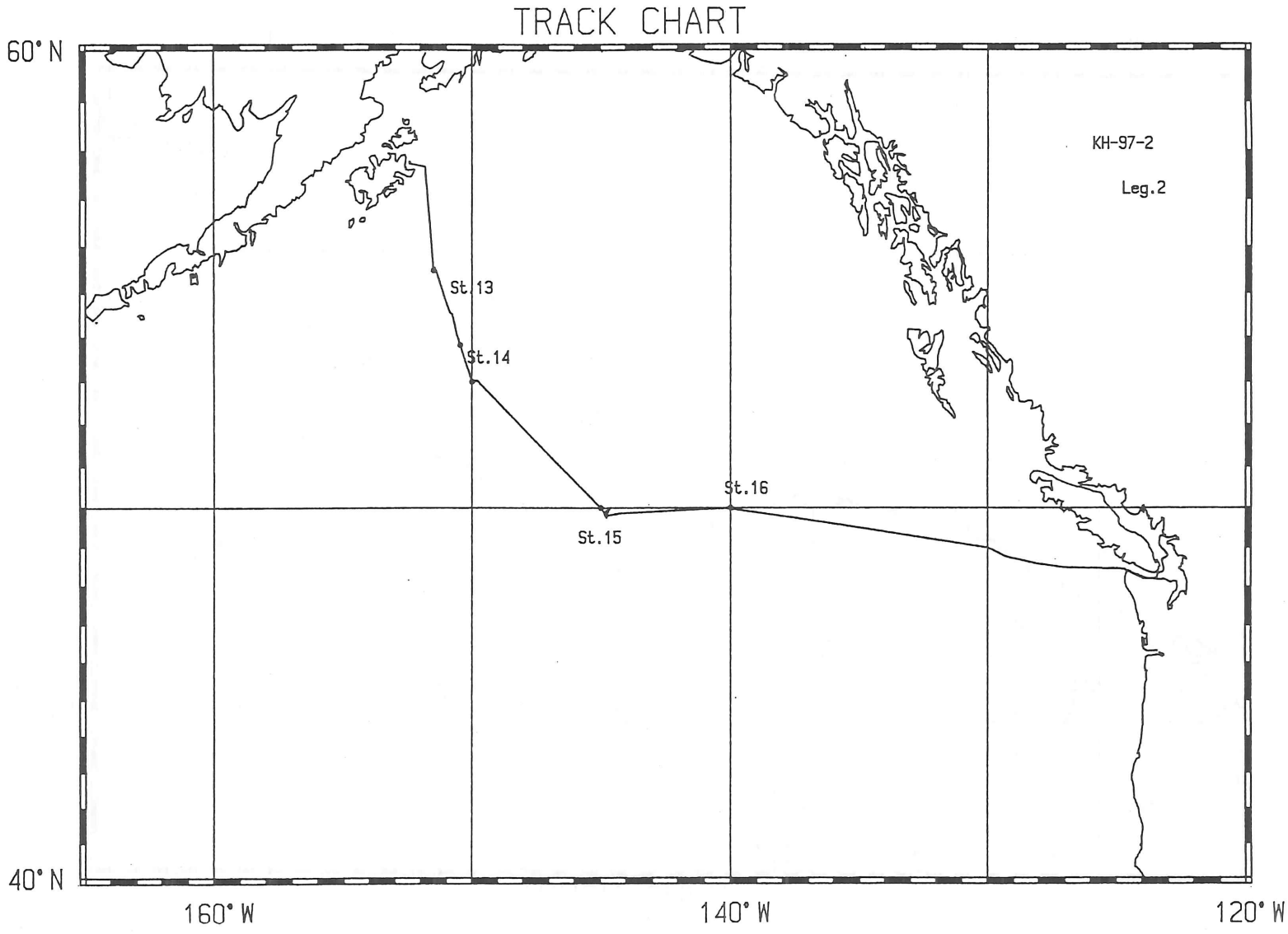

KH-97-2
Leg.1
60° N
40° N
St.1
St.2/3
St.4
St.5
St.6
St.7
St.8
St.9
St.10
St.11
St.12
140° E
160° E
180°
160° W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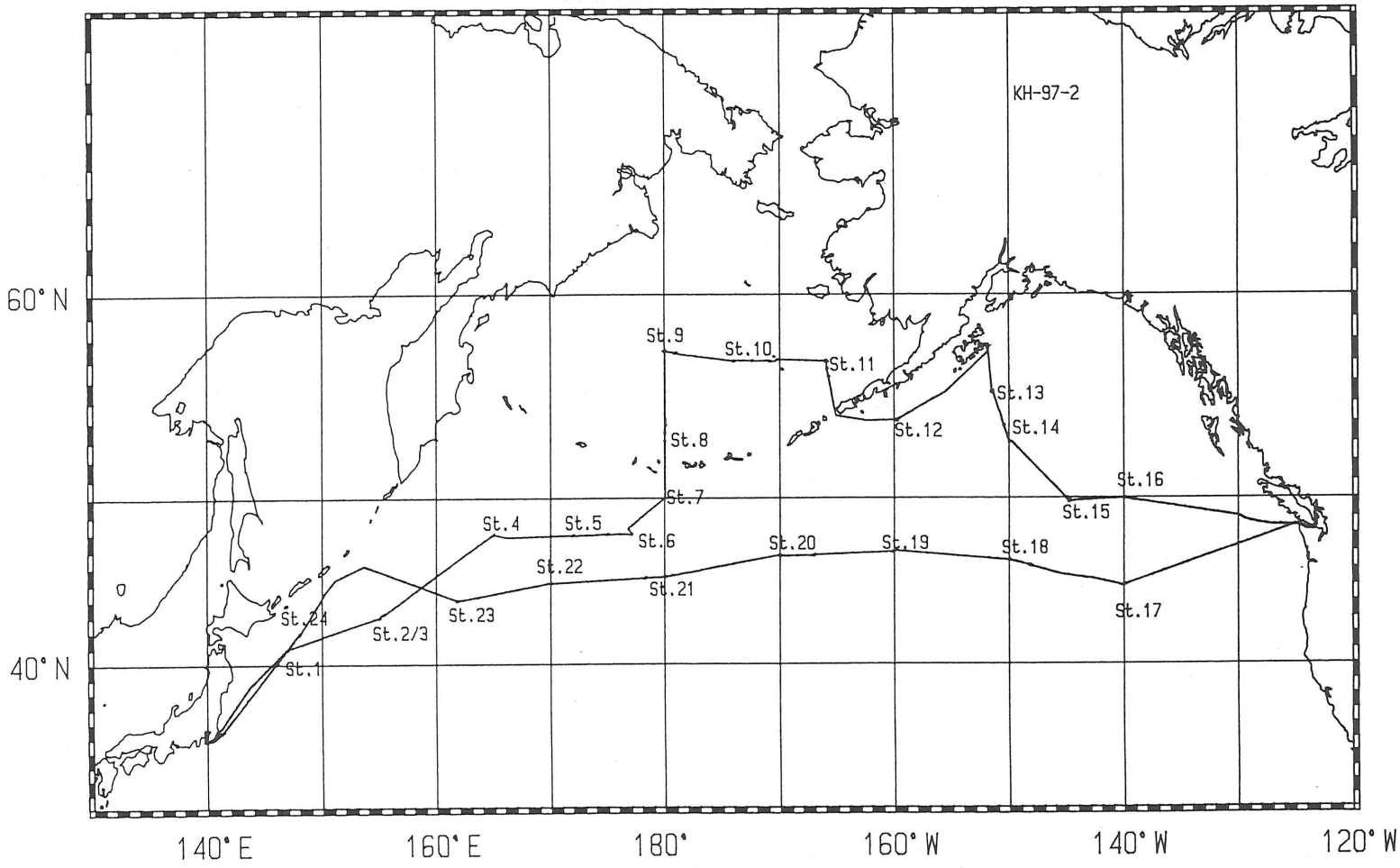
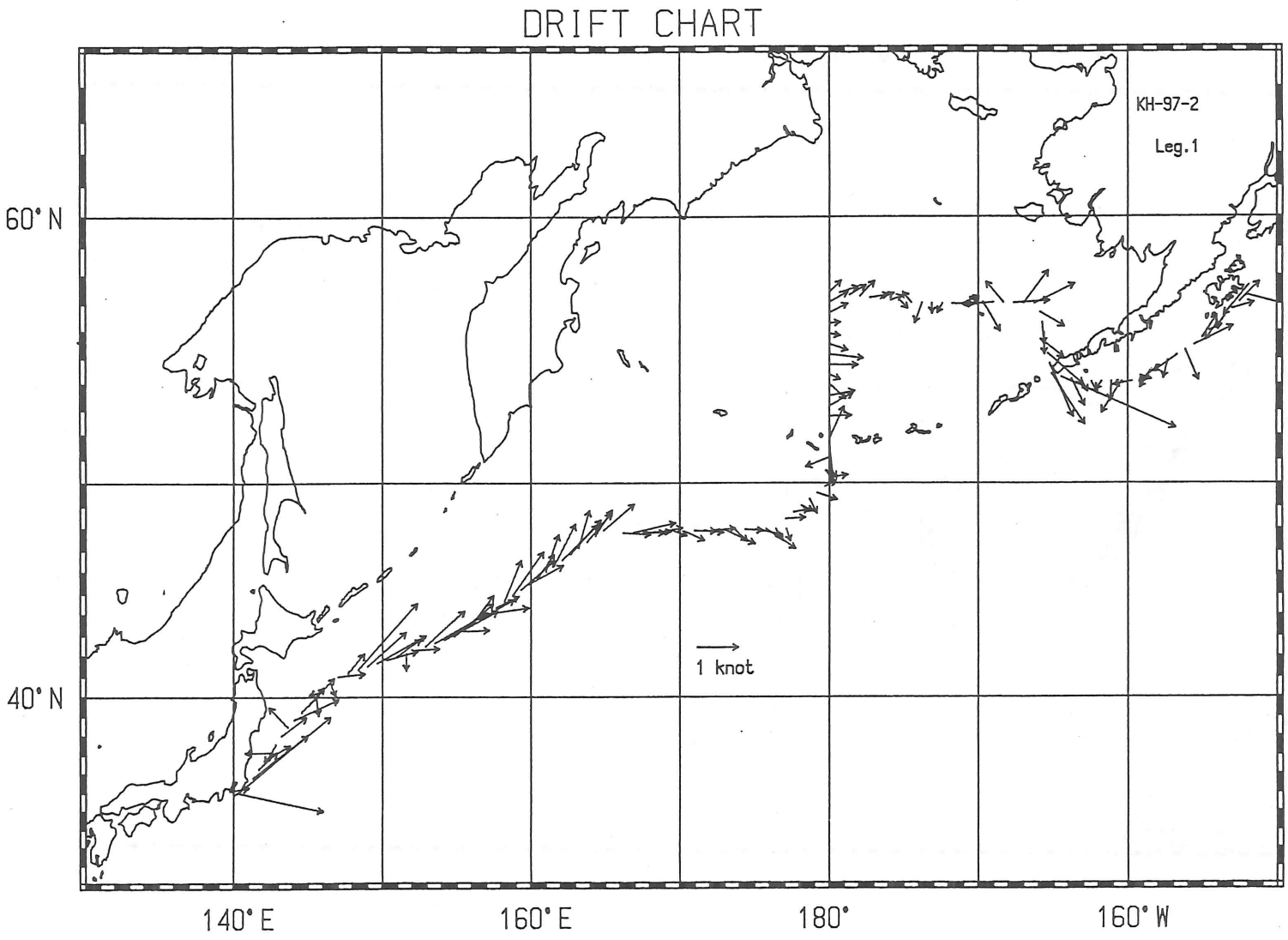
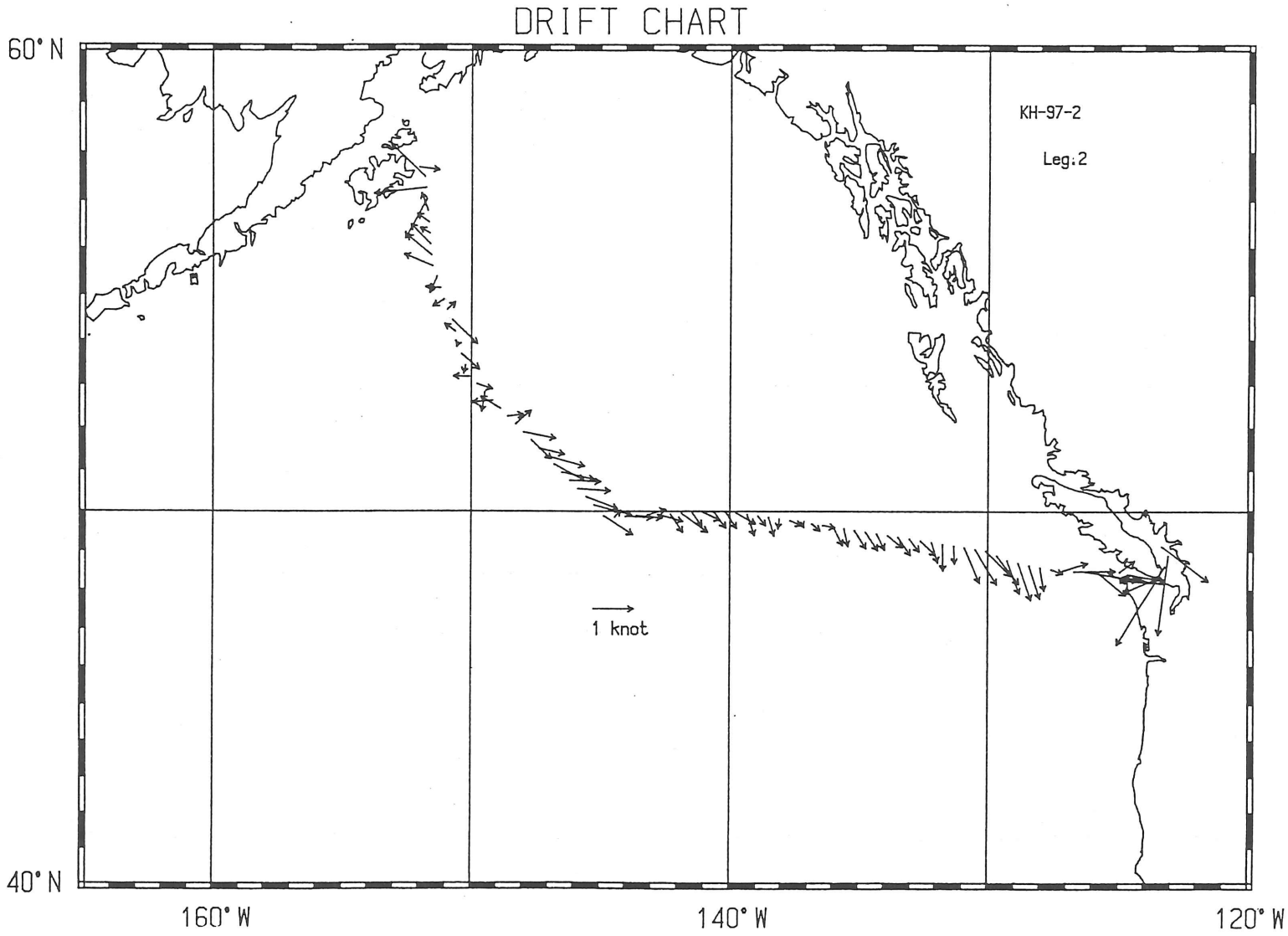
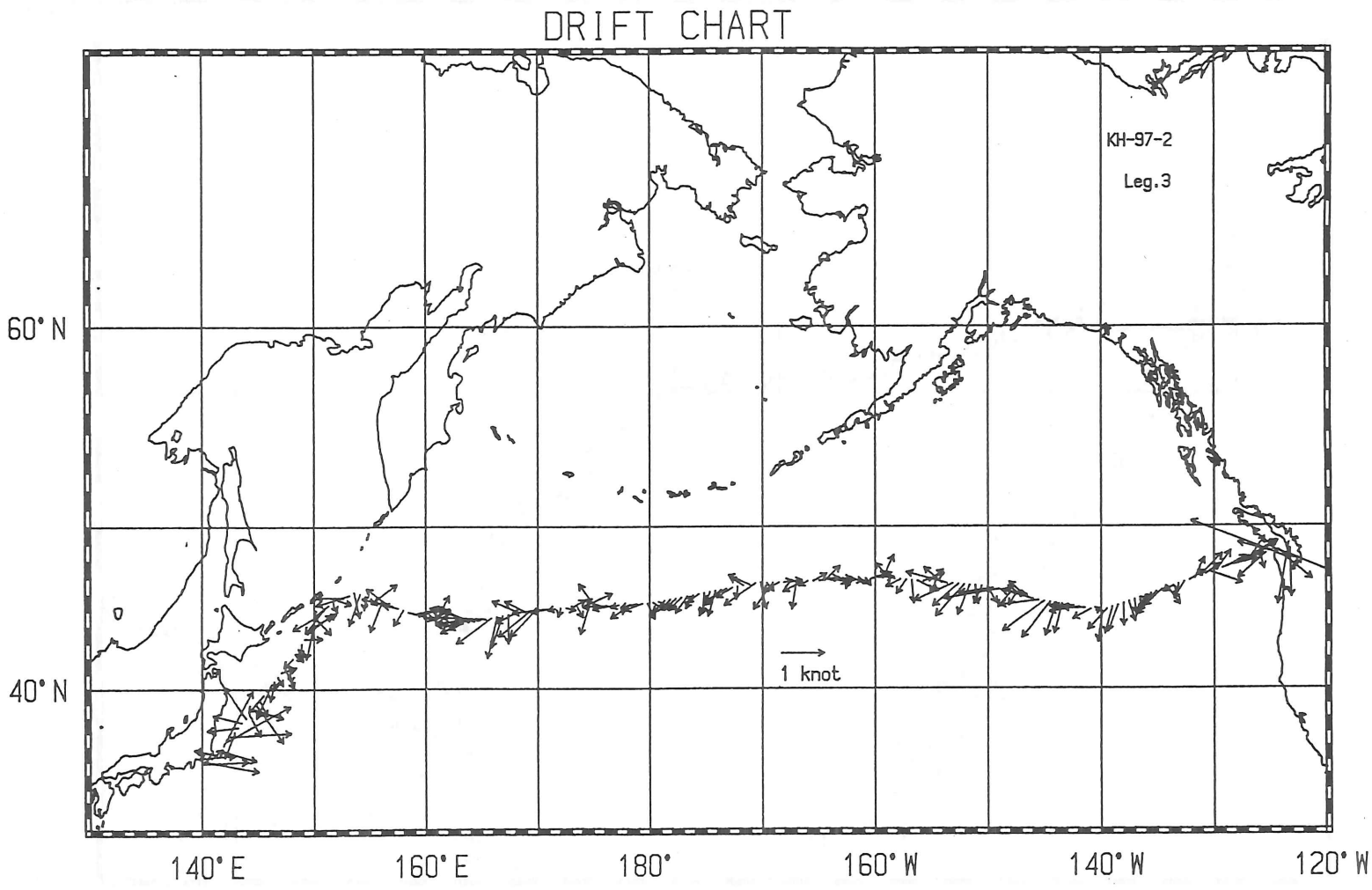
60° N
40° N
160° W
140° W
120° W
KH-97-2
Leg.2
St.13
St.14
St.15
St.16

TRACK CHART


KH-97-2
60° N
40° N
140° E
160° E
180°
160° W
140° W
120° W
St.1
St.2/3
St.4
St.5
St.6
St.7
St.8
St.9
St.10
St.11
St.12
St.13
St.14
St.15
St.16
St.17
St.18
St.19
St.20
St.21
St.22
St.23
St.24


DRIFT CHART
KH-97-2
Leg.1
60° N
40° N
1 knot
140° E
160° E
180°
160° W


DRIFT CHART
60° N
40° N
160° W
140° W
120° W
KH-97-2
Leg:2
1 knot


DRIFT CHART
KH-97-2
Leg.3
60° N
40° N
1 knot
140° E
160° E
180°
160° W
140° W
120° W

Cruise log

Leg.1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
July. 09. 97'														Tokyo Departur										
July. 11. 97'				St.1 CTD-R,Norpac,IKMT 41.00N,147 00E																	Time 21:00+1			
July. 12. 97'							St.2-3 CTD-R,Nor,Surf.tow,Multi********** 43 01N,15501E							CTD-F******** IR		CTD-R1********** Nor.			19:20 Sunset		IK-2 IKMT********** ORI			
July. 13. 97'	13day01:00+1																							
July. 14. 97'				04:14 Sunrise			St.4 Multi********** 48 00N,165 00E			IR Trap Buoy Release		MTD*******		CTD-R ***** Nor.H.Tow		*****	*****	Multi	*****	*****	*****	MTD	*****	****
July. 15. 97'	CTD-A1******	VMPS		CTD-A2***** 04:15 Sunrise	VMPS		CTD-B1***** IR	VMPS		CTD-A3*****	VMPS		CTD-B2***** IR	VMPS		CTD-A4*****	IR	VMPS	CTD-B3***** 19:57 Sunset	VMPS		CTD-A5*****	VMPS	
July. 16. 97'	CTD-A6*****	VMPS		CTD-A7***** 04:16 Sumrise	VMPS		CTD-B4***** IR	VMPS		CTD-A8*****	VMPS		CTD-B5***** IR	VMPS		CTD-A9***** IR		VMPS	CTD-B6 19:54 Sunset	VMPS		CTD-A10*****	VMPS	
July. 17. 97'	CTD-A10,MTD*****			CTD-C1,Nor.H.tow******* 04:14 Sunrise				Trap Buoy pickup, and Release	RMT Net**********					CTD-C2**********				Multi	***** 19:53 Sunset	*****	*****	RMT Net	IKMT**** ORI	
July. 18. 97'	IKMT**********			CTD-C3,H.tow********** 04:15 Sunrise			RMT Test*****	ORI****	*****	IKMT**	*****		Shift	*******	*****	*****		RMT Test	RMT Net 19:50 Sunset		*****	*****	****
July. 19. 97'	RMT********** 04:16 Sunrise																					VMPS	RMT Net***	
July. 20. 97'	**********		Multi********** 04:15 Sunrise				Trap Buoy pickup															IKMT******* ORI		
July. 21. 97'				03:46 Sunrise				St.5 CTD-R Nor.847 59N,175 00E) 21day 08:00+1								St.6 IR Trap Buy Relese 47.60N,177 06E			CTD-R Nor.H.Tow	*MTD********* 20:03 Sunset			***CTD-A1	Nor.
July. 22. 97'	Multi**********			04:33 Sunrise	RMT Net**********							MTD*******		CTD-C1********** H.Tow,Nor.					20:03 Sunset			RMT**********		
July. 23. 97'	**********		****CTD-A2 04:35 Sunrise		Multi**********		IR,CTD-B1,RMT Net*******		IR	CTD-B2, ORI********				IR,CTD-B		Trap Buy picup********** CTD- Norpac,H.Tow			RMT********** 20:02 Sunset				IKMT	
July. 24. 97'	ORI******			04:31 Sunrise								St.7 CTD-R,Nor,H.Tow 50 00.N,179 59E									20:04 Sunset				
July. 24. 97'	IKMT,ORI***			St.8 CTD-R Nor.Multi***** 53 30N,179 59E			IR,CTD-F														20:28 Sunset				
July. 25. 97'	St.9 MTD*** 57 30N,179 59E		IKMT,ORI	CTD-R*** Nor. 04:41 Sunrise	*****	*****	IR Trap Buoy Release, MTD	*****	*****	RMT	*****	*****	*****	*****	*****	*****	*****	CTD-C Nor.H.Tow	***** Time21:00+1	*****	RMT	***** 21:30 Sunset	CTDA1	
July. 26. 97'	RMT**********			CTD-C2**** H.Tow,Nor.04:44 Sunrise	*****	*****	VMPS	*****	IR,CTD-F***	VMPS	IR,CTD-F***		VMPS	CTD-A2	IR	VMPS	CTD-F		VMPS	CTD-A3		VMPS		
July. 27. 97'	CTD-A4****		VMPS	CTD-A5**** 04:42 Sunrise		VMPS	CTD-A6**	RMT**********						ORI***		Trap Buoy Pickup********** Multi Nor.				21:27 Sunset				
July. 28. 97'	Time02:00+1		IK-10****** ORI													St.10 IR,Nor.H.Tow,CTD-F,CTD-R 57 00N,174 00W					IK-11	*****		
July. 29. 97'					Time05:00+1												St.11 IR,CTD-F,CTD-R,Multi,IKMT********** 57 00N,166 00W		Nor,H.Tow	21:54 Sunset				
July. 30. 97'						06:08 Sunrise											St.12 Multi,CTD*** 54 07N,159 45W		*****	*****	*** 22:42 Sunset			

Leg.2	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Aug. 05. 97'														Kodiak Departure										
Aug. 06. 97'	St..13 CTD-R,Nor.IKMT,ORI 55 30N,151 30W			H.Tow		06:36 Sunrise											St.14 IR,CTD-F******** 53 50N,150 28W			CTD-R,Nor.********** 21:45 Sunset				IKMT ORI
Aug. 07. 97'	****** Multi.**********					06:25 Sunrise													21:15	1Sunrise		St.15 Multi.******** 50 00N,145 00W		
Aug. 08. 97'	MTD**: *****		IKMT****** ORI		CTD-R Nor.	**********			IR,Trap Buy,MTD***	*****	ORI********			CTD-C1**********					VMPS	CTD-A1**********			VMPS	CTD-A2
Aug. 09. 97'	VMPS CTD-A3 *****			VMPS CTD-A4*****		06:19 Sunrise	VMPS,IR, CTD-B1		Relese	VMPS CTD-A5*****		VMPS,IR, CTD-B2**********			Nor.H.Tow	CTD-A5,IR********			Nor.	CTD-B3*****	21:12 Sunset 21:13 Sunset	VMPS,CTD-A7*****		
Aug. 10. 97'	VMPS CTD-A8*****			VMPS CTD-A9*****		06:20 Sunrise	VMPS CTD-B4*****			VMPS CTD-A10*******		VMPS CTD-B5*****		IR		VMPS CTD-B5*****		IR		CTD-B6,Multi**********	Nor.	21:08 Sunset	RMT*****	
Aug. 11. 97'	**********				VMPS********	06:23 Sunrise			RMT***	**********								CTD-C2 Nor.H.Tow			**********	21:10 Sunset	RMT********	
Aug. 12. 97'	**********				CTD-C3,Nor.H.Tow******	06:25 Sunrise			**Trap Picup	RMT**********											Nor.**** 21:00 Sunset	MTD**********		
Aug. 13. 97'	**		Time 3:00+1											St.16 IR, CTD-F,Multi******* 50 00N,140 00W				CTD-R********** H.Tow			Multi,Nor.********** 21:44 Sunset			Multi** Nor.
Aug. 14. 97'	*******IKMT******* ORI																				21:20 Sunset			
Aug. 16. 97'	Arrived at Vancouver																							
Leg.3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Aug. 22. 97'														Vancouver Departure										
Aug. 24. 97'																				20:17 Sunset				
Aug. 25. 97'	*****					06:16 Sunrise												St.17,IR,CTD-R,Nor.H.Tow******** 40 00N,140 00W			20:13 Sunset		CTD-F	IKMT
Aug. 26. 97'	ORI					06:38 Sunrise														20:37 Sunset				
Aug. 27. 97'		IK-18 IKMT Time 01:00-1	ORI			06:06 Sunrise			St.18,CTD-R.Nor. 46 28N,150 00W											20:05 Sunset				
Aug. 28. 97'					Time 05:00-1 05:40 Sunrise								St.19,CTD-R,Nor********** 47 02N,160 00W			Multi**********			19:31 Sunset	CTD-C1**********				
Aug. 29. 97'	IKMT** CTD-C2**********	H.Tow			ORI*** CTD-F,IR 05:54 Sunrise														19:47 Sunset			Time 21:00-1		
Aug. 30. 97'		IKMT-20			05:28 Sunrise					St.20 CTD-R,Nor. 46 43N,170.00W									19:15 Sunset					
Sep. 01.97'	Time 01:00-1				05:01 Sunrise										St.21 CTD-R,Nor 45 30N,180.00			18:45 Sunset			IKMT-21 ORI			
Sep. 02. 97'				04:36 Sunrise Time 01:00-1														18:16 Sunset		St.22 CTD-R,Nor,IKMT 45 07N,170.00E				
Sep. 04. 97'																		18:44 Sunset		St.23 CTD-R,Nor,IKMT,ORI 44 05N,161 44E				
Sep. 05. 97'	Time 01:00-1			04:19 Sunrise														17:36 Sunset			St.24 MTD,********** 41 58N,147 57E			
Sep. 08. 97'	**********			IKMT****** 04:36 Sunrise		***CTD-R,Nor,MTD**********												17:47 Sunset						
	Arrived at Tokyo																							

Bio-optical measurements in the subarctic Pacific

Motoaki Kishino[1], Seiichi Saitoh[2] and Hiroaki Sasaki[2]

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The solar incoming radiation in the subarctic Pacific shows large variability seasonally and by sky conditions. No or extremely low radiation reaches on the sea surface in the winter season or by heavy cloud coverage. These radiant environment could effect the photosynthetic characteristics of phytoplankton in the areas.

The bio-optical algorithms in the high latitude regions were different from the general algorithms (Mitchell, 1992). Then, the new bio-optical algorithms for the high latitude regions need to be developed as soon as possible.

The present study is focusing on understanding of the biological radiant environment and development of the bio-optical algorithms of future ocean color remote sensing in the high latitude regions. The bio-optical parameters, such as underwater light field, and optical absorption coefficient of phytoplankton, detritus, and dissolved yellow substance, were measured in this cruise. Measurement of underwater light field and water sampling were carried out at Stns 2/3, 4, 6, 8, 9, 10, 11, 14, 15, 16, 17, and 19. At Stns 20, 21, 22, 23, and 24 only water sampling was carried out.

Measurements of underwater light field

The underwater spectral downward irradiance and upward radiance were measured using the underwater unit, MER-2040 (Biospherical Instrument Inc.). The measurements were carried out from the sea surface down to depth 60 m or 100 m depth depending on the water turbidity. The incident solar spectral irradiance was measured using the deck unit, MER-2041 (Biospherical Instrument Inc.). The measurement 3 times per day were carried out 3 times per day during the 2 days at Stns 4 and 15, one day at Stns 6 and 9. At

other stations measurements were made once a day. At Stn 4 the control unit of MER-2040/41 was troubled and replaced by PRR-600/610 (Biospherical Instrument Inc.). The spectral channels of MER-2040/41 covered the wavelengths of 412, 443, 465, 490, 510, 520, 555, 565, 625, 665, 670, 683 nm and PAR (710 nm for upward radiance). These channel were selected for compatible satellite ocean color sensor, SeaWiFS and GLI. The spectral channels of PRR-600/610 covered the wavelengths of 412, 443, 490, 520, 565, 670, 683 nm, and PAR (710 nm for upward radiance).

The vertical distribution of PAR is shown in Fig. 1.

Measurement of optical absorption coefficients of seawater

Absorption coefficients of phytoplankton, detritus, and dissolved organic matter were measured using the water samples from the euphotic zone. The chlorophyll a concentration was measured by fluorometric method with N, N-Dimethylformamide (DMF) as extracted solvent and suspended solid weight (SS) was measured by gravimetric method using Millipore HA filter.

The absorption coefficients of phytoplankton and detritus were determined by the opal-glass and methanol extraction method (Kishino et al., 1985) using a spectrophotometer (Shimadzu MPS-2000). The absorption coefficient of dissolved organic matter was determined by spectrophotometer using 15 cm cell. The sample was filtered by Nuclepore filter (pore size 0.4 μm) with Milli-Q water as reference.

These data was analyzed with HPLC data for the effects of phytoplankton to underwater light field in cooperation with Dr. Ken Furuya's group of the University of Tokyo.

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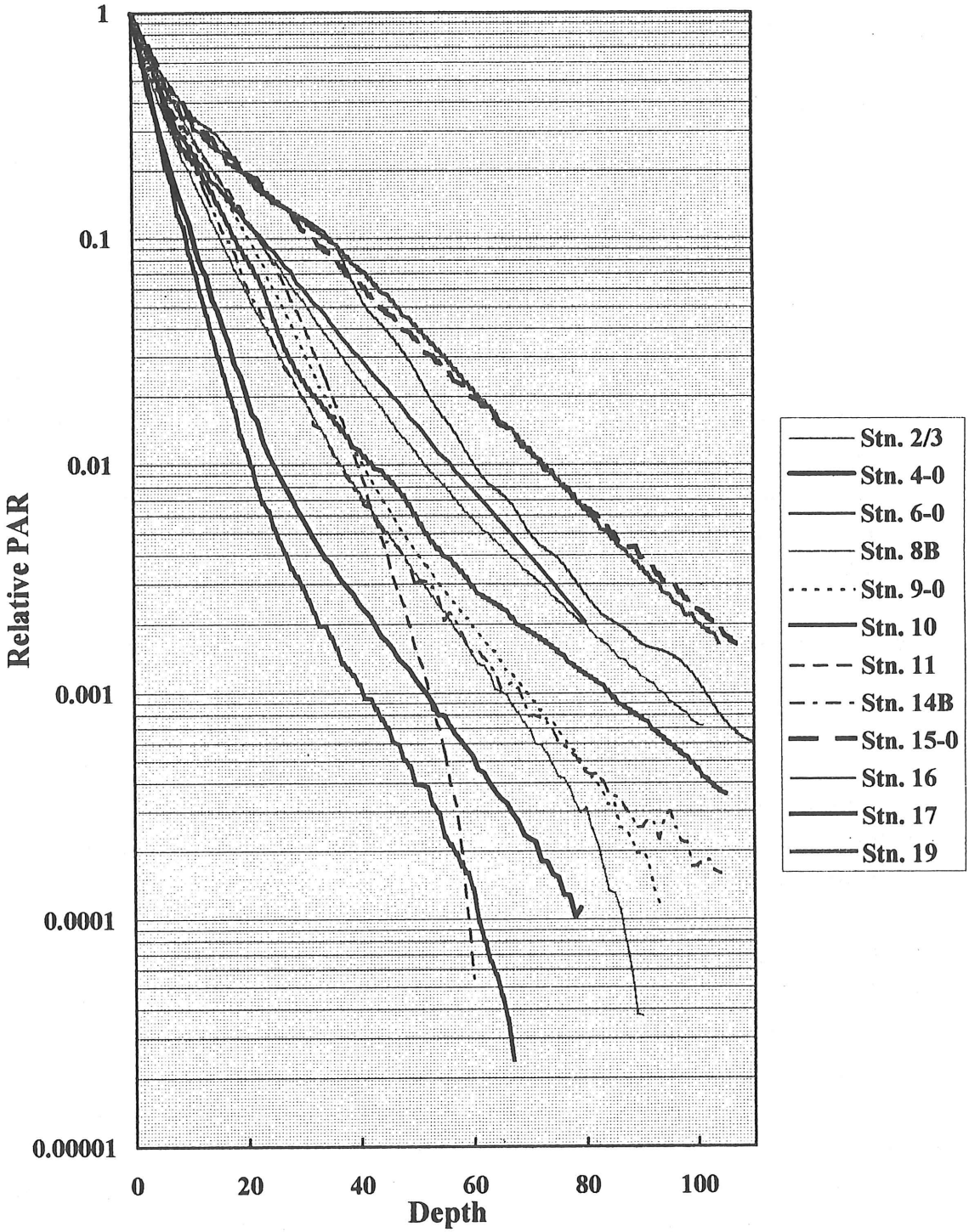

Fig. 1. Vertical distribution of PAR.

Photosynthetic characteristics of planktonic algae in a boreal region of the subarctic Pacific

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The present study is focusing on measuring the radiant environment in terms of the photosynthetically available radiation (PAR) in the subarctic waters of the North Pacific by in situ measurements and also determining actual photosynthetic characteristics of plankton algae in relation to both quality and quantity of the radiation at various depth layers.

Materials and methods

1. Measurements of radiant environment

Upward and downward PAR was determined simultaneously at several depths in the water column (0-100m) using a underwater radiometer (Biospherical Instruments Inc. MER-2040/41) at several different stations in cooperation with Dr. Saitoh's group of the Hokkaido University.

2. Determination of photosynthetic characteristics of planktonic algae

Photosynthetic rates of planktonic algae collected from 3-5 depths in the water column at Stns 2/3, 4, 6, 9, 10 and 15 were determined at various intensities of white, blue, green and red lights by a photosynthetron with 1 kw halogen lamp using the ^{14}C tracer technique. Algal biomass in the sample water was evaluated by chlorophyll a determined by the fluorometry using N, N-Dimethylformamide (DMF) as extracted solvent. Light absorption of planktonic algae for various wavelengths was determined by the opal-glass and methanol extraction method (Kishino et al., 1985) using a spectrophotometer (Shimadzu MP-2000) in cooperation with Dr. Saitoh's group of the Hokkaido University.

Phytoplankton population dynamics and primary productivity in the subarctic Pacific Ocean in summer

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The subarctic Pacific is characterized by a marked difference in population dynamics of lower trophic levels between the western and the eastern North Pacific (e.g., Longhurst et al., 1995). Phytoplankton are considered to play a central role in producing the difference. The present study aims to examine community structures of phytoplankton, primary productivity and zooplankton grazing both in the western and eastern Pacific Ocean to evaluate the role of phytoplankton community.

Oceanographic observation and water sampling

Hydrographic conditions in the upper 200-m water column were investigated by CTD casts fitted with a Sea Tech fluorometer (CTD-F casts). Underwater light field was also monitored using an underwater spectroradiometer (MER 2040, Biospherical) in cooperation with M. Kishino and S. Saitoh. Water sampling was made from the surface to 200-m depth using a rosette multi-bottle sampler mounted on the CTD, and the samples were used for analysis described below. Chlorophyll a obtained by the CTD-F casts is shown in Table 1. Analysis was done by the standard fluorometry with D. Han and H. Sasaki (Suzuki and Ishimaru, 1990).

Community structure of phytoplankton

Phytoplankton cell counting and analysis of class-specific biomarker pigments were made to deduce spatial and temporal variations in phytoplankton biomass and composition. Aliquots of the

water sample were fixed with 1 % glutaraldehyde, and specimen for fluorescence microscopy was prepared after Tsuji and Yanagita (1981) for counting of pico- and nanophytoplankton cells. Subsamples were preserved in 1 % (v/v) buffered formalin for identification and enumeration of microplanktonic algae. Another portions of the samples were filtered through Whatman GF/F filter in the dark at 5°C for analysis of chlorophyll a and other chlorophylls and carotenoids by HPLC (Furuya et al., in press). The filters were stored in liquid nitrogen and brought back to land laboratory for analysis. At stations where not CTD-F was done, samples were obtained by R-CTD casts. Surface water was also taken for analysis of phycobilins.

Using the observed pigments' concentration, light absorption spectrum of phytoplankton will be reconstructed for analysis of bio-optical characteristics of the water column in combination with the chlorophyll-a specific light absorption of phytoplankton (a*) and the underwater light field as a cooperative work with M. Kishino and S. Saitoh.

Photosynthetic activity as a function of irradiance, and primary production

Photosynthesis vs. irradiance curves (P-E curves) were determined for several depths above 0.1 % light level of the surface at Stns 2-3, 4, 6, 9, 10 and 15. Uptake of ^{14}C-bicarbonate was measured at in situ temperature under white and blue (peak wave length, 480 nm) light using the photosynthetron (Lewis and Smith, 1983) with 22 different light intensities ranging from 0 to 1750 μmol m^{-2} s^{-1} for white light and from 0 to 150 μmol m^{-2} s^{-1} for blue light. After 30 to 40 min incubation, photosynthesis was terminated by addition of HCl, and activity was measured by liquid scintillation counter with the external standard channel ratio method. Primary production was determined based on the a*, the underwater light field, vertical profiles of chlorophyll a and parameters describing the P-E curves (Morrel, 1991).

Grazing activity of herbivores

Degradation of phytoplankton pigments by copepod grazing was analyzed. Fecal pellets of *Neocalanus* were collected by 24-h

incubations in filtered seawater for pigment analysis at Stns 1, 2-3, 4, 9, 11, 16. For comparison the animals were fed on clonal cultures of cryptomonas, diatoms, dinoflagellates, haptophytes, chrysophytes and chlorophytes and their fecal pellets were obtained. Chlorophyllous and carotenoid pigments were determined by HPLC to examine feeding preference of the grazers. Similar experiments were conducted for salps at Stns 15 and 19. Feeding activity of salps was also obtained from time courses of changes in pigment concentration during the 24-h incubation with natural and cultured phytoplankton. These experiments were done in cooperation with H. Hattori and J. Nishikawa.

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Table 1. Chlorophyll *a* ($\mu g\ L^{-1}$) obtained by CTD-F casts. Depths are given in meter.

ST2.3F
12 Jul 97 14:35
43°03.35'N 155°04.91'E

Depth	Chl a
0	0.586
10	0.564
15	0.564
20	0.520
25	0.469
30	0.440
35	0.440
40	0.403
45	0.374
50	0.337
60	0.213
80	0.072
100	0.026

ST4B1
15 Jul 97 7:40
48°03.70'N 165°04.81'E

Depth	Chl a
0	1.347
10	2.189
15	2.261
20	2.141
25	1.515
30	0.477
35	0.367
40	0.271
50	0.205
65	0.166
80	0.097
100	0.059

ST4B2
15 Jul 97 13:33
48°00.28'N 165°07.11'E

Depth	Chl a
0	2.045
5	2.165
10	2.093
15	2.165
20	2.141
25	3.007
30	0.608
35	0.469
40	0.257
50	0.242
65	0.183
80	0.099
100	0.062

ST4B3
15 Jul 97 19:59
47°58.60'N 165°10.10'E

Depth	Chl a
0	1.660
5	1.660
10	1.660
15	1.684
20	1.732
25	1.780
30	0.828
35	0.345
40	0.279
50	0.220
65	0.164
80	0.119
100	0.059

ST4B4
16 Jul 97 7:31
47°57.00'N 165°11.90'E

Depth	Chl a
0	1.299
5	1.323
10	1.299
15	1.395
20	1.179
25	1.203
30	0.748
35	0.440
40	0.367
50	0.220
65	0.138
80	0.080
100	0.050

ST4B5
16 Jul 97 13:27
47°55.24'N 165°20.16'E

Depth	Chl a
0	1.515
10	1.684
15	1.684
20	1.636
25	1.323
30	0.586
35	0.433
40	0.279
50	0.191
65	0.139
80	0.091
100	0.049

ST4B6
16 Jul 97 19:20
47°55.32'N 165°24.23'E

Depth	Chl a
0	1.660
10	1.828
15	1.540
20	0.890
25	0.623
30	0.440
35	0.323
40	0.257
50	0.176
65	0.121
80	0.075
100	0.041

ST6B1
23 Jul 97 8:25
48°06.94'N 176°54.92'E

Depth	Chl a
0	0.359
10	0.293
15	0.271
20	0.293
25	0.286
30	0.301
35	0.301
40	0.293
50	0.359
60	0.396
70	0.315
85	0.138
100	0.060

ST6B2
23 Jul 97 12:00
48°08.84'N 176°48.16'E

Depth	Chl a
0	0.293
10	0.352
15	0.381
20	0.323
25	0.279
30	0.286
35	0.389
40	0.403
50	0.440
60	0.491
70	0.249
85	0.139
100	0.067

Stn. 6B3
23 Jul 97 20:28
48°06.81'N 176°54.99'E

Depth	Chl a
0	0.271
10	0.293
15	0.309
20	0.293
25	0.279
30	0.271
35	0.286
40	0.352
50	0.462
60	0.513
70	0.462
85	0.129
100	0.062

ST8F
24 Jul 97 8:48
53°52.95'N 179°53.19'W

Depth	Chl a
0	0.953
10	0.887
15	0.986
20	0.289
25	1.155
30	1.058
35	1.107
40	0.842
50	0.579
60	0.433
70	0.121
85	0.070
100	0.082

ST9B1
26 Jul 97 10:29
57°19.22'N 179°51.25'W

Depth	Chl a
0	0.660
10	0.579
15	0.623
20	0.711
25	0.836
30	0.843
35	0.821
40	0.572
50	0.323
60	0.161
70	0.116
85	0.054
100	0.054

Table 1. (continued)

ST9B2
26 Jul 97 13:20
57°22.80'N 179°55.44'W

Depth	Chl a
0	0.433
10	0.447
15	0.579
20	0.733
25	0.858
30	0.784
35	0.667
40	0.550
50	0.359
60	0.151
70	0.119
85	0.084
100	0.064

ST9B3
26 Jul 97 19:20
57°25.58'N 179°54.28'W

Depth	Chl a
0	0.608
10	0.520
15	0.542
20	0.799
25	1.058
30	1.131
35	0.924
40	0.704
50	0.411
60	0.205
70	0.099
85	0.067
100	0.050

ST10F
26 Jul 97 16:23
57°00.44'N 174°00.88'W

Depth	Chl a
0	2.622
10	2.598
15	2.670
20	1.660
25	0.916
30	0.323
35	0.271
40	0.233
50	0.166
60	0.138
80	0.042
100	0.026

ST11F
29 Jul 97 17:52
56°59.92'N 165°59.26'W

Depth	Chl a
0	0.139
10	0.220
15	0.389
20	0.330
25	0.264
35	0.293
40	0.293
50	0.286
60	0.330

ST14F
6 Aug 97 16:15
53°50.13'N 150°27.83'W

Depth	Chl a
0	0.682
10	0.660
15	0.594
20	0.506
25	0.411
30	0.367
35	0.301
40	0.345
50	0.337
60	0.286
70	0.198
85	0.106
100	0.052

ST15B1
9 Aug 97 8:30
49°54.26'N 144°49.82'W

Depth	Chl a
0	0.231
10	0.241
20	0.286
30	0.279
40	0.286
50	0.286
60	0.308
70	0.249
80	0.359
90	0.359
100	0.323
120	0.087
150	0.022

ST15B2
9 Aug 97 14:50
49°56.167N 144°46.96'W

Depth	Chl a
0	0.205
10	0.206
20	0.279
30	0.264
40	0.257
50	0.257
60	0.235
70	0.271
80	0.271
90	0.203
100	0.129
120	0.032
150	0.017

ST15B3
9 Aug 97 20:30
49°56.95'N 144°41.84'W

Depth	Chl a
0	0.233
10	0.215
20	0.208
30	0.308
40	0.286
50	0.257
60	0.271
70	0.257
80	0.315
90	0.330
100	0.286
120	0.119
150	0.024

ST15B4
10 Aug 97 8:50
49°55.38'N 144°43.57'W

Depth	Chl a
0	0.249
10	0.220
20	0.220
30	0.249
40	0.213
50	0.249
60	0.235
70	0.257
80	0.279
90	0.330
100	0.249
120	0.086
150	0.024

ST15B5
10 Aug 97 14:40
49°56.65'N 144°42.64'W

Depth	Chl a
0	0.233
10	0.210
20	0.279
30	0.211
40	0.220
50	0.242
60	0.279
70	0.301
80	0.337
90	0.227
100	0.139
120	0.028
150	0.015

ST15B6
10 Aug 97 19:15
49°55.41'N 144°40.78'W

Depth	Chl a
0	0.230
10	0.216
20	0.235
30	0.308
40	0.242
50	0.242
60	0.308
70	0.286
80	0.345
90	0.264
100	0.154
120	0.039
150	0.024

ST16F
13 Aug 97 14:40
49°59.85'N 140°00.06'W

Depth	Chl a
0	0.153
10	0.153
20	0.144
30	0.323
40	0.418
50	0.499
60	0.455
70	0.345
80	0.205
90	0.092
100	0.044
120	0.027
150	0.029

Table 1. (continued)

ST17F		ST19F	
24 Aug 97 23:04		28 Aug 97 7:00	
44°57.79'N 139°59.44'W		46°58.07'N 160°10.85'W	
Depth	Chl a	Depth	Chl a
0	0.455	0	0.156
10	0.345	10	0.153
15	0.352	20	0.154
20	0.652	30	0.179
25	1.467	40	0.227
30	1.371	50	0.301
35	1.275	60	0.345
40	1.034	70	0.315
50	0.374	80	0.315
60	0.249	90	0.205
80	0.084	100	0.151
100	0.029	120	0.086

Community structure of phytoplankton and primary productivity in the subarctic North Pacific Ocean

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Objectives

Phytoplankton communities in the subarctic region are generally considered to be dominated by large sized algae, mostly diatoms. However, recent studies suggest the importance of pico- and nanophytoplankton. For instance, they comprise a large proportion of phytoplankton biomass in Bering Sea and Gulf of Alaska in summer (Odate, 1996). Nonetheless, both production and biomass of pico- and nanophytoplankton in the subarctic region is still poorly understood. The purpose of this study is to investigate the contribution of pico- and nanophytoplankton to primary production in the subarctic North Pacific Ocean in summer.

Primary production and community respiration

Community production and respiration of pico- and nanophytoplankton (<20 μm) and microphytoplankton (>20 μm) in the euphotic layer were examined at Stns 15 and 19. Water samples were collected at six depths from the surface down to the 1 % light level of the surface using Niskin bottles mounted on a CTD-rosette.

Water samples were siphoned into BOD bottles and then incubated for 24 hours under the simulated *in situ* conditions on deck. Another subsample with pico- and nanoplankton, which had been filtered through 20 μm mesh, was also incubated in the same way. Rates of *in vitro* changes in oxygen concentration were measured by high precision Winkler titration (Furuya and Harada, 1995).

Additional experiments for production and respiration of pico-, nano-, and microphytoplankton were conducted using surface water of all stations in leg III.

Community structure of phytoplankton

Water samples for determining size-fractionated chlorophyll *a* concentration and abundance of pico- and nanophytoplankton were collected at the same stations where the incubation experiments for primary production and community respiration were carried out. Aliquots were filtered separately through Nucleopore filters with pore sizes of 2 and 10 μm and a Whatman GF/F filter. The filters were immediately put into glass vials containing 6 ml of DMF, and kept at -20℃ until their analyses. Then, total chlorophyll *a* as retained on the GF/F filters, picoplankton fraction of <2 μm and the 2-10 μm size fraction were obtained.

In addition, other aliquots of water samples were fixed with 1 % glutaraldehyde for counting bacteria and pico- and nanophytoplankton cells by fluorescence microscopy.

Post expedition research

All samples and data on primary production and community respiration are currently under processes at Mie University.

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Studies on planktonic composition and biological processes regulating oceanic greenhouse gasses and environmental diagnostic compounds

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Distribution of marine organic compounds including greenhouse gasses and environmental diagnostic compounds is governed by *in situ* biological activities in addition to physical conditions. Phytoplanktons play an important role in the production of these compounds as a primary producer and also in sedimentation process of organic compounds through grazing and sinking particle formation. Their contribution to these processes has been suggested to be changeable with their biomass as well as their taxonomic composition.

In the present study, we attempted to clarify the relationship between the phytoplankton taxa and biological processes such as growth, grazing, decomposition and sedimentation. For this, following observations and experiments on board and sediment sampling for the analysis of environment diagnostic compounds were performed.

Distribution of phytoplankton and their taxonomic composition estimated by phytoplankton pigments

Suspended particles in surface layer shallower than 125 m were collected onto Whatman GF/F filter at Stns 1 - 16. Phytoplankton pigments will be extracted and analyzed using high performance liquid chromatography (HPLC). From this result, the taxonomic composition of phytoplankton assemblage will be estimated.

Estimating rates of growth and grazing mortality of phytoplankton

1. Outline of the experiment

Dilution experiments were carried out at Stns 4, 6, 9 and 15. This

experiment can be used to estimate the instantaneous rates of growth and grazing mortality of phytoplankton using dilution of natural microbial plankton communities with particle-free water. In this study, we will estimate the rates associated with specific groups of phytoplankton by coupling the dilution experiment with HPLC separation of phytoplankton pigments.

2. Methods

Seawater was collected at around midnight. Filtered seawater was prepared using Gelman capsule filter (0.2 μm pore size). Five degree of dilution (15, 30, 50, 85 and 100 % concentration of unfiltered seawater) were made and subsampled for initial condition of pigments and nutrients in each dilution. Each diluted sample and filtered seawater (for control) were transferred into polycarbonate bottles with triplicate and incubated in on-deck incubator under simulated light intensity corresponding to sampled depth with neutral density screen and cooled with flowing surface seawater. Incubations began at dawn and lasted 24h or 48h. At the end of the experiments, incubated samples were filtered onto Whatman GF/F filters for HPLC pigment analysis.

3. Expected results

Pigment concentration in the samples taken before and after incubation in each dilution will be analyze using HPLC. The change of pigment concentration is comparable with the net growth, which can be expressed by subtracting grazing mortality from growth rate of phytoplankton. For constant growth rate and grazing mortality, net growth rate of phytoplankton varies linearly as a function of grazer density with the slope indicating the grazing mortality and the intercept indicating growth rate of phytoplankton.

In this study, standard linear regression analysis will be applied to chlorophyll *a* and marker pigments of each phytoplankton group, and phytoplankton growth and microzooplankton grazing rates will be estimated in the level of individual phytoplankton taxa.

Contribution of each phytoplankton group to vertical transport

Settling particle was collected by the floating sediment trap at Stns 4, 6, 9 and 15, and was filtered onto GF/F filters for pigment analysis.

Details about the sediment trap experiments are shown in Hamanaka and Hama (in this report).

Pigment composition in the settling particles will be estimated and compared to those of water column. This analysis can afford significant information on the contribution of each phytoplankton group to vertical transport of material.

Analysis of environmental diagnostic compounds in the sediments

The sediment samples were collected at Stns 2/3, 4, 6, 9 and 15 by use of a multiple sediment corer. The core sample was cut into 1cm-sections on board and frozen. These samples will be analyzed for organic carbon and nitrogen contents, then extracted with solvent. The compound groups of alkenone and lignin phenol will be separated from the solvent-soluble and residual fractions, respectively, and analyzed for individual constituents. Compositional patterns of alkenones and lignin phenols will provide us information on the time- and space-variabilities of the surface water temperature and inflow of terrestrial materials, respectively.

Primary production and vertical transport of particulate organic matter in the subarctic North Pacific

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The sinking of particulate organic matter in the ocean links food webs below the euphotic zone to primary production and is an important pathway for the downward transport of many elements. The flux of particulate matter has been considered as one of the main controlling factors of the partial pressure of carbon dioxide in the ocean surface and atmosphere. Thus, the study of dynamics of particulate organic matter biosynthesized by marine organisms inhabiting the euphotic zone is essential in further understanding biogeochemical cycling of carbon in the ocean.

To investigate the qualititative and quantitative changes of particulate organic matter in the surface water column, the ^{13}C uptake experiments and the sediment trap experiments were carried out simultaneously. Photosynthetic products and sinking particulate materials in the surface water will be determined, not only in elemental composition level, but also in monomer level (such as amino acid, monosaccharide and fatty acid). From this details analysis of the primary production rates and the sedimentary rates of organic compound, we will consider the lability of an organic compound and mechanisms controlling transport of materials.

Primary production in the subarctic North Pacific

1. Methods

The ^{13}C uptake experiments by the simulated *in-situ* method were carried out at Stns 4, 6, 9 and 15. Water samples for incubations were collected from 6 depths correspond to the 100 to 0.1 % of light penetration depths, and transferred into polycarbonate bottles. The on-deck

incubations were started at dawn and continued to the following dawn. Particulate materials were filtered onto pre-combusted glass fiber filter (Whatman GF/F) immediately after incubations.

The concentration and ^{13}C atom % of particulate organic carbon (POC) were determined by an elemental analyzer-mass spectrometer (TracerMAT). The production rate of POC was calculated after Hama et al. (1983). Pigment concentrations were measured on DMF extracts using a Turner fluorometer and nutrients concentrations were analyzed using an AutoAnalyser (AA2).

The composition of photosynthetic products will be measure by application of the ^{13}C/GC/MS method.

2. Results

Vertical profiles of chlorophyll *a* concentration, primary production rate and density (σt) are shown in Figure 1. At Stn 4 (western subarctic gyre), high chlorophyll *a* concentrations (> 1.3 $\mu g\ l^{-1}$) were observed over the euphotic zone. On the other hand, the sub-surface chlorophyll *a* maximum was found at 1 % light depth at Stn 6 (the subarctic central Pacific) and Stn 9 (the Bering Sea) with maximum values of 0.5 and 0.8 $\mu g\ l^{-1}$, respectively. The weak and diffuse sub-surface chlorophyll *a* maximum lain within 10～1 % light depth at Stn 15 (Alaskan gyre). At all stations, profiles of primary production rate showed the highest value at the surface and the rate rapidly decreased with water depth.

Depth-integrated primary production rates through the euphotic zone at Stns 4, 6, 9 and 15 were 570, 330, 420 and 380 mg C $m^{-2}\ d^{-1}$, respectively (Table 1). At all stations, mean concentrations of nitrate plus nitrite in the euphotic zone were > 10 mmol m^{-3}. At Stn 15, integrated chlorophyll *a*-specific primary production rate was highest (21 mgC mgChl.$a^{-1}\ d^{-1}$) and being 1.3 times as high as other three stations.

Vertical transport of particulate organic matter in the subarctic North Pacific

1. Methods

Sediment traps (145 mm i.d.) were attached to the free-floating array for drogue, which consisted of 3 traps each correspond to the 10, 1 and 0.1 % light penetration depths (Fig. 2). The free-floating array was deployed for 47～96 h. No preservation such as formalin was used.

Sinking materials were filtered onto pre-combusted glass fiber filter immediately after recovery and stored at -20℃. Zooplankton swimmers in traps were meticulously picked out under a dissecting microscope.

The analytical procedures of sinking materials in elemental composition level and monomer level will be as same as those of photosynthetic products.

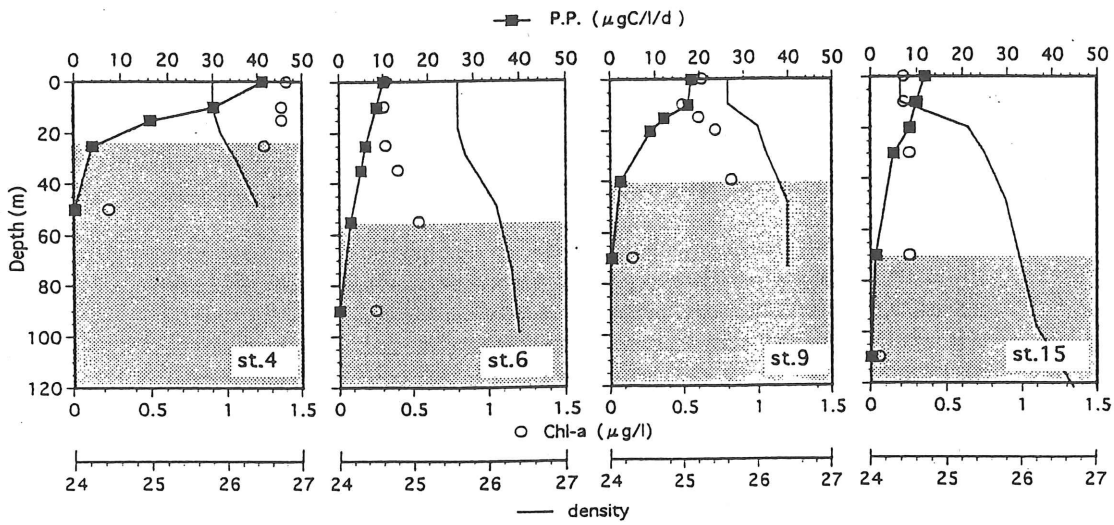

Figure 1 Vertical profiles of chlorophyll *a* concentration, primary production rate and density (σ t). The stippled shading indicates the depth of < 1% light penetration.

Table 1 Depth of the euphotic zone, mean concentrations of nitrate plus nitrite, integrated chlorophyll *a*-specific primary production rates and primary production rates in the euphotic zone.

Location	Depth(m) of euphotic zone	NO3+NO2 (mmol/m³)	Prod./Chl-*a* (mgC/mgChl.*a* /d)	Primary production (mgC/m²/d)
N.W. Pacific st.4	25	18.2	17	570
N.C. Pacific st.6	55	18.8	16	330
Deep Bering Sea st.9	40	15.8	16	420
N.E. Pacific (st.P) st.15	70	11.2	21	380

KH-97-2 Free-floating sediment trap

IHAS, Nagoya Univ.

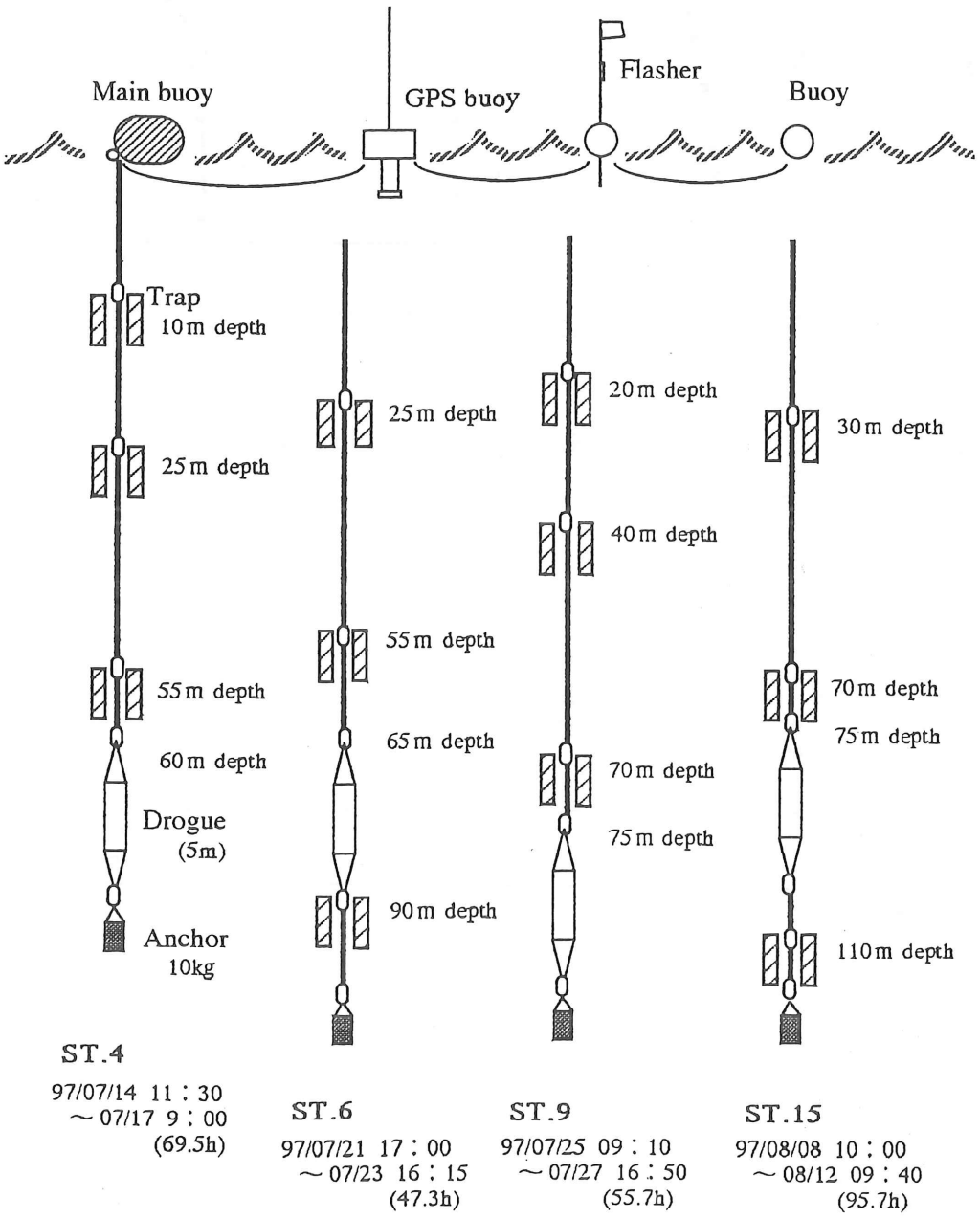

Figure 2 Schematics of the free-floating sediment trap array.

In situ tests of a fluorescence oxygen sensor

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Oxygen is one of the molecules most closely related to the energy metabolism of organisms, reflecting respiration of organisms and processes of organic oxidation and decomposition. The oxygen concentration of seawater has generally been measured by the Winkler method, oxygen-electrode method, or derivatives from these methods. While the Winkler method has been widely used in oceanographic researches, it requires a large volume of seawater, usually >100 ml, and the whole process involves quite a few steps which would lead to an increase of errors. The oxygen-electrode method also involves source of errors, such as exhaustion and contamination of an electrode or a membrane, and care must be taken for the maintenance and calibration of a measurement system. Furthermore, this method involves an essential problem that it measures oxygen by consuming oxygen, that is, the method measures the quantity of oxygen electrochemically reduced in an electrolyte. Hence, it has been expected to establish a new method devoid of the defects in the both methods.

The fluorescence oxygen sensor has been developed for use in oxygen measurement in general. The performance of the fluorescence oxygen sensor was compared with that of the Winkler method on board Hakuho Maru in 1995, demonstrating that the sensor is applicable to measurement of oxygen in seawater. However, the time required for a measurement is still too long (ca. 3 min or more) and little is known of its pressure resistance.

During the present cruise we attempted to test the response speed and the pressure resistance of the sensor and to examine the suitability of the data to be obtained. In the first two trials only a cylindrical housing of stainless steel (outer diameter: 68 mm; length: 710 mm) was put on the cable and lowered to 1000-m depth, with no leakage of

seawater. In the third trial the housing containing the whole unit of the sensor was attached to the end of a conductor-cable and lowered to 1000-m depth. After recovery a leakage of seawater was detected through a space between the housing and an O-ring; no measurement data was obtained. By a detailed inspection of all the parts for the housing, this leakage was attributed to a deformation of the O-ring.

An improvement of the housing and measurements of the response speed are now in progress on land. We are planning to use this fluorescence oxygen sensor in combination with a CTD.

Response of subarctic phytoplankton to ultraviolet radiation: UV protect compounds

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In response to increasing UV radiation, phytoplankton synthesize many compounds that absorb light in the UV region of the spectrum. One of such compounds is mycosporine-like amino acid (MAAs) and has been hypothesized to act as a screen and thus to decrease influx of UV radiation.

Effects of increasing UV radiation on the marine ecosystems are complex. UV affects directly on phytoplankton and reduces the rates of photosynthesis, growth, survival and nutrient uptake and concentration of photosynthetic pigments, which in turn affects indirectory on supplies of food and oxygen to the heterotrophic components of the ecosystems. It has been reported that long term exposure of a natural phytoplankton assemblage to in situ UV irradiance changes its species composition. This can modify the trophic interactions and carbon flux among the marine ecosystems. NASA scientists have shown that ozone levels in the higher latitudes than 65°S or 65°N decreased by ca. 3 % during the past decade, while the ozone loss was close to zero at the equator. Some scientists argue that the ozone loss during the same period was about 5 % at 50°N. These phenomena in the northern hemisphere should be investigated.

Aim of this ship-board experiment was to investigate natural phenomena appeared on phytoplankton in the subarctic North Pacific. We concentrated our efforts on phytoplankton in the upper water column.

We sampled phytoplankton to analyze their pigments and to incubate them under UV radiation of different intensities. Natural UV radiation was also recorded on deck. Water samples from 22 stations were obtained with 12-liter Niskin bottles attached to probe of a multichanneled profiling system.

Particulate matter including phytoplankton were collected from each water sample onto a Whatman glass fiber filter (GF/F) and stored immediately at -70°C. Light absorption of these filter relative to a blank filter saturated with seawater was measured on a UV/VIS spectrophotometer (MPS-2000 Shimadzu) by following the guidelines of Mitchell and Kiefer (1988). Absorption spectra were recorded for wavelength between 300 and 750 nm with a 1 nm slit. After this measurements, the filter was placed in methanol following the procedure of Kishino (1985). After this treatment, the residual filter was again put on the spectrophotometer to record absorption spectrum of non-extractable detrital material in methanol (ad(λ)). Extracts were stored immediately at -70°C for later pigment analyses, which will be done using a high-performance liquid chromatography (HPLC) system (Mantoura and Llewellym, 1983) in land laboratory. In addition, total concentration of UV-absorbing compounds including non-pigment amino acids will be measured on the same methanol extracts.

Another water samples were collected from the upper layers at 4 stations with 12-liter Niskin bottles and then incubated. The incubation were made under solar radiation in order to determine the effect of natural UV on pigment composition of phytoplankton. All samples were incubated in either of Teflon bottles or Polycarbonate bottles, which were placed in an on-deck water bath with circulating sea surface water. During these incubation experiments, incident solar radiations in both PAR and UV regions were recorded every 10 min.

Community structure, vertical distribution, and feeding impact of zooplankton and micronekton in the subarctic North Pacific Ocean

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The subarctic North Pacific encompasses three major regions based on gyral systems: the western region (western subarctic gyre), the Gulf of Alaska (Alaskan gyre), and the Bering Sea (Bering Gyre). The biological productivity in these regions are relatively high, with larger standing stock of zooplankton and micronekton, major components of secondary and tertiary producers, than in the central waters and transitional regions. Recent investigations have revealed differences between these regions in community structures and productivity of primary producers, as well as those in the environmental parameters supporting the production, such as the distribution of nutrients and trace metals. However, still little is known of the differences, if any, in the community structure of zooplankton and micronekton between these three regions. In addition, we have only limited information on relationships of the vertical distribution of trophically-higher organisms with environmental parameters and distribution and production of trophically-lower organisms. To fill this gap, comprehensive investigations within limited seasons enabling a comparison between regions are necessary.

The present study, as described in detail below, aims to investigate and evaluate the community structure, standing stocks, and feeding impact of zooplankton and micronekton in the subarctic Pacific, with emphasis on the vertical and diel patterns in the three major gyral regions.

Vertical structure of zooplankton and micronekton communities

Vertical structures of zooplankton and micronekton communities were investigated by a day-night series of collection from 12 different layers covering the upper 1000 m at Stns 4 (western gyre), 6 (transitional area), 9 (Bering Sea) and 15 (Gulf of Alaska). These stations were Lagrangian ones where a drogue carrying a GPS buoy was traced. Samples were collected with a Rectangular Midwater Trawl (RMT-1+8) equipped with three pairs of a 1-m^2 net (mesh aperture: 0.33 mm) and an 8-m^2 net (mesh aperture: 4.5 mm), all opening-closing-type, by oblique tows at ca. 2 kt. Each vertical series consisted of four sets of tows; each pair of nets sampled the surface mixed layer, thermocline, and the layers at 100-m intervals below the base of thermocline. Samples were immediately fixed and preserved in 10 % formalin/seawater solution buffered with sodium tetraborate (this method applies to all fixation below).

Primary sorting of the samples into major taxonomic groups is now in progress. Analysis will be made on the standing stocks and patterns of day-night vertical distribution by higher taxa, and by species for dominant groups such as copepods, chaetognaths, thaliaceans and myctophid fishes.

Diel vertical migration and feeding rhythm of zooplankton

Patterns of diel vertical migration, feeding rhythm and feeding impact of major zooplankton (primarily copepods, chaetognaths and thaliaceans) were investigated at Stns 4, 9 and 15 for periods of 24-48 h by successive samplings at 3-h intervals. This is a co-operative study with Hokkaido Tokai University, Tohoku University and University of Tokyo. Samples were collected with a Vertical Multiple Plankton Sampler (VMPS) equipped with four nets (mesh aperture: 0.33 mm) with opening-closing mechanics. The VMPS was towed twice at each collection time. Each tow covered four layers in the upper 500 m: surface mixed layer, thermocline, and two layers below the base of thermocline. The samples from the first tow were immediately fixed and preserved. The samples from the second tow were enclosed in vials filled with nitrogen gas and frozen and preserved at -80℃ for later analys is of gut-content pigments by fluorometry and HPLC (see Hattori et al., Furuya & Hayashi in this report).

Another series of experiments were conducted on the diel pattern of feeding, respiration and excretion of salps and doliolids, which predominated the zooplankton community in the Gulf of Alaska. Samples were collected by gently towing a plankton net from subsurface depths at Stns 15 and 16. Salps and doliolids were transferred to glass bottles containing filtered seawater (GF/F) or cultured algae and incubated for 24-72 h. The initial and final quantity of food, dissolved oxygen, PO_4-P and NO_2-N were determined (for details see Furuya & Hayashi in this report).

Primary sorting of the samples into major taxonomic groups is now in progress. According to a preliminary observation on the daytime samples from Stn 4, there was a marked difference in vertical distribution of different groups of zooplankton. At Stn 4, while the whole water column of the upper 500 m was dominated by copepods by number, the surface mixed layer (0-20 m) was dominated by small zooplankton such as the copepods *Oithona* spp. (<< 1 mm), small chaetognaths and appendicularians, while the layers below the base of thermocline (below 150 m) were dominated by larger (>> 1 mm) forms such as the copepods of the genera *Neocalanus*, *Paraeuchaeta* and *Eucalanus*, ostracods and large chaetognaths. Future analysis will be made on the specific patterns of diel vertical migration of major taxa (copepods, chaetognaths, amphipods, ostracods, etc.) and diel change of zooplankton biomass. These results will be compiled with those of gut-pigment analysis and of gut-evacuation experiments (see Hattori et al., Furuya & Hayashi in this report) to evaluate the feeding impact of zooplankton communities.

Geographical patterns in distribution of zooplankton and micronekton

Geographical patterns in distribution, community structure, and biomass of zooplankton and micronekton were investigated by collections at all the stations covering the three major gyral regions and the transitional waters in between.

Epipelagic zooplankton were collected at each station by a vertical tow of a Norpac Net (mesh aperture: 0.33 mm) from 150-m depth to the surface regardless of the time of day, while micronekton were collected

only at night (in between stations where near-by stations were occupied in the daytime) by an oblique tow of a 10-foot Isaacs-Kidd Midwater Trawl (IKMT, mesh aperture: 1 mm) from ca. 1000-m depth to the surface. In parallel with IKMT-tows an ORI Net (mesh aperture: 1 mm) was towed at surface to collect a particular group of micronekton emerging at surface at night. All samples from the Norpac Net were immediately fixed and preserved. A fraction of each IKMT- and ORI-Net sample was removed and frozen at -80°C for later analysis on biomass, while the other was fixed and preserved as above.

Species identification, weight measurement, and determination of body carbon- and nitrogen contents are now in progress.

Life history of micronekton in the subarctic Pacific

A series of net-tows were conducted as a part of our ongoing study on the life history of myctophid fishes and squids, major components of micronekton in the subarctic Pacific. For a study of vertical distribution of larval- and postlarval forms, day-night series of vertically-stratified samples were collected at Stns 4, 9, 15 and 24 with Motoda Horizontal Nets (mesh aperture: 0.5 mm) at 17 strata covering 0-700 m. For collection of larger forms (juveniles and adults) a Midwater Trawl (mouth area: 16 m^2, mesh aperture: 8 mm) was towed in the upper 200-m layer at night in the Oyashio region (Stn 24). In addition, both adults and larvae were examined from the collection with an IKMT (0-ca. 1000-m depth, Stns 1-24) as described above.

Life-history analysis, including species identification, measurements of body size and weight, determination of maturity stages and otoliths analysis, is now in progress.

Plankton records

Details of all the collection with plankton nets and trawls in this cruise are compiled in the Plankton Records: KH-97-2; copies are available from the Plankton Division, Ocean Research Institute, University of Tokyo.

Diel changes in vertical distribution and feeding of copepods in the subarctic North Pacific

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Field research and observations

To observe diel vertical migration and feeding rhythm of copepods in the subarctic North pacific, zooplankton samplings were carried out every three hours at Stn 4 from 15 to 17 July and at Stn 9 during 26 and 27 July. VMPS (Vertical Multiple Plankton Sampling) net with 330 μm mesh openings was used for the sampling from 4 layers of 500-300, 300-170, 170-20, and 20-0 m. Upper 2 layers of 20-0 m and 170-20 m were coincided with the surface mixing layer and the intermediate cold layer, respectively.

VMPS tow was done twice at each sampling. First series of samples are used for numerical abundance of zooplankton to observe diel change in vertical distribution of copepods and second one is used for the gut pigment contents of copepods to estimate feeding rhythm of copepods. Gut pigment content as chlorophyll and chlorophyll equivalent phaeopigments of copepods will be analyzed by the method shown by Baars and Helling (1985).

Immediately after sampling, copepods for gut pigment sample were filtered onto 100 μm nylon mesh screen and rinsed with glass fiber (GF/F) filtered sea water. Then, the screen was kept in a vial filled with nitrogen gas under dark condition at -20°C and brought to the laboratory to analyze chlorophyll *a* and phaeopigments for each stage of a copepod species.

To determine gut evacuation rates of copepods, copepods were collected 7 times with the Norpac net with 100 μm mesh at night at Stns 4, 6, and 9. After the sampling, copepods were immediately placed into filtered sea water to rinse animals and put into a 10-liter bottle filled with filtered sea water to monitor the decrease of gut

pigment contents at every 5-minutes. Gut evacuation rate was described by the exponential relation (Dagg and Wyman, 1983). The monitoring duration was not to be longer than 40 min to avoid underestimation of the rate through long incubation. Measurement of the evacuation rate was made at as various stages as possible.

Chlorophyll ingestion rate of a copepod will be calculated according to a model of Elliott and Persson (1978) assuming the evacuation rate is exponential.

This work was done under the cooperative study with Plankton Division, ORI, University of Tokyo and Laboratory of Aquatic Ecology, Tohoku University.

Diel changes in vertical distribution of copepods at Stn 9

Copepods were numerically abundant, making up 81.6 % of the zooplankton assemblage at Stn 9. Chaetognaths, ostracods, and amphipods were subdominant accounting for 8.6, 2.1, and 0.3 %, respectively. Among copepods, *Eucalanus bungii*, *Metridia pacifica* were dominant accounting for 24.0 and 23.8 % of copepods in number, respectively. *Neocalanus plumchrus*, *N. cristatus*, and *Pleuromamma scutullata* were subdominant however their percent compositions were as low as 2.0, 0.6, and 0.3 %, respectively.

Diel changes in vertical distribution of total number of copepods, *E. bungii*, *M. pacifica*, *N. plumchrus*, *N. cristatus*, and *P. scutullata* were shown in Fig. 1. Diel vertical migration was not seen in the total number of copepods (Fig. 1-A). *E. bungii* consisted with copepodid III and IV stages, was mainly inhabiting in 20-170 m layer throughout the day and less abundant in 0-20 m layer even at night (Fig. 1-B). Diel vertical migration was observed in *M. pacifica* inhabiting in 20-170 m layer during the day and migrating into 0-20 m layer at night (Fig. 1-C). Copepodid stages III and IV were dominant in *M. pacifica* accounting for 50.9 and 35.8 % in the daily mean, respectively. *N. plumchrus* dominating with copepodid V (51.0 %) and IV (47.8 %) did not show diel vertical migration inhabiting in the surface layer throughout the day (Fig. 1-D). *N. flemingeri* was not observed in the present study. *N. cristatus* however was mainly distributed in 170-300 m layer throughout the day (Fig. 1-E). Most typical diel vertical migration

was observed in *P. scutullata* consisted by copepodid stage CVI (86.6 %) , inhabiting in the deepest layer of 300-500 m layer during the day and migrating up to 20-170 m at midnight (Fig. 1-F). This species never moved up to the surface layer of 0-20 m.

Copepod feeding

Measurement of the diel changes in gut pigment contents of copepods and the gut evacuation rate were not finish yet. The gut pigment analysis will be done in 1998 to estimate the grazing pressure on phytoplankton.

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Dagg, M.J. and K.D. Wyman, 1983. Natural ingestion rates of the copepods *Neocalanus plumchrus* and *N. cristatus* calculated from gut contents. Mar. Ecol. Prog. Ser., 13, 37-46.

Elliott, J.M. and L. Persson, 1978. The estimation of daily rates of food consumption for fish. J. Anim. Ecol., 47, 977-991.

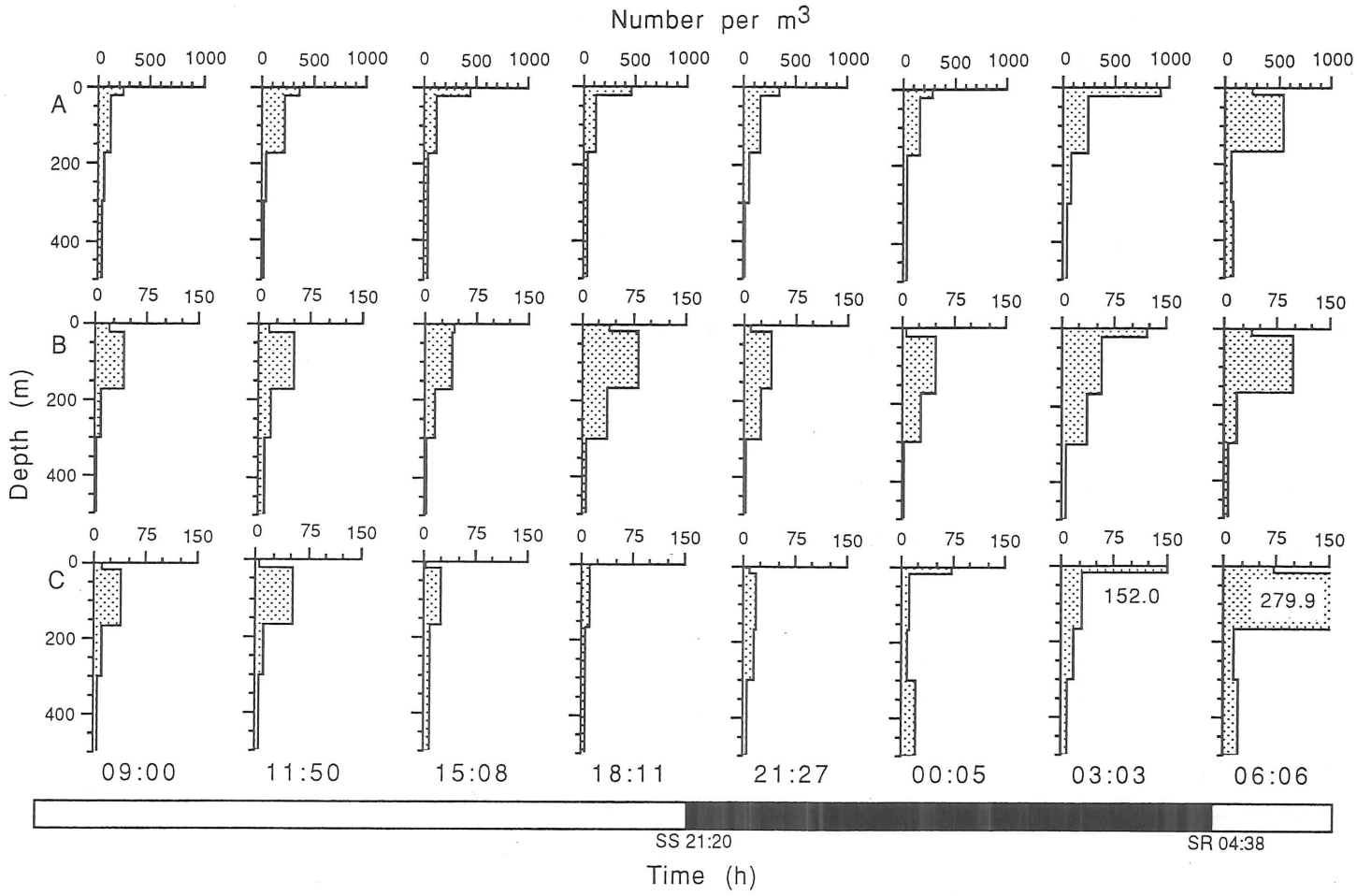

Fig. 1. Diel changes in vertical distribution of total copepod number (A), *Eucalanus bungii* (B), and *Metridia pacifica* (C), *Neocalanus plumchrus* (D), *N. cristatus* (E), and *Pleuromamma scutullata* (F) at Station 9. Open and filled bars represent day and night, respectively.

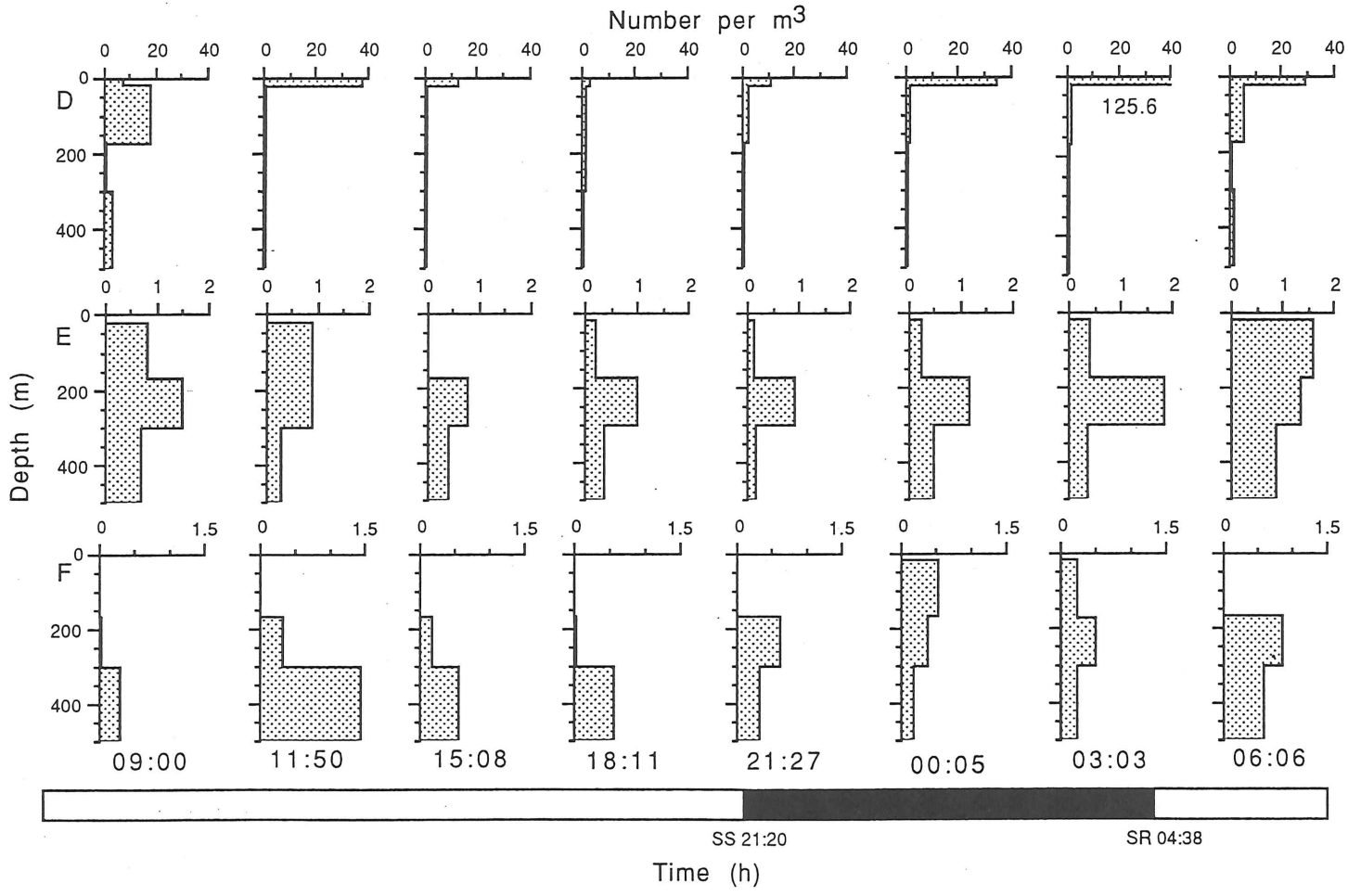

Fig. 1. continued

Studies on diel feeding rhythms and vertical distribution of pelagic chaetognaths

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Chaetognaths are one of the most abundant carnivorous zooplankton group in the world ocean. The purpose of this study is to clarify their feeding habits, especially paying on attention to the diel rhythms in feeding, in the subarctic Pacific. Such knowledge may help later estimation of their feeding impact on zooplankton community.

Samples were collected with a Vertical Multiple Plankton Sampler (VMPS) made of 0.33 mm - mesh nets from four sampling layers at three stations, i. e. Stn 4 (500 - 300 m, 300 - 150 m, 150 - 20 m and 20 - 0 m), Stn 9 (500 - 300 m, 300 - 170 m, 170 - 20 m and 20 - 0 m) and Stn 15 (500 - 300 m, 300 - 120 m, 120 - 15 m and 15 - 0 m). These VMPS hauls were carried out at 3 hour intervals by following a drifting buoy for 48 hours at Stn 4 and Stn 15 but for 24 hours at Stn 9. Samples were immediately fixed and stored in 10 % borax - buffered formalin sea water on board and brought back to land laboratory. Detailed data on the samplings are given in the tables of sampling data of this volume.

After the cruise, specimens of chaetognaths were sorted out from these samples, and offered to identification of species and five developmental stages under a biocular stereo - microscope. To clarify diel feeding rhythms and temporal changes in feeding behavior at different layers at different stations, I will analyze the sorted samples to count number of prey items by species in their guts.

Biomass and production of microzooplankton in the subarctic North Pacific

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Two different works were made for microzooplankton studies as follows: (1) Water samples were collected to estimate biomass of planktonic ciliates, which are prominent members of microzooplanktonic assemblages, and (2) to estimate reproductive rates of the ciliates which is an essential information to understand their contribution to material flow. Basic methods of these works were:

(1) Water samplings to estimate biomass

Water samples were collected with a CTD-RMS from 11 layers in the top 200 m depth at 22 stations, 250 ml aliquot of these samples was preserved with Bouin's fixative and brought back to land laboratory. Individual number of each species of the planktonic ciliates are counted with measuring their cell size under an inverted microscope in land laboratory.

(2) Estimation of reproductive rates by FDC technique

To avoid artifacts caused by incubation experiments which require several stressful manipulations, so-called frequency of dividing cells (FDC) technique was employed. Water samples were collected from one or four layers at 3h intervals for a 24-48 h period at four stations to determine the diel pattern of frequency of dividing cells. These water samples were also preserved with Bouin's fixative. Along with the water samplings, culturing experiments were carried out to check the stability of time duration completing one cell division under varying growth rate. For this, 20 l of waters were sampled from one or two layers at each station and contained in separate polycarbonate cowboy(s), which was (were) placed in a deck tank with running sea surface water. Subsamples were withdrew from the cowboy(s) at 2 h intervals for 24 h to illustrate diel change in FDC. From the results, time duration need to complete one cell division would be calculated.

Table 1. Data on water sampling to estimate microzooplankton biomass. Eleven depth layers in the upper 200 m water column were sampled at every station except at St. 11, where 8 depths in the upper 66 m were sampled because of shallower depth to the bottom (76 m).

St.	Date	Time	Lat.	Long.
St. 1	10-Jul-97	20:50	41°00.60N	147°00.97E
St. 2-3	12-Jul-97	0:42	43°01.87N	155°02.57E
St. 4	14-Jul-97	7:25	48°01.23N	165°03.11E
St. 5	20-Jul-97	22:23	47°58.98N	175°00.79E
St. 6	21-Jul-97	8:24	48°00.92N	177°03.82E
St. 7	24-Jul-97	1:29	49°59.90N	179°59.34E
St. 8	24-Jul-97	17:33	53°29.65N	178°59.01E
St. 9	25-Jul-97	18:28	57°23.76N	178°53.76E
St. 10	29-Jul-97	4:15	57°01.63N	174°01.33E
St. 11	30-Jul-97	4:26	56°59.32N	165°56.68E
St. 13	6-Aug-97	13:19	55°31.26N	151°26.58E
St. 14	7-Aug-97	7:55	53°01.43N	149°59.29E
St. 15	8-Aug-97	17:02	49°53.16N	144°52.77E
St. 16	14-Aug-97	4:00	49°59.12N	140°01.46E
St. 17	25-Aug-97	5:29	44°58.74N	139°59.57E
St. 18	26-Aug-97	19:28	46°27.83N	149°59.50E
St. 19	28-Aug-97	3:10	47°00.37N	159°59.25E
St. 20	30-Aug-97	0:16	46°42.17N	169°59.86E
St. 21	31-Aug-97	4:42	45°30.55N	179°59.96E
St. 22	1-Sep-97	10:45	45°07.50N	169°58.50E
St. 23	2-Sep-97	11:35	44°05.03N	161°43.79E
St. 24	4-Sep-97	22:41	41°59.69N	147°59.15E

Table 2. Data on water sampling to estimate reproductive rate of ciliates by FDC technique.

St. 4		
Cast	Date	Time
A1	14-Jul-97	14:37
A2	14-Jul-97	18:36
B1	14-Jul-97	21:25
A3	15-Jul-97	0:28
B2	15-Jul-97	3:46
A4	15-Jul-97	6:02
B3	15-Jul-97	9:42
A5	15-Jul-97	12:08
A6	15-Jul-97	15:27
A7	15-Jul-97	18:10
B4	15-Jul-97	21:25
A8	16-Jul-97	0:14
B5	16-Jul-97	3:18
A9	16-Jul-97	5:58
B6	16-Jul-97	8:59
A10	16-Jul-97	12:13

St. 6		
Cast	Date	Time
1	21-Jul-97	6:30
2	21-Jul-97	8:30
3	21-Jul-97	10:30
4	21-Jul-97	12:30
5	21-Jul-97	14:30
6	21-Jul-97	16:30
7	21-Jul-97	18:30
8	21-Jul-97	20:30
9	21-Jul-97	22:30
10	22-Jul-97	0:30
11	22-Jul-97	2:30
12	22-Jul-97	4:30
13	22-Jul-97	6:30

St. 9		
Cast	Date	Time
B1	26-Jul-97	22:06
B2	27-Jul-97	1:11
A2	27-Jul-97	4:13
B3	27-Jul-97	6:59
A3	27-Jul-97	10:30
A4	27-Jul-97	12:58
A5	27-Jul-97	16:07
A6	27-Jul-97	19:15

St. 15		
Cast	Date	Time
A1	9-Aug-97	5:21
A2	9-Aug-97	8:43
A3	9-Aug-97	11:33
A4	9-Aug-97	14:13
B1	9-Aug-97	17:11
A5	9-Aug-97	20:28
B2	9-Aug-97	23:31
A6	10-Aug-97	2:05
B3	10-Aug-97	5:08
A7	10-Aug-97	8:27
A8	10-Aug-97	11:15
A9	10-Aug-97	13:55
B4	10-Aug-97	17:34
A10	10-Aug-97	20:22
B5	10-Aug-97	23:16
B6	11-Aug-97	3:55

Studies on heterotrophic microbial activities and cycling of bioelements in the subarctic Pacific and the Bering Sea

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Distinct difference of primary productivity exists between western and eastern part of the subarctic Pacific Ocean. High abundance of phytoplankton and productivity of the upper layer in the Bering Sea and the western part of subarctic Pacific have been recognized for many years, while the Gulf of Alaska has been known as high nutrient and low chla (HNLC) region. The above difference of biological community structures and production at primary and secondary trophic levels should also give the significant differences in the function of microbial food webs, i.e. biomass, metabolic activities of heterotrophic microbes and associated cycling of bioelements, from the upper layer to the abyssal depth of the ocean. To test the above hypothesis, we conducted following chemical analyses, biomass estimation and metabolic activity measurements during the cruise.

Biochemical characters of dissolved and particulate organic materials

a) Particulate organic carbon and nitrogen (POC and PON) concentration (all the routine sampling depths at Stns 4, 9, 15)
b) Dissolved organic carbon and nitrogen (DOC and DON) concentration (all the routine sampling depths at Stns 4, 6, 9, 14, 15, 19 and down to 1000 m depths at all stations for DOC)
c) Composition and concentration of dissolved amino acids (All the sampling depths at Stns 4, 6, 9, 15, 19)
d) Composition and concentration of dissolved carbohydrates (All the sampling depths at Stns 4, 6, 9, 15, 19)

e) Size distribution and number of submicron sized particles (at the routine depths of all stations)
f) Electron microscopic observation of submicron sized particles (at the routine sampling depths of Stns 4, 6, 9, 15, 19)

Components of microbial food webs

a) Biomass of bacterioplankton (at the routine sampling depths of all the stations)
b) Number of heterotrophic nanoflagellates (at the routine sampling depths of Stns 4, 6, 9, 15, 19)
c) Number of viruses (at the routine sampling depths of Stns 4, 6, 9, 15, 19)

Distribution of microbial activities through the whole water column

a) Estimation of bacterial production rates (Stns 4, 6, 9, 15, 19, and other selective stations)
b) Estimation of extracellular enzyme activities (Stns 4, 6, 9, 15, 19 and other selective stations)

Dissolved organic carbon and nitrogen/dissolved amino acids

Based on the recent improvements of analytical precision regarding various components of dissolved organic matters in seawater, large accumulation of semi-labile dissolved organic compounds has been proposed in the upper layer of open ocean. Those large pool of dissolved organic components are degraded by microbial processes gradually during the horizontal and vertical physical transport of water masses. And turnover time of those components would be an order of a few years to several decades. From the above findings, occurrence of the basin scale horizontal and vertical transport of dissolved organic materials has been hypothesized, since the above turnover time is long enough to meet basin scale physical mixing processes.

In this study, role of dissolved organic carbon and nitrogen on the dynamics of carbon and nitrogen in the subarctic Pacific and the Bering Sea was investigated by analyzing vertical and horizontal distribution of dissolved organic carbon and nitrogen (DO and DON) as

well as dissolved amino acids and carbohydrates. Measurements of particulate organic carbon and nitrogen (POC and PON) also important to understand the dynamics of organic carbon and nitrogen pool. At the Stns 4, 9, 15, seawater samples were filtered through GF/F filter and preserved in frozen condition in sealed glass ampoules. Samples from the other stations were preserved as the above without filtration. Dissolved organic carbon and nitrogen are measured by a high temperature catalytic hydrolysis method by using the modified Shimadzu TOC-5000. Dissolved amino acids are measured by a HPLC method after vapor-phase hydrolysis.

Electron microscopic observation of submicron sized particles

In 1990, large abundance of non-living organic colloidal aggregates of submicron size range (submicron particles) has been reported in upper layer of the ocean. The origin and dynamics of those colloidal particles has not been identified in the field, although the presence of those particles has significant effects on the various oceanographic processes, such as light scattering, adsorption of dissolved organic materials as well as metal compounds, and food for micrograzers. Previous studies in our group have shown that 1) several biological parameters (number of heterotrophic nanoflagellates and bacterioplankton, chla concentration) are positively correlated with the abundance of those colloids, and 2) interaction of microbial food web components are important to produce those particles under laboratory model experiments). One of the difficulties to identify the major source of those colloidal particles in the ocean is the technical limitation of previous approaches, i.e., abundance and size distribution by a particle counting method.

To identify the origin of non-living colloidal particles in the ocean, we applied electron microscopic technique using a thin section of the samples obtained from various depth of several stations, together with the use of previous particle counting method. Colloidal particles were collected on Nucleopore filter (0.2 μm) and embedded in Spurr or LR-White resin after dehydration of the samples by series of alcohol solution. For the characterization of the colloidal particles under electron microscope, immunological method will also be applied

together with conventional morphological observation.

Estimation of bacterial biomass and their production

Previous studies in our group have prevailed for the first time that close correlation between the bacterial biomass in deep water (1000-5000 m depth) and biomass of primary producers in the euphotic layer exists in various regions of Pacific Ocean. From the above findings, following hypothesis (upper and deep ocean linkage hypothesis) was proposed, i.e. primary production in upper layer and bacterial production in deep water column is linked closely through the flux of sinking organic particles from upper ocean (biological pump). This hypothesis suggests the important role of bacterial biomass in deep ocean, which has been neglected before, on cycling of bioelements in global ocean scale.

In this cruise, we tested the above hypothesis and tried to expand the scope by measuring bacterial biomass and their production at all the water column (0-5000 m) in the subarctic Pacific and the Bering Sea. Bacterial number was obtained by epifluorescence microscopy after DAPI staining and bacterial production was evaluated by 3H-leucine uptake (10 nM addition) under normal pressure at the in situ temperature. Extraction of high-molecular fraction of isotope-labeled bacteria (5 % TCA and 80 % methanol) was followed by the method of Ducklow, et al. (1990).

Abundance of heterotrophic nanoflagellates in the whole water column of the subarctic Pacific

Presence of heterotrophic nanoflagellates, known as the major grazers of bacterioplankton in the ocean, has been reported from the upper layer to abyssal depth of various oceanic region. Previous knowledge of their abundance, however, is restricted to mostly 200-500 m depth of upper water column, and very few information regarding their abundance are available in middle and deep layer of the ocean. Within euphotic layer of various marine environments, the abundance of heterotrophic nanoflagellates are known to be an order of 10^{-3} of that of bacterioplankton. Also, based on the previous studies in our group, the above correlation can be expanded to below the euphotic layer

(200-400 m depth).

To evaluate the structure of microbial food webs in middle and deep layer of the subarctic Pacific, we tried to count abundance of heterotrophic nanoflagellates at the whole water depth. Nanoflagellates in the samples were collected on Nucleopore filter (0.8 μm) after double staining with DAPI and FITC and evaluated their abundance by using an epifluorescence microscope. Auto- and heterotrophic-nanoflagellates were distinguished by the presence of photosynthetic pigments.

Activities of extra-cellular hydrolytic enzymes in the whole water column of the subarctic Pacific

Since degradation of most marine organic detritus is mediated by the activities of various extra-cellular hydrolytic enzymes, analysis of those enzymes activities give an important clue to understand the degradation mechanisms of organic detritus under natural marine environments. Our previous studies also indicated that large amounts of alkaline phosphatase would be transported to the abyssal depth of ocean through the association of sinking particles.

To expand our understanding of organic carbon and nitrogen dynamics in whole water column of the ocean, we measured three extra-cellular hydrolytic enzymes (alkaline phosphatase, peptidase, β-glucosidase) by using the fluorescence substrate analogues. With the substrate addition of saturated concentrations (0.2 mM), we can interrupt the obtained activity as correlated with the standing stock of respective hydrolytic enzymes. For the samples from 0-300 m depth, the enzyme activities were measured using the sample without any treatments under normal pressure at the in situ temperature. The activities below 300 m depth (300, 1000, 3000 m) were evaluated after concentration of suspended particles in sample water on 0.2 μm Nucleopore filter. Peptidase activities were also measured without any pre-treatments down to the bottom (5000 m depth). Size fractionation of enzyme activities, bacterial abundance and production was tried after concentration of each fraction on 0.2, 0.8, 2.0, 10 μm filters to test the size distribution of three hydrolytic enzymes associated with various aggregates at the middle and abyssal depth.

Microbial degradation of high molecular weight organic materials in upper and deep layers in the subarctic Pacific

As the possible candidate for semi-labile dissolved organic materials (DOM) in the upper ocean, studies on biochemical characters and biodegradation of high molecular DOM in the upper ocean has been conducted during the last several years. Using coastal waters, biodegradation of high molecular DOM was reported to be much faster than that of low molecular DOM. On the other hand, presence of high molecular DOM components, which remained or relatively increased with time among the toal DOM, was observed. The mechanisms of their degradation processes are still poorly understood, partially because of the lack of comprehensive studies from both microbial and biochemical aspects.

In this study, we applied experimental approach to evaluate the control mechanisms of microbial degradation of high molecular organic materials in the ocean. Also, to observe the possible difference of microbial processes associated with DOM in the two contrasted regions of the subarctic Pacific, water samples were collected at western and eastern part of subarctic Pacific (Stns 4 and 15) at two depths (within euphotic layer and deep water). After fractionation of the sample waters into high molecular fraction (>0.1 μm- MW. 10,000) and low molecular fraction (> MW. 10,000), the two fraction samples were incubated with the addition of in situ bacterial population. During the incubation, microbial responses to each organic materials fraction (activities of extracellular hydrolytic enzymes, bacterial biomass, bacterial production) and characters and changes of various organic components (degradation rates of TOC, TON, amino acids and carbohydrates) were monitored at the same time.

Biogeochemical evaluation of marine organic matter in the subarctic North Pacific Ocean and the Bering Sea, by means of biomarkers and their carbon and nitrogen stable isotopic compositions

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Introduction

The aim of this study is to evaluate chemical indicators found in marine organic matters as an appropriate proxies estimating marine productivity and its biogeochemical qualification regarding to the material cycling in the North Pacific Ocean. It has been expected that carbon and nitrogen isotopic compositions of particulate organic matter (POM) in surface water vary with reflecting various environmental factors such as nutrient concentration, dissolved carbon dioxide and primary productivity as well as other diagenetic alteration of organic compounds. Although such usage of isotopes should be continuously investigated for applying it to actual field research, these would be useful to evaluate biogeochemical conditions in the ocean. Biomarkers from both marine plankton and terrestrial plants are known to be useful to assess the origin of organic matter from marine and land ecosystems. Because bulk organic matter is mainly used for stable isotope analysis, isotopic result would be interfered by signal of terrestrial organics. Hence it is necessary to evaluate contribution of terrestrial organics by means of independent indicators for land plant. In addition, such biomarkers have been often used for reconstructing paleoproduction and paleoclimate. We intend to corroborate these parameter based on comparison with modern oceanographic observation, especially on production rate and nutrient abundance. In this context, the analyses are now progressing. We reported here preliminary result of $\delta^{13}C$ and $\delta^{15}N$ of POM collected from Stn 6 located

in south of Aleutian islands arc.

Methods and samples

Particulate organic matter (POM) was collected on a glass-fiber filter(GF/F) from seawater from various water depth. Filters were kept in frozen and dried at a laboratory, decarbonized by diluted HCl, then combusted by sealed quartz tube method. The $\delta^{13}C$ and $\delta^{15}N$ were analyzed by a mass spectrometer (MAT252 and 251). Surface sediment and plankton were treated by organic solvent to extract lipid fractions for biomarker analyses. Long-chained hydrocarbon and alkenone were purified using liquid chromatography technique, and finally introduced in a gas-chromatography system fitted with mass spectrometer. In order to interpret the $\delta^{15}N$ of PON, we are going to analyze $\delta^{15}N$ of nitrate in seawater from major stations in the cruise.

Preliminary results of POC and PON analyses

The analytical results of POC, PON at Stn 6 (46°60'N, 177°06'E, water depth: 5515 m) were shown in Fig. 1. The maximum concentration of organic carbon and nitrogen were found in 20 m layer and 82 μg/l and 16.2 μgN/l, respectively. POC decreases in the mixed layer rapidly along water depth, thus basically in consistent with previously reported profiles in this region. PON reaches 20 μg/l at 2000 m.

The ^{13}C content of POC decreases from -25 ‰ at near surface layer to -29 ‰ in 300 m, suggesting that the carbon isotope ratio of plankton would be controlled by relatively large isotope discrimination probably due to higher dissolved CO_2 in seawater, and furthermore the biological degradation of POC would cause a isotope fractionation towards lighter isotopic values (Table1).

The typical isotopic change on ^{15}N was found for PON-$\delta^{15}N$ in the upper layer; the $\delta^{15}N$ increased from -1 to +10 ‰ along the biological uptake of nitrate in the upper water layer (Table 1). The $\delta^{15}N$ values in this station was thus in the range interpreted by previously reported nitrate drawdown model used for areas where nitrate concentration is sufficient in compared to uptake by phytoplankton. However, present data set suggested that diagenetic isotopic effect due to organic matter

degradation should be also examined to consider for PON as well as in the case of POC. We will investigate this possibility by analyzing $\delta^{15}N$ of nitrate in seawater from same water column.

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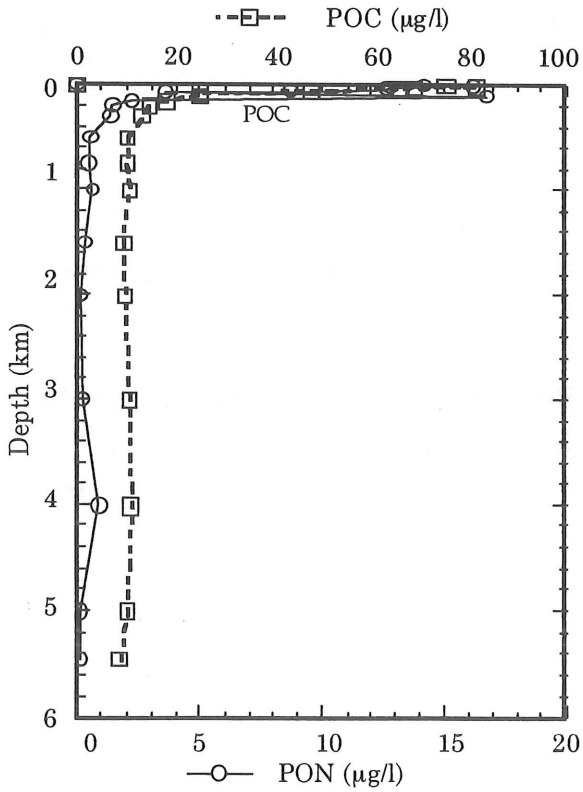

Fig 1. Vertical profile of POC and PON in St.6 (KH 97-2)

Table 1. Analytical results of POM at St.6 (46°60N , 177°06E)

Depth(m)	T (℃)	NO3	POC(μg/l)	PON(μg/l)	$\delta^{13}C$ (vs PDB)	$\delta^{15}N$ (vs AIR)
0	8.90	16.6	75.6	14.21	-25.07	-0.16
10	8.83	16.6	82.0	16.22	-26.08	-1.60
20	8.82	16.7	68.8	12.80	-24.76	-1.41
30	8.27	16.7	66.3	12.65	-25.19	-1.90
50	5.44	18.8	48.0	8.71	-28.25	-2.44
75	4.21	20.6	25.0	3.59	-28.73	0.35
100	3.41	23.7	25.0	16.74	-27.93	-0.12
150	3.11	40.2	18.1	2.21	-28.46	9.06
200	3.33	43.4	14.7	1.44	-29.77	10.06
300	3.46	45.5	13.4	1.35	-29.28	
500	3.32	44.6	10.4	0.50	-31.59	

Distribution of trace elements in the subarctic North Pacific and the Bering Sea

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The distribution and speciation of trace elements in seawater are controlled by various physical, chemical and biological processes. Deficiency of trace elements may limit phytoplankton growth. Our object is to reveal the behavior of trace elements and to elucidate the processes occurring in the ocean. During this cruise, we are studying the distribution of trace elements (Al, Sc, Ti, V, Fe, Co, Ni, Zn, Ga, Y, Zr, Nb, Mo, Hf, Ta, W, etc.) in seawater samples collected with a CTD carrousel sampler.

Distribution of trace bioelements in seawater

Martin et al. reported the distribution of iron and affirmed that iron deficiency is limiting phytoplankton growth in high-nutrient and low-chlorophyll (HNLC) areas such as the subarctic North Pacific and the Antarctic[1,2]. They suggested that oceanic iron fertilization aimed at the enhancement of phytoplankton production may turn out to be the most feasible method of stimulating the active removal of atmospheric CO_2. Concerning this hypothesis, many studies have been carried out and controversies have occurred[3-5]. Also, the possibility of zinc limitation has been reported. However, the data on trace bioelements are limited spatially and temporally. We are now developing a novel simultaneous determination method for the trace bioelements (Fe, Zn, Al, V, Co, etc.). Our method is superior to previous methods in that many bioelements can be determined with a small volume of seawater.

Method

Immediately after sampling, 250 ml of seawater were filtered through a 0.2 μm Nuclepore filter using a closed filtration system in a clean room (No. 4 laboratory). Hydrochloric acid was added to the

seawater samples for preservation. In our laboratory, the samples were adjusted to pH 5 with ammonium acetate buffer and passed through a column of 8-quinolinol immobilized fluoride containing metal alkoxide glass (MAF-8HQ). Collected trace elements on MAF-8HQ were eluted with 25 ml of 0.5 M nitric acid. We are now determining the elements in the eluents with a high resolution ICP-mass spectrometer (HR-ICP-MS; JEOL JMS-PLASMAX1).

Distribution of second and third transition series elements in seawater

Although our knowledge on the distribution of trace elements in the ocean has greatly advanced in the last two decades[6,7], the data on second and third transition series elements are still few. We are investigating the marine chemistry of elements of groups 4, 5 and 6 (Zr, Hf, Nb, Ta, Mo and W). The dissolved species of the elements are presumed to be Zr(OH)4, Hf(OH)4, Nb(OH)6-, Ta(OH)5, MoO42- and WO42- [8]. Except molybdenum, these elements are not thought to be essential to organisms, and their distributions may not be significantly influenced by the active uptake of primary producers. The chemistry of the second and third transition series elements in the same group is very similar, because their ionic radii are close to each other owing to lanthanoid contraction. Zr, Hf, Nb and Ta are incompatible elements and their ratios are little changed by magmatic differentiation[9]. We expect that comparing the distribution and circulation of them will improve our knowledge on the chemical and physical processes which fractionate the elements in the ocean.

Method

The method is basically the same as that for trace bioelements except that the eluent is 0.5 M nitric acid containing 10-2 M oxalic acid. Immediately after sampling, 250 ml of seawater were filtered through a 0.2 μm Nuclepore filter, to which hydrochloric acid and hydrofluoric acid were added for preservation. The samples were brought back to our laboratory and will be subjected to preconcentration with MAF-8HQ and determination by HR-ICP-MS.

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Distributions and speciation of trace metals in the subarctic North Pacific Ocean and the Bering Sea

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Distributions of trace metals

1. Purpose

It has long been thought that trace metals are essential micronutrients for phytoplankton growth in the ocean. Recently, relationships between trace metals and phytoplankton in the ocean have been extensively investigated since "Iron Hypothesis" was advocated by Martin and coworkers. However, only a few data concerning distributions of trace metals were obtained in the worldwide open ocean because of contaminations during sampling and analyses. We have conquered such contaminations completely by using automated analytical methods conducting in closed systems.

In this study, we will extensively investigate distributions of trace metals (iron, manganese, chromium, vanadium and copper) in the subarctic North Pacific and the Bering Sea, which are " High Nutrient, Low Chlorophyll (HNLC)" regions, and reveal biogeochemical cycles of these elements in the ocean.

2. Method

Sampling

Two kinds of samplers were used: lever-action Niskin samplers and conventional Niskin samplers. In order to reduce the contamination level as low as possible, all the samplers had been completely coated with Teflon paint on their inside walls before the cruise. Silastic tubings, contamination-free silicone rubber, is used as rubber spring for the Niskin sampler. Samplers were washed with previously reported method (Obata et al., 1997).

Analyses on board

a) Iron

Iron(III) in seawater was determined on board automatically in a closed flow system using chelating resin concentration and chemiluminescence detection (Obata et al., 1993). 125 mL of unfiltered seawater was adjusted to pH 3.0 with 5 M formic acid-ammonium formate buffer solution. The sample solution was passed through the chelating resin column (MAF-8HQ, 8-quinolinol immobilized fluoride containing metal alkoxide glass). Then the column was rinsed with cleaning solution (pure water), and the eluent (0.3 M hydrochloric acid) was passed through the column. The eluent was mixed with alkaline luminol solution, solution of hydrogen peroxide and 0.6 M aqueous ammonia, and the mixture was introduced into the CL cell through the mixing coil. The Fe(III) was determined by measurement of CL intensity. The column was washed with 1M hydrochloric acid after elution and washed with pure water to remove the hydrochloric acid. The relative standard deviation was 5 % for 10 replicate measurements of purified seawater containing 0.1 nM Fe(III). The detection limit (3s) was 0.01 nM.

b) Manganese

Manganese was determined on board by the automated-Mn analysis system which is based on column electrolysis preconcentration and chemiluminescence(CL) detection (Nakayama et al., 1989). In brief, 50 mL of unfiltered seawater adjusted to pH 5.0 by adding ammonium acetate buffer solution was introduced to the system. Mn in the sample was adsorbed onto a glassy carbon column electrode. The column was rinsed with the cleaning solution (pure water), and then hydrogen peroxide solution adjusted to pH 4 with ammonium acetate buffer solution was passed through the column. The eluent was mixed with alkaline luminol solution and the mixture was introduced into the CL cell through the mixing coil. Finally, Mn was determined by measurement of the CL intensity. Mn determined with this system was called "total adsorbable Mn", which contained Mn(II) ions and part of the colloidal Mn. The relative standard deviation for five replicate measurements at 3.6 nM was 3.2 % and the determination limit(3s) was 0.14 nM for the typical analysis condition. The total throughput

of analysis was 8 samples per hour.

c) For other metals, samples were brought back to our laboratory

Chromium and copper will be determined with chemiluminescence method and vanadium will be determined with catalytic method.

3. Sample

Seawater samples were taken at each depth in the Stns 1 - 23.

4. Result and discussion

Now, we are analyzing the samples and discussing the data. One of the results already obtained is presented here. Figure 1 shows the vertical profile of iron, obtained in this study, in the Stn 15 and that measured by Martin and coworkers in the same station (Stn P) in 1987. Our data show a maximum concentration of iron in the surface layer. Iron is mainly supplied to the surface in this area by precipitation containing aeolian mineral dust. The maxima are thought to exhibit a strong aeolian signature. Same maxima are also reported by Bruland et al. (1996) and Wu et al. (1996). Our result is quite different from that of Martin et al. One of possible causes is temporal variations of iron distribution since the residence time of iron is very short in the surface. Another possible cause is the difference of the sampling methods and analytical methods. Our data were obtained by analyzing only one sample series. It is necessary to measure another series of the samples and discuss the reliability of the data strictly. We are going to analyze and discuss the samples pretreated with a different method.

Speciation of copper in seawater

1. Purpose

Interaction between trace metals and phytoplankton in the ocean depends on not only its concentration but also its species. Especially, organically bound iron and copper may give some effects to phytoplankton growth in the ocean. We will study organically bound copper in seawater qualitatively and quantitatively.

2. Method

a) Separation of the hydrophobic fraction of the organically bound copper

We separated and concentrated the hydrophobic fraction of the

organically bound copper by passing 100 mL of seawater samples through a hydrophobic ODS column (SepPakC18Plus), washed with 1N hydrochloric acid, methanol and MQW, successively before use. The columns on which organically bound copper was concentrated, were brought back to the laboratory and preserved.

b) Decomposition of the organically bound copper with UV-irradiation and determination of copper

After eluting hydrophobic fractions collected on the ODS column with methanol, their concentrations are determined with chemiluminescence method using o-phenanthroline-hydrogen peroxide system in alkaline condition. The eluted hydrophobic fractions will also be decomposed with low-pressure Hg lamp (400W) and copper in this fraction will be determined with the same method.

c) Determination of dissolved copper

Copper which can be concentrated on a chelating resin column directly and after decomposition with UV-irradiation will also be determined with above mentioned chemiluminescence method.

3. Sample

Seawater samples were taken at each depth in the Stns 17, 19, 21, 22 and 23.

4. Result

Now, we are studying the condition of decomposition of the sample with UV irradiation. Decomposition time depends on the structures and its concentrations of the organic ligands. Therefore, after we carry out the basic examination using samples of which concentrations are relatively high, eg., lake water samples and coastal samples, we will apply the method to the samples obtained during this cruise.

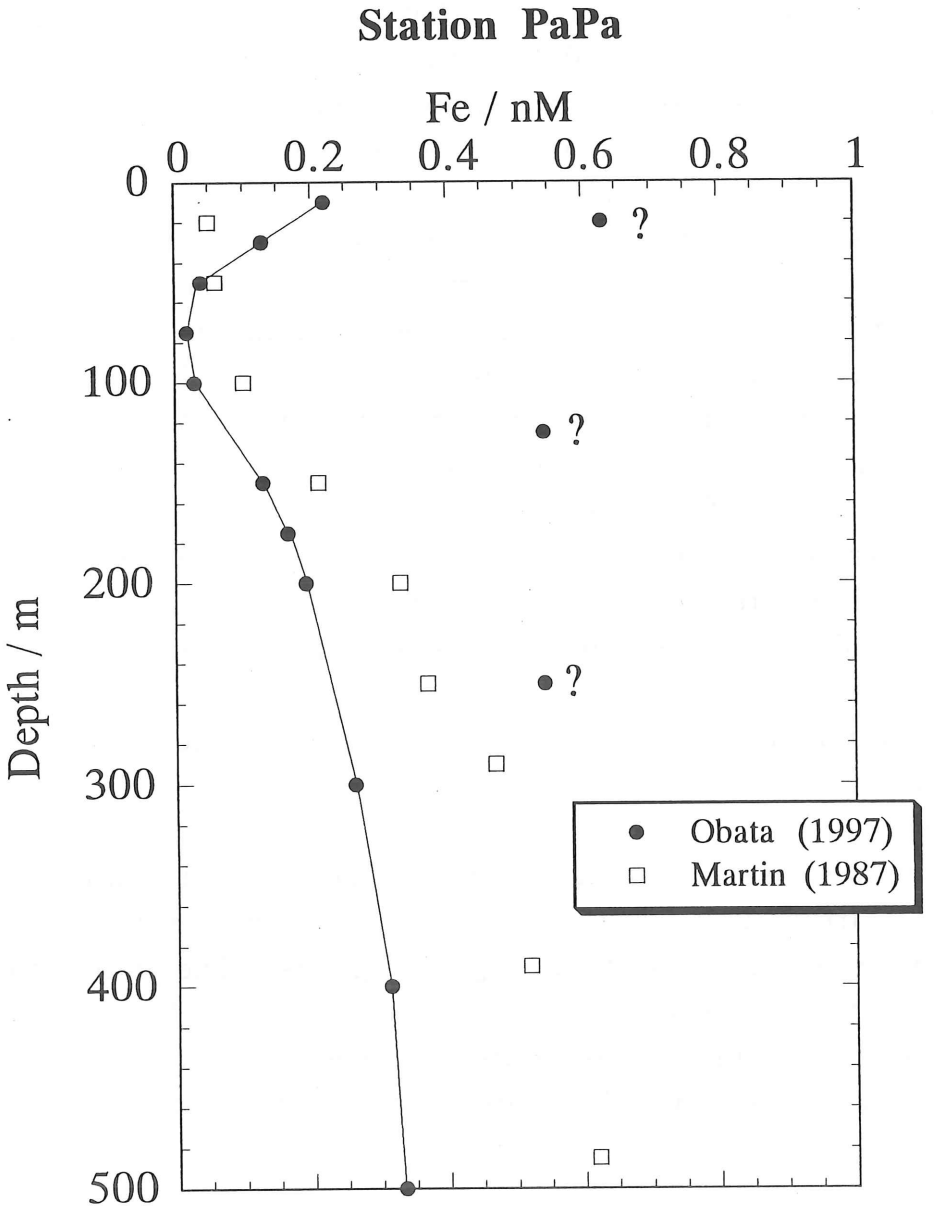

Figure 1. Vertical Profiles of iron in St. PaPa

Dynamics of biophile trace elements with biological production in the subarctic North Pacific and the Bering Sea

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Biological products are the starting materials of marine biogeochemical cycles. Marine organisms accumulate not only major biophile elements (C, N, P, Si, S, etc.) but also trace elements. But data on multi-element compositions of marine biological products, that is, organic matter, opal, and calcium carbonate, have been quite limited (e.g., Bowen, 1979) especially for plankton of known species.

The present study aims to obtain multi-element compositions of phytoplankton, zooplankton species, and suspended particles in the euphotic zone, and to clarify the relationships of multi-element composition among these categories. The constancy of the multi-element composition relative to the average river water composition found for the zooplankton species from the Japan Sea (MKT plot; Masuzawa et al., 1988, 1994) will be examined for phyto- and zooplankton samples from the North Pacific and the Bering Sea.

Sampling

Phytoplankton samples were collected from the euphotic zone with a NORPAC P-25 net (mesh aperture: 25 μm) with a pre-net of NGG 52 (335 μm) at 14 stations as listed in Table 1. At each station usually four samples were collected and concentrated in 50-ml pre-washed polyethylene centrifuge tubes by centrifugation with a SAKUMA M-200 refrigerated centrifuge in a refrigerated room at 4°C. One of the

four samples at each station was washed with Milli-Q water. All centrifuged samples were stored in a freezer, carried back to the laboratory on land, and freeze- and vacuum dried. Sea salt content of a dried sample was estimated from the weight loss of water during drying (Table 1).

Zooplankton species were identified and separated from the ORI net samples collected in 0- ca. 1000 m layer at 5 stations (Table 2) and rinsed in Milli-Q water once and stored in a freezer. The frozen samples carried back to the laboratory on land were also freeze- and vacuum dried.

Suspended particles were collected by filtration with 0.2 μm nuclepore filters for 1.5 liter of seawater sampled from the euphotic zone and stored in a freezer.

Chemical analysis

Major components of phytoplankton samples (organic matter, opal, calcium carbonate and clay) will be measured by stepwise chemical leaching technique and trace element composition in each fraction will be determined by ICP atomic emission spectrometry (ICP-AES). Zooplankton samples and suspended particles will be subjected to ICP-AES analysis.

Milli-Q washed phytoplankton and zooplankton samples were analyzed by instrumental neutron activation analysis (INNA; Masuzawa et al., 1988, 1989) using the KUR reactor of Kyoto University.

Results and discussion

The preliminary results of short lived nuclides by INNA are tabulated for phytoplankton and zooplankton samples in Tables 3 and 4, respectively.

Aluminum contents, which show clay (lithogenous aluminosilicate) contents, were relatively high in spring diatom samples from the Otsuchi Bay ranging from 0.22 to 1.8 % (Masuzawa, 1997). The Al contents in phytoplankton samples from the North Pacific have been relatively low except for PL125 from Stn 13 located near Kodiac Island. This suggests that Al contents of phytoplankton samples are affected

by the distance of collection sites from lands.

The analysis of long-lived nuclides are being processed. After obtaining major component data and trace element data, more detailed discussion will become possible.

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Table 1. Phytoplankton samples (25-335μm) collected with a NORPAC P-25 net from the North Pacific and the Bering Sea during KH97-2 Cruise.

Stn.	Name	Date	Time	PL No.	Sampling Depth(m)	Times	Sweep V. (m^3)	Dried W. (g)	Net W.* (g)
1	1a	970711	6:00-7:00	PL073	50	1	7.95	0.1646	0.0018
	1bMQ**			PL074	60	4	38.15	0.1350	0.1350
	1c			PL075	60	3	28.61	0.5724	0.2393
	1d			PL076	60	3	28.61	0.4749	0.1238
2/3	2/3aMQ	970712	9:15-10:30	PL077	100	3	47.69	0.1323	0.1323
	2/3b			PL078	100	3	47.69	0.4683	0.1323
	2/3c			PL079	100	3	47.69	0.5028	0.1518
	2/3d			PL080	100	3	47.69	0.4827	0.1718
4	4Aa1MQ	970714	15:00-15:30	PL082	50	2	15.90	0.2072	0.2072
	4Aa2			PL083	-	-	-	0.9103	0.2824
	4Ab1			PL084	50	1	7.95	0.7167	0.1725
	4Ab2			PL085	-	-	-	0.7041	0.1936
4	4Ba1MQ	970717	5:45-6:15	PL086	50	1	7.95	0.0479	0.0479
	4Ba2			PL087	-	-	-	0.2504	0.0543
	4Bb1			PL088	50	1	7.95	0.3088	0.0444
	4Bb2			PL089	-	-	-	0.2867	0.0299
4	4Ca	970719	4:30-5:00	PL090	50	1	7.95	0.2887	0.0322
	4Cb			PL091	50	1	7.95	0.2792	0.0299
6	6Aa	970721	7:00-8:00	PL092	100	3	47.69	0.1550	0.0648
	6AbMQ			PL093	100	3	47.69	0.1569	0.1569
6	6BaMQ	970722	4:15-5:30	PL094	90	3	42.92	0.0726	0.0726
	6Bb			PL095	90	3	42.92	0.1351	0.0585
	6Bc			PL096	90	3	42.92	0.0926	0.0014
	6Bd			PL097	90	3	42.92	0.0854	-0.0021
6	6CaMQ	970723	4:40-5:50	PL098	90	3	42.92	0.1622	0.1622
	6Cb			PL099	90	3	42.92	0.1670	0.1273
	6Cc			PL100	90	3	42.92	0.1404	0.1098
	6Cd			PL101	90	3	42.92	0.1249	0.0985
7	7aMQ	970724A	0:40-1:15	PL102	50	1	7.95	0.0339	0.0339
	7b			PL103	50	1	7.95	0.1856	0.0679
	7c			PL104	50	1	7.95	0.1708	0.0574
	7d			PL105	50	1	7.95	0.1881	0.0657
8	8aMQ	970724B	4:00-5:00	PL106	50	3	23.84	0.0574	0.0574
	8b			PL107	50	3	23.84	0.0364	0.0214
	8c			PL108	50	1	7.95	0.0859	0.0369
9	9AaMQ	970725	6:30-7:30	PL109	50	3	23.84	0.0672	0.0672
	9Ab			PL110	50	3	23.84	0.2124	0.1143
	9Ac			PL111	50	3	23.84	0.1959	0.1026
	9Ad			PL112	50	3	23.84	0.2156	0.1150
9	9BaMQ	970725	19:15-20:15	PL113	50	3	23.84	0.2164	0.2164
	9Bb			PL114	50	3	23.84	0.3108	0.1937
	9Bc			PL115	50	3	23.84	0.3232	0.1804
	9Bd			PL116	50	3	23.84	0.4180	0.2315
9	9CaMQ	970726	5:30-6:30	PL117	50	3	23.84	0.1298	0.1298
	9Cb			PL118	50	3	23.84	0.3666	0.2068
	9Cc			PL119	50	3	23.84	0.2704	0.1299
	9Cd			PL120	50	3	23.84	0.2146	0.1213

Table 1. (Continued)

Stn.	Name	Date	Time	PL No.	Sampling Depth(m)	Times	Sweep V. (m^3)	Dried W. (g)	Net W.* (g)
10	10aMQ	970728	13:00-13:30	PL121	30	1	4.77	0.0398	0.0398
	10b			PL122	30	1	4.77	0.3056	0.0685
	10c			PL123	30	1	4.77	0.1599	0.0430
	10d			PL124	30	1	4.77	0.2240	0.0463
13	13aMQ	970806	4:30-5:30	PL125	50	3	23.84	0.0754	0.0754
	13b			PL126	50	3	23.84	0.2692	0.0834
	13c			PL127	50	3	23.84	0.1465	0.0370
	13d			PL128	50	3	23.84	0.1305	0.0245
14	14aMQ	970806	20:30-21:30	PL129	50	3	23.84	0.0008	0.0008
	14b, c, d			PL130	50	3*3	71.52	0.0692	0.0104
15	15Aa,bMQ	970808	14:00-1500	PL133	70	3*2	66.76	0.0048	0.0048
	15Ac,d			PL134	70	3*2	66.76	0.0603	0.0603
15	15BaMQ	970811	18:00-19:20	PL135	50	6	47.69	0.0007	0.0007
	15Bb			PL136	50	6	47.69	0.0668	0.0004
15	15CaNPF	970812	6:20-7:50	NPF235	50	6	47.69	0.0079	0.0079
	15CbNPF			NPF236	50	6	47.69	0.0071	0.0071
16	16aMQ	970813	18:00-19:00	PL137	90	6	85.84	0.0024	0.0024
	16b			PL138	90	6	85.84	0.0078	-0.0075
	16c			PL139	90	3	42.92	0.0019	-0.0110
17	17aMQ	970824	18:30-19:30	PL140	50	3	23.84	0.1705	0.1705
	17b			PL141	50	3	23.84	0.5552	0.1561
	17c			PL142	50	3	23.84	0.4877	0.1356
	17d			PL143	50	3	23.84	0.4495	0.1231
19	19a	970827	13:30-14:30	PL144	50	3	23.84	0.0839	-0.0006
	19b			PL145	50	6	47.69	0.1927	0.0051
19	19cMQ	970827	3:30-4:00	PL146	70	5	55.64	0.0117	0.0117
	19d			PL147	70	5	55.64	0.1103	0.0100

* Net weight is estimated by subtracting salt content, which is estimated from the loss of water by freeze drying, from dry weight.

** MQ denotes the samples which were washed with Milli-Q water by centrifugation.

Table 2. Zooplankton samples collected from the North Pacific and the Bering Sea during KH97-2 Cruise.

Stn.	Date	Zoo No.	Species	Wet Weight (g)
4	970718	1	*Neocalanus cristatus(CV)*	0.8918
		2	*Sagitta elegans*	1.1478
		3	*Hymenodora frontalis*	2.5388
		4	*Eucopia grimaldii*	1.2898
		5	*Beroe spp.*	-
6	970723	6	*Neocalanus cristatus(CV)*	0.5778
		7	*Hymenodora frontalis*	2.5168
		8	*Eucopia grimaldii*	1.1778
		9	*Sagitta elegans*	1.2418
		10	*Bentheogennema borealis*	2.4738
9	970727	11	*Neocalanus cristatus(CV)*	1.2698
		12	*Sagitta elegans*	1.6568
		13	*Hymenodora frontalis*	4.1978
		14	*Eucopia grimaldii*	1.9618
		15	*Themisto pacifica*	1.4288
15	970808	16	*Neocalanus cristatus(CV)*	0.7108
		17	*Eucopia grimaldii*	1.5268
		18	*Sagitta elegans*	0.3628
		19	*Hymenodora frontalis*	2.0728
		20	*Bentheogennema borealis*	5.6438
		21	*Cyclosalpa bakeri*	-
19	970828	22	*Neocalanus cristatus(CV)*	0.6348
		23	*Sagitta elegans*	1.4168
		24	*Hymenodora frontalis*	1.1788
		25	*Eucopia grimaldii*	1.4168
		26	*Eucopia grimaldii*	1.4598
		27	*Bentheogennema borealis*	0.9308

Table 3. Chemical compositions of phytoplankton samples (25-335μm) collected from the North Pacific and the Bering Sea during KH97-2 Cruise by neutron activation analysis.

Stn.	Name	PL No.	Al (ppm)	Ca (%)	Na (%)	Cl (%)	Br (ppm)	I (ppm)	V (ppm)	As (ppm)
1	1bMQ	PL074	1070	6.40	0.332	1.161	890	194	ND	ND
2/3	2/3aMQ	PL077	1220	2.67	0.261	0.945	387	64	17.4	ND
4	4Aa1MQ	PL082	1340	ND	0.277	0.848	230	68	ND	ND
6	6AbMQ	PL093	1180	ND	0.297	0.393	248	48	ND	ND
6	6BaMQ	PL094	950	ND	0.236	0.637	754	123	13.7	ND
6	6CaMQ	PL098	1140	ND	0.256	ND	238	38	9.2	ND
7	7aMQ	PL102	1130	5.30	0.156	0.484	1743	317	11.9	ND
9	9AaMQ	PL109	1230	2.35	0.138	0.31	1089	109	ND	ND
9	9BaMQ	PL113	3400	ND	0.141	0.148	938	100	ND	ND
9	9CaMQ	PL117	1340	ND	0.136	ND	882	121	52.6	ND
13	13aMQ	PL125	8660	1.40	0.319	1.291	560	148	38.2	ND
17	17aMQ	PL140	1560	ND	0.092	0.738	391	150	52.0	ND

Table 4. Chemical compositions of zooplankton species collected from the North Pacific and the Bering Sea during KH97-2 Cruise by neutron activation analysis.

Stn.	Zoo No	Species	Al (ppm)	Ca (%)	Na (%)	Cl (%)	Br (ppm)	I (ppm)	V (ppm)	As (ppm)
4	Z-01	*Neocalanus cristatus(CV)*	ND	ND	0.55	1.68	168	ND	ND	8.2
4	Z-02	*Sagitta elegans*	ND	ND	0.86	7.20	242	ND	ND	ND
4	Z-04	*Eucopia grimaldii*	ND	0.91	1.19	3.14	162	ND	ND	6.1
6	Z-06	*Neocalanus cristatus(CV)*	33	ND	0.44	1.37	296	ND	ND	11.7
6	Z-08	*Eucopia grimaldii*	ND	ND	1.76	4.76	216	ND	ND	ND
6	Z-09	*Sagitta elegans*	ND	ND	0.78	2.91	77	ND	ND	ND
9	Z-11	*Neocalanus cristatus(CV)*	ND	ND	0.53	1.29	183	ND	ND	8.8
9	Z-12	*Sagitta elegans*	34	ND	0.58	3.64	132	ND	ND	ND
9	Z-14	*Eucopia grimaldii*	ND	ND	1.23	2.98	181	ND	ND	6.0
9	Z-15	*Themisto pacifica*	ND	4.46	1.32	2.69	385	ND	ND	6.8
15	Z-16	*Neocalanus cristatus(CV)*	ND	ND	0.89	4.44	692	60	ND	ND
15	Z-17	*Eucopia grimaldii*	ND	ND	1.67	2.31	165	ND	ND	8.7
15	Z-18	*Sagitta elegans*	ND	ND	0.69	4.08	153	ND	ND	ND
19	Z-22	*Neocalanus cristatus(CV)*	ND	ND	0.62	3.64	651	51	ND	ND
19	Z-23	*Sagitta elegans*	ND	ND	0.59	3.41	82	ND	ND	ND
19	Z-25	*Eucopia grimaldii*	138	ND	2.05	4.61	244	ND	ND	8.5
19	Z-26	*Eucopia grimaldii*	ND	ND	1.98	4.73	292	ND	ND	7.3

Organic geochemistry of aerosols, particulate organic matter, and sediments in the subarctic North Pacific

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Introduction

Organic aerosols have been studied in the remote marine atmosphere for better understanding the long-range atmospheric transport of continental materials over the ocean. Peltzer and Gagosian (1989) and Kawamura (1995) reported lipid class compounds including n-alkanes, fatty alcohols, fatty acids and long chain dicarboxylic acids in the marine aerosols from the western Pacific and showed that they are derived from terrestrial higher plants and soil organic matter mainly from the Asian continent. The organic compounds in the marine atmosphere are scavenged to the ocean surface by wet and dry deposition processes and transported to the deep sea floor as sinking particles in the water column. The terrestrial biomarkers which are abundantly present in the deep sediments from the Pacific Ocean (Kawamura, 1995, Ohkouchi et al., 1997a) have been used to reconstruct past changes in the atmospheric transport of continental materials over the western Pacific Ocean (Ohkouchi et al., 1997b). However, terrestrial biomarkers have rarely been studied in the sinking particles and particular organic matter in the water column of the Pacific Ocean.

Organic geochemical studies on the marine aerosols have also shown that water soluble organic acids including oxalic and other small dicarboxylic acids are abundant in the marine aerosols (Kawamura and Usukura, 1993). They comprise up to 18 % of total aerosol carbon in the Pacific atmosphere and their latitudinal distribution showed that the small diacids are produced in the marine atmosphere by photochemical oxidation of various organic compounds,

mostly light hydrocarbons and oxygen-containing organic compounds (Kawamura and Sakaguchi, 1998). The water soluble organic compounds in the marine atmosphere are probably transported over the central and eastern Pacific and the organic aerosols should be enriched with oxalic acid and other water soluble organic species. Water soluble organic acids have recently received much attention as important aerosol species because they can act as cloud condensation nuclei (CCN) and play a role in radiative forcing (cooling the earth surface) by scattering solar radiation. Recent studies suggested that organic aerosols are more important CCN than inorganic aerosol species such as sulfate. However, molecular distributions of organic aerosols are rarely studied in the atmosphere of the Pacific Ocean, in which an impact of an increasing anthropogenic emissions derived from incomplete combustion of fossil fuels in the Asian countries on atmospheric compositions are continuously increasing.

In contrast, marine sediments contain many organic compounds which are produced in the euphotic zone. Some of them can be used as tracers to understand biogeochemical processes in the ocean surface. For example, sedimentary long chain unsaturated ketones (C37 alkenones) which are produced by haptophyte algae, are now widely used to reconstruct the sea surface temperatures in the past ocean (Brassel et al., 1986, Ohkouchi et al., 1994, Ikehara et al., 1997). Fatty acids and other lipid compounds are also useful to better understand microbial degradation and their resynthesis of organic matter in the water column (Kawamura et al., 1987, Wakeham, 1995).

In this study, we collected various geochemical samples including marine aerosols, atmospheric gases, water particulates, and deep sea sediments from subarctic North Pacific and Bering Sea for the further development of marine organic geochemistry. The sample analyses are now going on in the laboratory for various elements (C, N, and S) and organic molecules including alkanes, alkenones, fatty alcohols, fatty acids, dicarboxylic acids, etc.

Samples and methods

1. Gas sampling for nonmethane hydrocarbons in the marine boundary layer

Recently, tropospheric ozone levels appear to have stabilized in many regions in the world, except for Asia where its level is increasing. This has been attributed to anthropogenic emissions such as nitrogen oxides, CO, and nonmethane hydrocarbons (NMHCs). However, only a few data of NMHCs are available in the western North Pacific, where major air masses come from the Asian continent. The purposes of this work are (1) to observe longitudinal distribution of longer-lived NMHCs (e.g., ethane, propane), (2) to examine the spatial distributions of shorter-lived NMHCs (ethylene, propylene) in the Bering Sea, in which biological productivity is relatively high, (3) to assess the role of halogen (Cl) chemistry in air masses during long-range transport.

Air samples were collected on the forth floor of the R/V Hakuho Maru (about 20 meters above sea level) by pressurizing the stainless canisters with a metal bellows pump to about 1.5 atm. All the canister samples (total 25 samples) were shipped to the laboratory for gas chromatographic (GC) analysis. Light hydrocarbons (C2-C6) in the canisters were concentrated using a pre-concentration unit and measured using a GC equipped with a flame ionization detector.

2. Aerosol sampling for organic compounds in the remote marine atmosphere

Water soluble organics alter hygroscopic behavior of atmospheric particles, suggesting that water soluble organic compounds play an important role in controlling cloud albedo by acting as CCN. The cloud activity may compensate the potential global warming caused by the increased concentrations of greenhouse gases such as carbon dioxide. Their ability to act as CCN also depends on the size as well as chemical composition. However, molecular composition of water soluble organic aerosols have rarely been reported in the marine atmosphere. The aim of our measurements in this expedition is first to obtain the spatial distributions of total carbon, nitrogen and sulfur contents in the marine aerosol samples as well as the molecular composition of organic aerosols, including n-alkanes, n-alcohols, dicarboxylic acids, and fatty acids. We will also obtain data for their size distributions.

Marine aerosol samples (totally 11 samples) were collected on upper deck of R/V Hakuho Maru using a pre-combusted quartz fiber filter and high volume air sampler. Filter samples were stored in a pre-cleaned

glass jar with a Teflon-lined screw cap at 20°C prior to analysis. High volume sampler with 5-stage impactor was also operated on the ship to obtain size segregated aerosols using quartz fiber filters (total 5 sets). Rainwater samples were also collected using a stainless steel rain collector. The rain samples were stored in a brown-colored glass bottle with a Teflon-lined screw cap, to which small amount of HgCl2 (ca. 10 mg) was added as bactericide.

Small portion of filter samples will be subjected to a CHNS elemental analyzer to measure total carbon, nitrogen and sulfur contents. Aliquots of aerosol filter samples will be extracted with KOH/methanol under a reflux to separate lipids. The lipids extracts will be divided into neutral and acidic fractions and further isolated to individual compound classes. Normal alkanes, alcohols and fatty acids will be determined using a GC and GC/mass spectrometer.

3. Distribution of lipids in particulate organic matter in the subarctic North Pacific and the Bering Sea

The ocean plays an important role in the carbon cycle on the earth, which is largely influenced by biogeochemical processes. Particulate organic matter (POM) which is the second most important reservoir of organic carbon in the oceans following dissolved organic carbon, is primarily produced by phytoplankton. Thus, molecular distributions of the POM are highly variable in seawaters depending on season, location, water depth, etc. To understand the biogeochemical cycles of organic carbon, we need to analyze the POM at molecular levels.

For collecting seawater samples, we used CTD equipment. The data of seawater temperature, salinity and dissolved oxygen were measured simultaneously. After the sample collection, seawaters were filtrated through a Whatman GF/F filter (47 mm) on board. All the filter samples were taken in a glass vial and stored at -20°C until analysis.

Totally 105 POM samples were collected at 5 sites as below.

Station 4 (47°55.44' N, 165°21.03' E), 29 samples.
Station 6 (48°08.24' N, 176°41.87' E), 19 samples.
Station 9 (57°15.47' N, 199°48.48' W), 19 samples.
Station 15 (49°53.78' N, 144°74.86' W), 19 samples.
Station 19 (46°58.10' N, 160°07.59' W), 19 samples.

Lipids will be extracted from the particulate samples (filter samples) with organic solvents, followed by silica gel column chromatography prior to the determination of compound classes (hydrocarbons, alkenones, sterols and fatty acids) using capillary GC and GC/MS. We will also determine carbon isotopic ratio ($\delta^{13}C$) of the individual lipid compounds. The molecular and isotopic results will be discussed with the data of phytoplankton species.

We expect that the abundance of POM is high in the mixed layer because the sampling sites are located in high latitudes in which the productivity is regarded as high. A compositional change of lipids in POM will depend on the decomposition and resynthesis by microorganisms. In addition, the stable carbon isotopic analysis will give us a good chance to evaluate the contribution of phytoplankton to POM. We will discuss the difference in the molecular and isotopic composition of POM between the subarctic North Pacific and the Bering Sea; the former is open ocean and the latter is considered as relatively closed ocean. In this study, we also expect to find new types of organic compounds which can be used as new biogeochemical markers in the future.

4. Deep sea sediments

Deep-sea sediments were collected from the subarctic North Pacific and Bering Sea using the Multiple Corer (Fig. 1 and Table 1). These sediments are mainly composed of siliceous ooze with terrigenous materials in the Bering Sea and subarctic North Pacific. However, the lower fraction of the sediments (Stn 15) from Alaska Bay are composed of carbonate ooze. We obtained basically two sub-cores from each site. One of the cores were split into working and archive halves. The working half of each core was subjected to the sampling using a cube sampler (2.3 x 2.3 x 2.3 cm) for shore-based analysis, such as physical properties, magnetic susceptibility, and grain size. Another half was used for visual core description with means of a hand-held color scanner and smear slides. The archive half was photographed with color film and then stored in refrigerator. Another cores were sliced at every 1 cm from top to bottom. Each section was taken in the clean vials and stored in the freezer for organic geochemical analysis.

5. Preliminary results of the sediments in Stn 15MC

A multiple core (Stn 15aMC) was recovered from the near Stn PAPA (49°59.4'N, 144°59.3'W, 4268 m) in the Alaska Bay. The core sediments in the upper section are composed brownish gray siliceous clays with biogenic opal (radiolarians and diatoms) and those in the lower section are light gray calcareous clays (Fig. 1). Biogenic disturbance was weakly observed throughout the core, however, it was recognized moderately in the boundary section from the lower calcareous to the upper siliceous layers. The ice-rafted debris (IRD), which reached to coarse pebble size (>16 mm) in diameter, occurred in the surface and the lower section from 19 to 24 cm (Fig. 1). These results indicate that the sediments in the lower section with IRD may correspond to the last glacial period and will provide useful information on paleoceanography. Therefore, we plan to analyze this core sample for stable isotope ratios of planktonic and benthic foraminifera, some biomarkers (alkenones, hydrocarbons, fatty alcohols, and fatty acids), and microfossil assemblage (planktonic foraminifera, radioralians, and diatoms) to reconstruct the variations of paleoceanographic conditions in the Northeast Pacific.

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Table 1. Core list in KH97-2 cruise.

Core Name	Latitude	Longitude	Depth (m)	Area	Lipids core (cm)
St. 2/3MC	43°02.47'N	155°03.53'E	5350	Western North Pacific	0-27
St. 4aMC	47°51.43'N	165°37.77'E	5854	Western North Pacific	0-29
St. 4bMC	47°47.71'N	166°10.79'E	5902	Western North Pacific	-
St. 6aMC	48°00.96'N	176°58.89'E	5076	Western North Pacific	0-30
St. 6bMC	48°05.43'N	176°55.06'E	5289	Western North Pacific	-
St. 8MC	53°29.23'N	179°58.53'E	763	Bering Sea	0-26
St. 9MC	57°27.62'N	179°52.13'E	3810	Bering Sea	0-30
St. 11MC	56°59.77'N	165°58.42'W	76	Bering Sea	0-15
St. 12MC	54°06.55'N	159°46.68'W	2665	Eastern North Pacific	0-25
St. 14MC	53°01.79'N	149°49.00'W	4658	Eastern North Pacific	No recovery
St. 15aMC	49°59.4'N	144°59.3'W	4268	Eastern North Pacific	0-27
St. 15bMC	49°54.81'N	144°39.19'W	4186	Eastern North Pacific	-
St. 16MC	49°58.30'N	140°03.13'W	3916	Eastern North Pacific	-
St. 19MC	47°00.06'N	160°00.05'W	5149	Eastern North Pacific	0-29

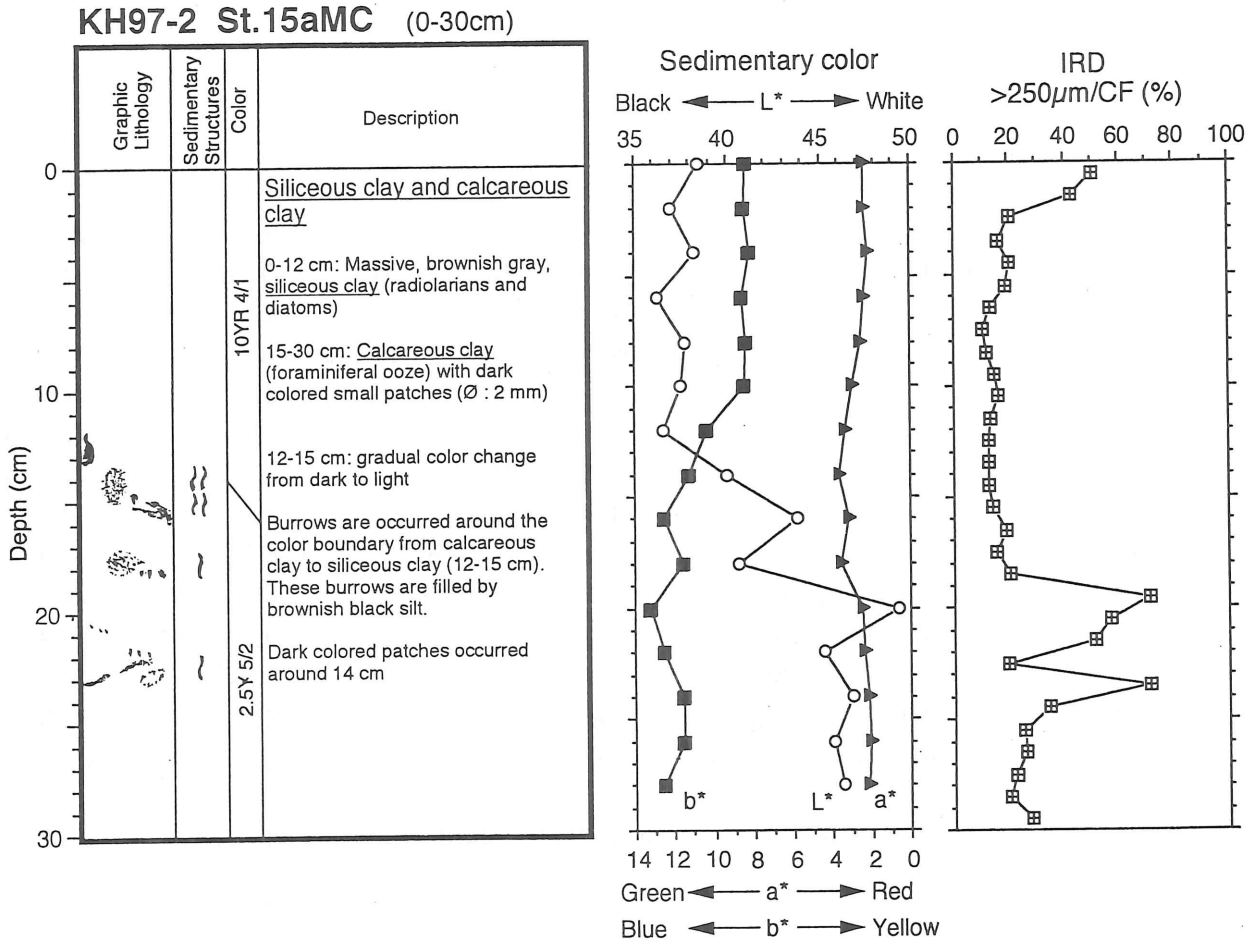

Fig. 1. Visual description and records of sedimentary color and ice-rafted debris (IRD) of multiple core KH-97-2 Stn 15aMC. IRD index is represented by relative concentrations of large grain (Ø:>250 μm) per coarse grains (Ø:>63 μm).

Electrical conductivity, aerosols and radon-222 concentration in the atmosphere over the subarctic North Pacific Ocean and the Bering Sea

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Introduction

We have analyzed the distribution trend of radon, its daughters and aerosols, which are dispersing from land to wide region over ocean, and the variation trend of electrical conductivity in the atmosphere near the sea surface.

We have repeatedly made the observation of these parameters by ship, mainly the research vessel "Hakuho Maru", Ocean Research Institute, University of Tokyo.

And the following we present about measuring instruments and methods used in this cruise, and the observation results and study of discussion on the observation results obtained from this cruise.

Instruments used in this cruise

1. Atmospheric electrical conductivity

We used a Gerdien-type apparatus for measurement of atmospheric electrical conductivity. The apparatus was set on the starboard side of the upper deck at height about 12 m above the sea surface. We measured alternately positive and negative conductivity at an interval of five minutes and also continuously through the full period of cruising.

2. Rn-222 concentration

We used semiconductor detector (HORIBA Ltd. Silicon Surface Barrier Type, 300SB 120L) for alpha ray detection from radon daughters collected on an air filter. Alpha ray spectrometry was adopted for measurement of Po-218 and Po-214. Assuming the radioactive equilibrium among Rn-222, Po-218, Pb-214 and Bi-214,

radon concentration is estimated from the alpha disintegration rates of Po-218 and Po-214 (Mochizuki, 1982).

The measurement was made at an interval of 4 hours or 8 hours (5 times a day) through the full period of the expedition cruise. Collection time of radon daughters and analyzing time were both set at 8000 sec.

Radon daughters were collected on a membrane filter (TOYO-ROSHI Ltd. TM-100) with a suction pump at flow rate of 60 liter/min. Sample air taken at the upper deck was introduced by sampling tube through a sampling hole of laboratory.

3. Particle concentration

We used a Pollak condensation nuclei counter for number concentration of Aitken particle ($r<0.1\mu m$). And, we used a Particle Counter (KC-01 RION Co. Ltd.,) for number concentration of large particles ($r>0.15\mu m$) and giant particles ($r>1.0\mu m$). We measured continuously though the full period of cruising.

Observation results obtained from this cruise

Observation results of the atmospheric electrical conductivity and the number concentration of particles during this cruise are shown in Fig.1. Fig.1 presents the results every an hour from Vancouver (8/22) to Tokyo (9/7). We used arbitrary unit for number concentration of Aitken particles for proofreading of the apparatus was imperfect. And we didn't measure Rn-222 concentration for an apparatus trouble. Atmospheric electrical conductivity levels ranged from 3.01×10^{-15} to 33.5×10^{-15}S/m, number concentration levels of large particles ranged from 0.94/cc to 104.77/cc, number concentration levels of giant particles ranged from 0.0001/cc to 1.41/cc on the sea.

On the observation data obtained in the North Pacific in 1983 (Tanji, 1994), atmospheric electrical conductivity levels ranged from 7×10^{-15} to 22×10^{-15} S/m. On the mid Indian Ocean in 1993 (Okino, 1996), those levels ranged from 13×10^{-15} to 31×10^{-15} S/m.

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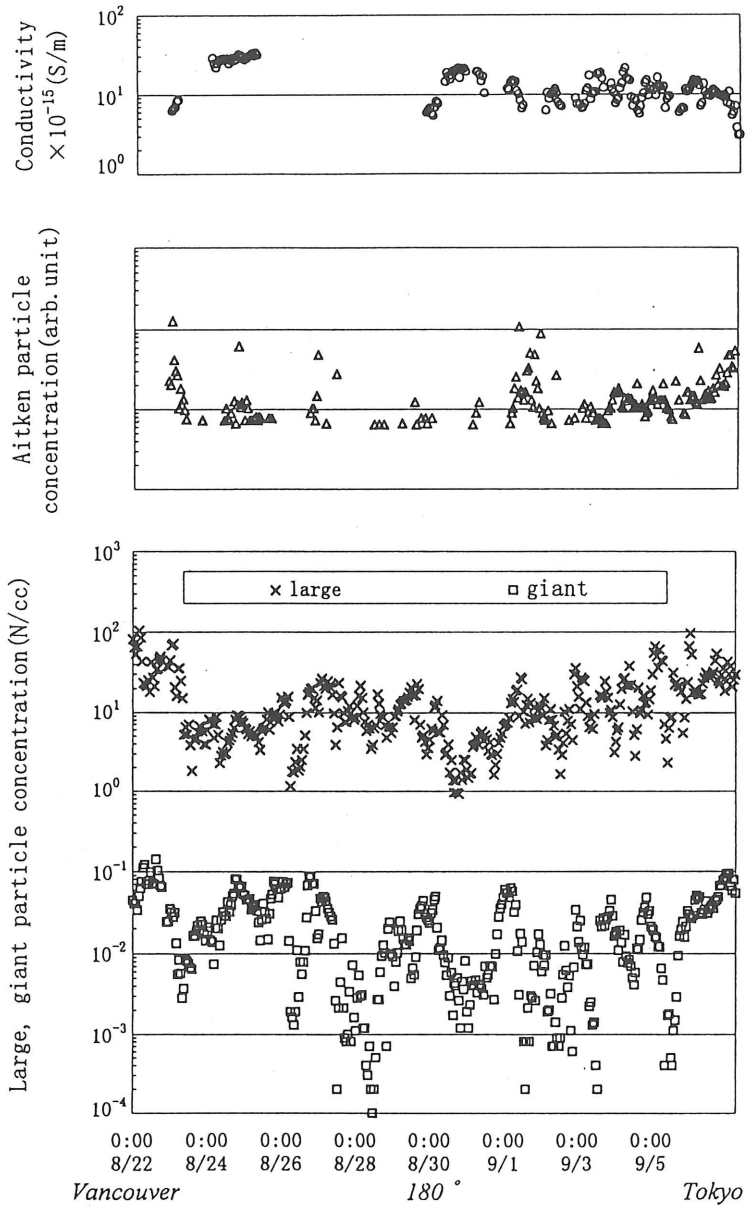

Fig. 1 Electrical conductivity and number concentration of particle(Aitken, large, giant)

Study on aerosol particles over the subarctic North Pacific Ocean and the Bering Sea

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Introduction

It is generally admitted that atmospheric aerosol particles has impact to the global climate directly and indirectly. The direct effects of aerosols on the climate are due to scattering solar radiation and absorbing infrared radiation. Aerosol particles also may indirectly influence on cloud formation process.

To examine the effect of aerosols to the global climate, it is suitable to do the measurements of aerosols in oceanic atmosphere, whose aerosols are well-known as background aerosols. We have measured the background aerosol particles on board in the past thirteen expeditions of the R/V Hakuho Maru (KH-89-T3, KH-89-2, KH-91-5, KH-92-5, KH-93-3, KH-94-1, KH-94-3, KH-94-4, KH-95-1, KH-95-2, KH-96-3, KH-96-5, KH-97-1) (Miura et al., 1991, 1993, 1995, 1996, 1997). In this expedition, we first measured aerosols over the subarctic North Pacific Ocean and the Bering Sea.

Methods

1. Particle concentration and size distribution

Counting of aerosol particles was continuously carried out with two counters on an upper deck, being about 15 m above the sea surface and in the direction of 30 degrees left from the front of a funnel. Aitken particle concentrations ($r<0.1$ μm) were measured with a Pollak condensation nuclei counter. Larger particle concentrations ($r>0.15$, 0.25, 0.5, 1, 2.5 μm) were measured with an optical particle counter (KC01, Rion Co. Ltd.). We used concentrations larger than 0.15 and 1

μm in radius as those of large and giant particles, respectively.

High concentration of aerosol particles was sometimes caused by the exhaust of ship. To avoid exhaust gases of ship, we omit the data measured during a calm (relative wind speed is less than 1 m/s) period or a period of blowing from the funnel.

2. Optical property of aerosols

In order to study the optical properties of aerosols over the ocean, solar radiation has been measured with two instruments. Portable sunphotometer (MS-120(S), Eko Co.) is convenient for measuring direct solar radiation on board, because it is light (1.5kg) and has a peak hold circuit. The light signals are detected by a photodiode after passing the interference filters with peak transmission wavelengths 368, 500, 675, 778, and 862 nm (Miura et al., 1997). Automatically scanning sky radiometer (POM-01, Prede Co.) was also used to measure optical thickness and size distribution. This radiometer with wavelengths of 315, 400, 500, 870, 940, and 1040 nm can measure not only direct solar radiation but also scattering radiation. To search the sun, sun sensor and active controller with horizontal sensor were used. We calculate volume distribution in column with these radiations (Nakajima et al., 1983).

3. Chemical property of aerosols and gas

We collected aerosols on a nuclepore filter (0.8 μm in pore size) with a low volume air sampler for 24 hours at least when the ship was running. Water solble components and insoluble components are analyzed with an ion chromatographic analyzer (IC200, Yokogawa Co.) and a wavelength dispersive X-ray fluorescence spectrometer (System 3270E1, Rigaku Denki Co.), respectively (Matsuda et al., 1995). Some gas was also collected on a filter (Whatman-41) impregated with K2CO3 and analyzed with the ion chromatographic analyzer.

Aerosols were also collected on a carbon-covered nitrocellulose film (supported on an electron microscopic grid with an cascade impactor (Model I-1L, PIXE Int. Corp.). Individual particles collected on the grid are analyzed with an energy disperse X-ray analyzer (EMAX200, Horiba Co.) attached to an electron microscope. This system can quantify all the elements with atomic numbers Z>= 11 within a particle (Miura et al., 1991).

In order to know the concentration level of carbonyl sulfide (COS) air was collected with sampling bag (10 L). In laboratory, COS is analyzed with a gas chromatograph (Shimadzu GC-15A) equipped with a flame photometric detector.

4. Radon and radon daughter concentration

Radon concentration was measured continuously by use of a radon monitor. The devise was composed of an semi-spherical stainless steal chamber with a volume, 24 liters and a ZnS(Ag) scintillation detector for alpha counting. A high voltage (2 kV) was applied between the chamber and the detector. The freshly formed RaA atoms which are positively charged were deposited on the detector covered with a thin aluminum foil and the alpha activity from the nuclide was counted. The radon concentrations were calculated based on a Bateman equation and the counts of the alpha for a hour.

Concentrations of individual radon daughter were also measured by a continuous radon daughter monitor. In the monitor, radon daughters were sampled on a membrane filter (1 μm in pore size) on a roll type (60 mm in width and 10 m in length) and the gross alpha activity was counted a three different times. The first counting was done for 15 min while the air sampling was going on; the second and third countings were done for 20 min each in succession while the sampling was stopped. The individual concentrations of RaA, B and C were calculated from a Bateman equation and the three counting values.

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The molecular oceanographic study of myctophid fish in the North Pacific

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Introduction

The present genetic structures of marine organism populations have been formed by both historical and contemporary environmental factors (Avise, 1993). If we can discriminate effects of contemporary factors from those of historical ones, the past oceanographic changes may be able to be estimated on the basis of the present information of the genetic structure of marine organisms. In order to establish such a "molecular oceanographic" methodology, it is necessary to accumulate information on genetic structure for many marine species of various taxa, which are chosen to cover the wide range of marine organisms both phylogenetically and ecologically and to analyze relationships among the structure of each species, its experienced environmental conditions and the biological characteristics such as larval types, feeding types and geographical distribution. For this purpose, we have already analyzed genetic structure of some group of marine animals, namely deep-sea giant clams (Kojima et al., 1995, 1997), intertidal barnacles (Hasegawa et al., 1996), vestimentiferan tube worms (Kojima et al., 1997), Japanese turban shells (Kojima et al., 1997), deep-sea gastropods (Kojima et al., in submitted), deep-sea demersal fish (Kojima et al., in preparation) and ship worms (Itani et al., in preparation). In the present study, we planned to analyze the genetic structures of dominant species of myctophids in the North Pacific. As myctophids are dominant mid-water fish of the North Pacific and each species is thought to has diverged at various taxonomic level between the western and eastern North Pacific, they are expected to offer ideal objects for molecular oceanographic researches.

Preliminary results and future study plan

During the present cruise, enough number of specimens for analysis of genetic structure could be obtained for five myctophid species, namely *Stenobrachius leucopsarus*, *S. nannochir*, *Diaphus theta*, *Protomyctophum thompsoni*, *Tarletonbeania taylori* / *crenularis*. As preliminary survey, we determined nucleotide sequences of a part (363 bp) of mitochondrial gene, cytochrome oxidase I (COI) for three specimens collected at station Stn 5 (the western North Pacific) and three specimens at Stn 15 (the eastern North Pacific) for all of the five species. Numbers of obtained polymorphic sites and haplotypes are summarized in Table. Although no species can not be divided into regional clusters, namely specimens from the western North Pacific and those from the eastern North Pacific, genetic differentiation between populations of those two sea areas will be able to be tested by statistical methods on the basis of information on haplotype compositions of populations, which will be obtained by analyzing enough number of samples (more than 15-20 specimens) for each population. Now, we are planning to sequence the same region (or longer region if necessary) of mitochondrial DNA for all frozen specimens of the dominant five species mentioned above, collected in the present cruise. Based on the obtained data, we will quantify a degree of the genetic divergence of each of those five species and analyze relationships between the genetic divergence and the ecological characteristics of each species.

Table. Number of polymorphic sites and haplotypes in a part of the COI region of obtained for each six specimens of five dominant species of the North Pacific myctophid fish

Species	Number of polymorphic sites	Number of haplotypes
Stenobrachius leusopsarus	9	5
Stenobrachius nannochir	3	4
Diaphus theta	2	3
Protomyctophum thompsoni	6	4
Tarletonbeania taylori / crenularis	3	4

Abyssal benthic foraminifera from the North Pacific -Toward a better understanding of the origin of deep-sea benthic communities-

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Introduction

The deep-sea environment is characterized by year-round low temperatures, high hydraulic pressure and complete darkness, and comprises one of the least-known ecosystems of the world. However, benthic organisms are unexpectedly diverse on abyssal plains. How and why are benthic organisms diverse in deep-sea environments? What is the origin of deep-sea taxa? This is the fundamental motivation for starting this research.

Benthic foraminifera are one of the most abundant deep-sea organisms. They sometimes account for up to 50 % of the total deep-sea biomass (Snider et al., 1984). They have tests composed of secreted calcite or agglutinated grains that can be preserved in the sediments, and they have been used to infer both present and past changes in deep water oxygenation, circulation, and surface productivity (Thomas, 1992). In addition to foraminifera with tests, soft-shelled benthic foraminifera have been reported from bathyal to abyssal depths of the north Atlantic Ocean (Gooday, 1986, Gooday et al., 1995). However, very few soft-shelled foraminifera have been reported from the Pacific up to the present, because few studies had been carried out for abyssal benthic foraminifera in the Pacific Ocean.

Recently, anthropological disturbances such as deep-sea mining and deep-sea dumping of waste materials are planned by many countries in the Pacific. Risk assessments are required to understand how anthropological disturbances impact deep-sea environments and deep-sea ecosystems. For doing environmental assessments, we should know what kind of organisms are living on the deep-sea floor of the

Pacific. Furthermore, we should know the role that deep-sea organisms play deep-sea food webs and the global carbon cyclings.

In this report, we preliminarily describe foraminiferal taxa from the deep-sea floor of the North Pacific. This is only the second report describing benthic foraminifera from the North Pacific deep-sea floor since the Challenger Report by Brady (1884).

Sampling procedure and treatments

Fourteen multiple core samples were collected both from the North Pacific Ocean and the Bering Sea during the KH-97-2 Cruise (Table 1). Sediments from the cores were sliced every 1 cm from the sediment surface through 15 cm at each locality. Sliced samples were fixed with 5 % Seawater-Formalin-Rose Bengal solution on board. Fixed samples were washed through a 391 mesh (38 μm) sieve. Residual sediment particles with small organisms were stored in 140 ml glass bottles in a 70 % ethylene glycol-tapwater solution. Foraminifera were picked from wet sediments in a petri dish with a small pipette and sealed in single-hole micro slide glasses.

Preliminary results

Three core-top samples from Stns 2/3, 4a and 6a were observed for benthic foraminifera. Specimens that were stained with Rose Bengal were picked and identified. Occurrences of benthic foraminifera are listed below.

Stn 2/3, 0 - 0.5 cm:
Reophax scorpiulus, *Reophax* spp., *Rhabdammina* sp., *Lagenammina* spp., *Resigella* sp., *Nodellum* sp., *Allogromia* sp., *Trochammina* sp., *Ginesina* ? sp., *Cystammina* sp., *Lagena* sp., mudball-type larger foraminifera, Komokiacea

Stn 4a, 0 - 1 cm:
Martinottiella sp., *Reophax scorpiulus*, *Reophax* spp., *Hormosina pilulifera*, *Hormosina* sp., *Marsipella* sp., *Lagenammina* spp., *Rhabdammina* sp., *Allogromia* sp., *Trochammina* sp., *Nodellum* sp., *Glomospira charoides*, mudball-type larger foraminifera, Komokiacea

Stn 6a, 0 - 0.5 cm:
Reophax gaussicus, *Reophax scorpiulus*, *Reophax* spp., *Nodellum membranaceum*, *Nodellum* sp., *Allogromia* sp., *Spirosigmoilina* sp., *Textularia* sp., *Resigella* sp., *Allogromia* sp., *Fursenkoina* sp., *Hormosina globulifera*, *Morulaeplecta* sp., *Tolypammina* sp., *Cystammina pusilla*, mudball-type larger foraminifera, Komokiacea

Foraminiferal associations were composed both of soft-shelled smaller species and large robust agglutinated species. Three calcareous species, *Lagena* sp., *Fursenkoina* sp. and *Spirosigmoilina* sp., occurred in samples even though samples studied were collected from a water depth below the CCD. However, no empty calcareous tests occurred in the sediments. This means that calcareous foraminifera can survive at below the CCD, but probably dissolve immediately after death. Large agglutinated foraminifera, one to several mm in size, are common in the North Pacific, as Brady (1884) noted. The faunal compositions were different from those of the equatorial Pacific Ocean (Snider et al., 1984, Kitazato and Okamoto, 1997). About 50 % of the species from the North Pacific were conspecific with those in the equatorial Pacific. However, *Saccammina* spp. are scarce in comparison to the equatorial Pacific. Species diversity in the foraminiferal fauna is lower in the North Pacific than in the equatorial Pacific. This may support the hypothesis that deep-sea organisms originate from the surrounding sea of the Antarctic and migrate to the north (Wilson and Hessler, 1987). Diversity should decrease towards north according to the hypothesis. Further faunal and taxonomic studies are required for a better understanding the diversity trends in deep-sea benthic foraminifera and their mechanisms and area of diversification in the Pacific.

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Table 1. Station list for multiple corer

Station	Date	Latitude	Longitude	Depth (m)	Sediment Description
2/3	7/12	43°02.47'N	155°03.53'E	5350	Siliceous ooze
4a	7/17	47°51.43'N	165°37.77'E	5854	
4b	7/19	47°47.71'N	166°10.79'E	5902	Siliceous clay
6a	7/21	48°00.96'N	176°58.89'E	5076	
6b	7/22	48°05.43'N	176°55.06'E	5289	Siliceous ooze
8	7/24	53°29.23'N	179°58.53'E	763	
9	7/28	57°27.62'N	179°52.13'E	3810	
11	7/30	56°59.77'N	165°58.42'W	76	Silty clay with sand
12	7/31	54°06.55'N	159°46.68'W	2665	
14	8/7	53°01.79'N	149°49.00'W	4658	
15a	8/9	49°59.4'N	144°59.3'W	4268	Siliceous clay and foraminiferal clay
15b	8/10	49°54.81'N	144°39.19'W	4186	
16	8/14	49°58.3'N	140°03.13'W	3916	
19	8/27	47°00.06'N	160°00.05'W	5149	Siliceous ooze with clay

Hydrographic structure in the subarctic Pacific

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During the present cruise oceanographic observations were conducted at a total of 23 stations in the subarctic North Pacific, including three stations (Stns 4, 9 and 15) for time-series observations in the Western Subarctic Gyre, the Bering Sea and the Gulf of Alaska, respectively. Temperature, salinity, dissolved oxygen and fluorescence intensity were measured and water samples were collected in the upper 1000 m (11 stations) or from near-bottom to the surface (12 stations) with a CTDO (SEA-BIRD'S, 9-plus) equipped with a Carousel water sampler (SEA-BIRD'S SEB32) and Aquatracka (CHELSEA Ltd., MCIII Type).

Station 4, in the Western Subarctic Gyre, was located to the west of the Emperor Sea Mount. The T-S diagram (Fig. 1) indicates that it belongs to the Pacific Subarctic Water, where a temperature-minimum layer, termed dichothermal water, remains at around 100-m depth in summer, despite warming of the surface water. The dichothermal water is associated below with the mesothermal water of a higher temperature. At Stn 4 there was no salinity minimum layer and the dichothermal water (<3°C) existed in the 73-140 m layer, with the temperature minimum (1.99°C) at about 125 m. Below this layer there was marked decrease of dissolved oxygen and marked increase of salinity with depth, a typical pattern in the Subarctic Water.

The Bering-Sea Water is formed of the inflow of Subarctic Current and the Alaska Stream, the latter originating from the Gulf of Alaska, but still little is known of the relative importance of these currents.

The Alaska Stream flows westward along the south side of the Aleutian Islands and enters the Bering Sea. A part of the stream flows to the Arctic Sea and a part forms an anti-clockwise gyral current. However, most of the inflow forms the East Kamchatka Current and outflows to the Pacific along the Kamchatka Peninsula. A part of the

outflow enters the Okhotsk Sea, while the other flows eastward to form the Subarctic Current.

The vertical patterns of temperature, salinity and dissolved oxygen at Stn 4 are largely similar to those at Stn 9 (located in the Eastern Aleutian Basin), except that the depth of temperature minimum and the upper limit of halocline is about 25 m shallower at Stn 4 (125 m) than at Stn 9 (150 m) (Fig. 2).

At Stn 15, in the Gulf of Alaska, the upper 20-m layer was well mixed, with the surface salinity (<32.6) lower, and the upper limit of halocline shallower (100-m depth) than at Stns 4 and 9. In addition, unlike at Stns 4 and 9, there was no dichothermal water.

The dichothermal water diminished gradually from the western side of the North Pacific to the east and was undetectable at Stn 20 (45°30'N, 180°00'E). The T-S diagram (Fig. 1) indicates that Stns 4, 9 and 15 all belong to the Pacific Subarctic Water, but the upper waters (salinity< 34) were characteristic to the respective regions, reflecting the influence local hydrographic conditions .

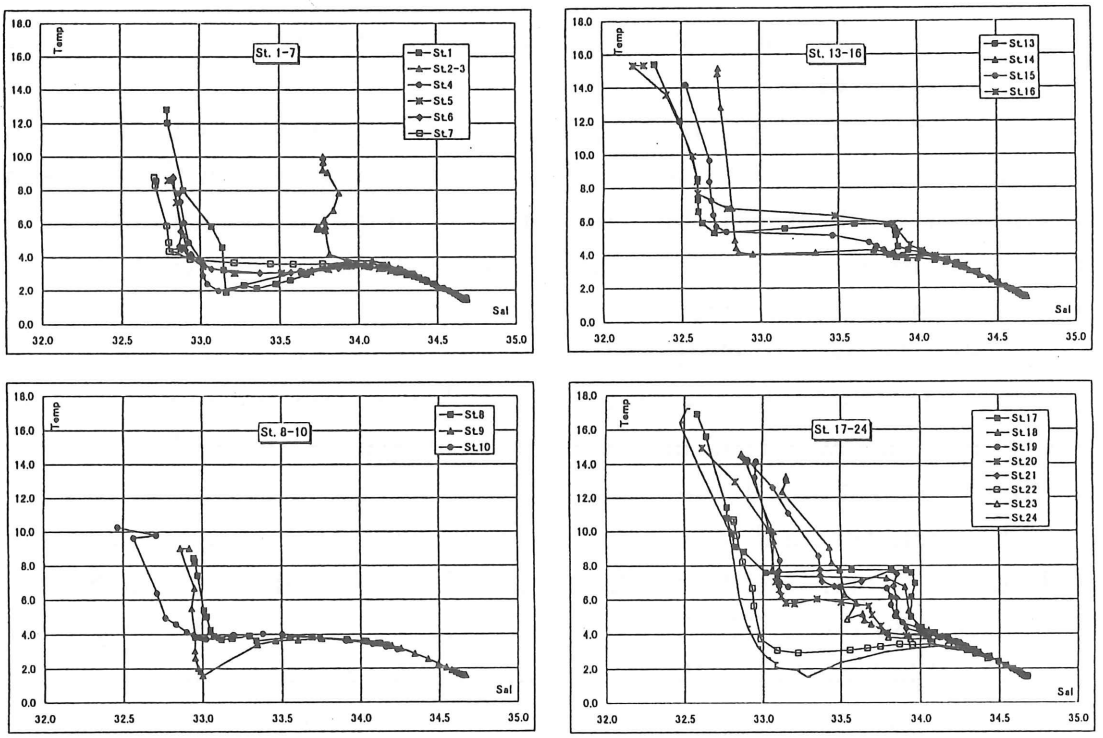

Fig. 1. T-S diagrams. Data collected from CTDO casts were used.

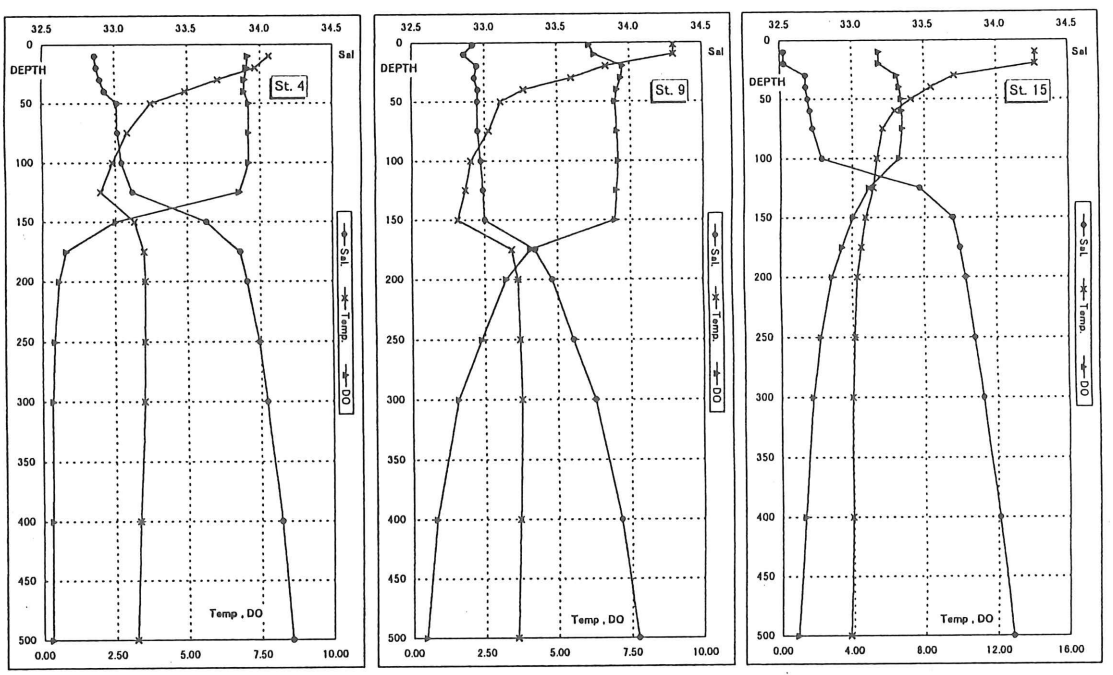

Fig. 2. Vertical profiles of temperature, salinity and oxygen at Stations 4, 9 and 15.