

Temporal Variability of Primary Production and Energy Flow in Arctic Sea Ice Area (PREFLA Project)

Mitsuo FUKUCHI,* Yasuhiko NAITO* and Takao HOSHIAI*

北極海氷域における基礎生産とエネルギー移動の時系列的変動の研究
(PREFLA 計画)

福地光男*・内藤靖彦*・星合孝男*

要旨:「北極海氷域における基礎生産とエネルギー移動の時系列的変動の研究」(“PREFLA”計画)は、昭和63年度から平成2年度までの3年計画であり、文部省科学研究費・国際学術研究として実施されている。本計画は、季節的に海水におおわれる北極海域において、基礎生産過程およびその深層への沈降過程を時系列的に明らかにすることを目的とする。同時に、エネルギー移動の過程における動物プランクトンの役割を明らかにするものである。南極沿岸域との比較を念頭におき、調査海域として、北部ベーリング海とチャクチ海を選んだ。本計画はアメリカ合衆国が同海域で実施している「大陸棚上における物質・エネルギーの移送と循環」計画(“ISHTAR”計画)と協同で実施されている。本研究計画の概要と昭和63年・平成元年の野外調査概要をまとめた。

Abstract: “Temporal variability of primary production and energy flow in Arctic sea ice area (PREFLA)” is a three-year program of 1988–1990, which is supported with a grant under the Monbusho International Scientific Research Program. The program aims to clarify the temporal variations of primary production and its downward flux as well as to evaluate the role of zooplankton in energy flow. The northern Bering Sea and the Chukchi Sea are selected to compare the ice-associated biological process in the Antarctic coastal areas. The program cooperates with the U. S. program of “Inner Shelf Transfer and Recycling (ISHTAR)”. Three field observations were made in 1988 and the other two observations were done in 1989.

1. Introduction

Sea areas covered with the seasonal sea ice expand in two polar oceans and their maximum areas are 15 and 20 millions km² in the Arctic and in the Antarctic, respectively (GLOERSEN and CAMPBELL, 1988). The whole ice areas occupy about 10% of the global sea surface.

In the Antarctic, the international BIOMASS (Biological Investigations of Marine Antarctic Systems and Stocks) program was carried out in 1977–86 to gain a deeper understanding of the structure and dynamic functioning of the Antarctic marine ecosystem. Seagoing activities with multiships operations were mostly confined in the summer season. Shore-based studies were designed to complement and add year-round continuity to the offshore ship-based studies. At Japanese Syowa Station (69°00'S, 39°35'E), the year-round observations were carried out for 3 years of 1982–84 and seasonal variability of hydrography, phyto- and zooplankton, and ice algal communities were investigated in the coastal fast ice areas (FUKUCHI *et al.*, 1985a, b; HOSHIAI, 1985; TANIMURA *et al.*, 1984a, b; WATANABE and SATOH, 1987). However,

* 国立極地研究所. National Institute of Polar Research, 9-10, Kaga 1-chome, Itabashi-ku, Tokyo 173.

the intermediate area, between the northern open water and the coastal fast ice has been less investigated, where the so-called pack ice area/ice edge zone exists.

The marginal ice zone not only in the Antarctic but also in the Arctic are known as a major area of high productivity (ALEXANDER, 1980; ALEXANDER and NIEBAUER, 1981; SMITH *et al.*, 1988; SULLIVAN *et al.*, 1988). However, the time series investigations on biological processes in these areas are very limited due partly to the logistic difficulties.

The principal objective of "Temporal variability of primary production and energy flow in Arctic sea ice area (PREFLA program)" is to clarify the biological processes peculiar to the existence of seasonal sea ice; temporal changes of primary production and its sedimentation and decomposition processes, dynamics of zooplankton and micronekton, and link to high trophic levels. The program is planned for three years of 1988–1990.

In the northern Bering and Chukchi Seas, where exists one of the productive seasonal sea ice areas, and an interdisciplinary oceanographic study (ISHTAR: Inner Shelf Transfer and Recycling) is carried out to clarify the biological processes and fluxes associated with water movements along the Anadyr Current into the Chukchi Sea. The study revealed that high primary and secondary productivity in the water column as well as high benthic biomass are found in two areas of the northern Bering and Chukchi Seas in the Bering Shelf-Anadyr Water; namely, one in the Chirikov Basin and the other in the southern Chukchi Sea (SAMBROTTO *et al.*, 1984; SPRINGER, 1985; GREBMEIER *et al.*, 1988). However, the direct time series observation on downward

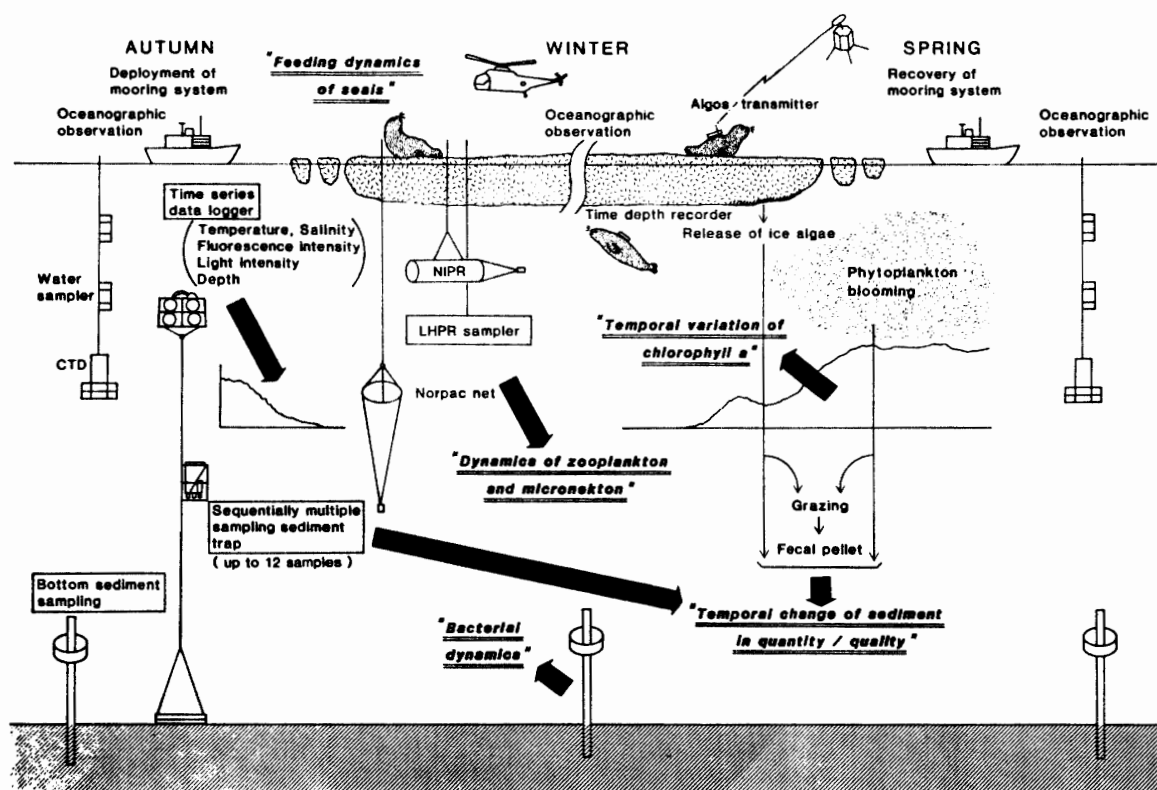


Fig. 1. Schematic representation of Japanese Arctic Program "Temporal variability of primary production and energy flow in Arctic sea ice area".

flux to link the surface primary production and the benthic production has not yet been made.

Therefore, the PREFLA program of 1988 was focused on the two areas mentioned in cooperation with the ISHTAR program as well as the sea bird observation at the breeding colony. The design of the PREFLA and its 1988 and 1989 field observations are summarized in this report.

2. Design and Organization of the PREFLA

The PREFLA program is the three-year program (1988–1990) and supported with a grant under the Monbusho International Scientific Research Program (63044144). The program consists of four components. (A) Moored biological instruments: to employ the moored instrumentations to acquire the time series data and samples of primary production and its sedimentation process. (B) Zooplankton and micronekton

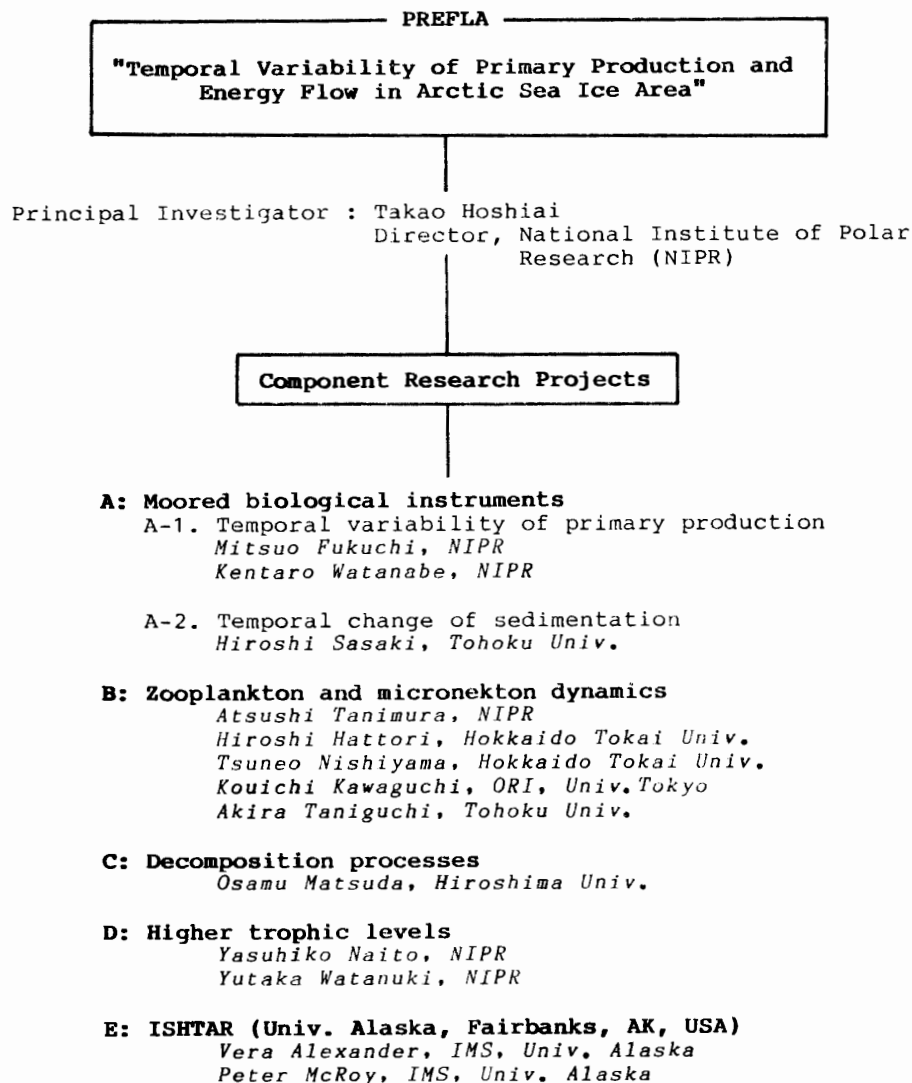


Fig. 2. Organization chart of "Temporal variability of primary production and energy flow in Arctic sea ice area (PREFLA)".

dynamics: to evaluate the role of these animals in energy and material transfer from primary production into higher trophic levels. (C) Decomposition processes: to clarify the recycling processes of materials along the course of sedimentation as well as in the bottom sediment. (D) Higher trophic levels: to assess the feeding activities of marine mammals and sea birds. Also, the PREFLA closely collaborates with the ISHTAR program of the U.S.A.

A design of the PREFLA is schematically illustrated in Fig. 1 and each component including participating scientists is summarized in Fig. 2.

3. 1988 Field Observation

In January of 1988, two of the authors (M.F. and Y.N.) attended the ISHTAR workshop in Corpus Cristi, Texas, U.S.A., to discuss the 1988 research plan, which had to be arranged with close collaboration of the ISHTAR cruise plan of 1988. Two legs of ISHTAR cruises (I and V) were available to the PREFLA program (Fig. 3).

A short-term mooring experiment was carried out and a long-term moored buoy was deployed in June on board R/V T. G. THOMPSON, University of Washington (1988

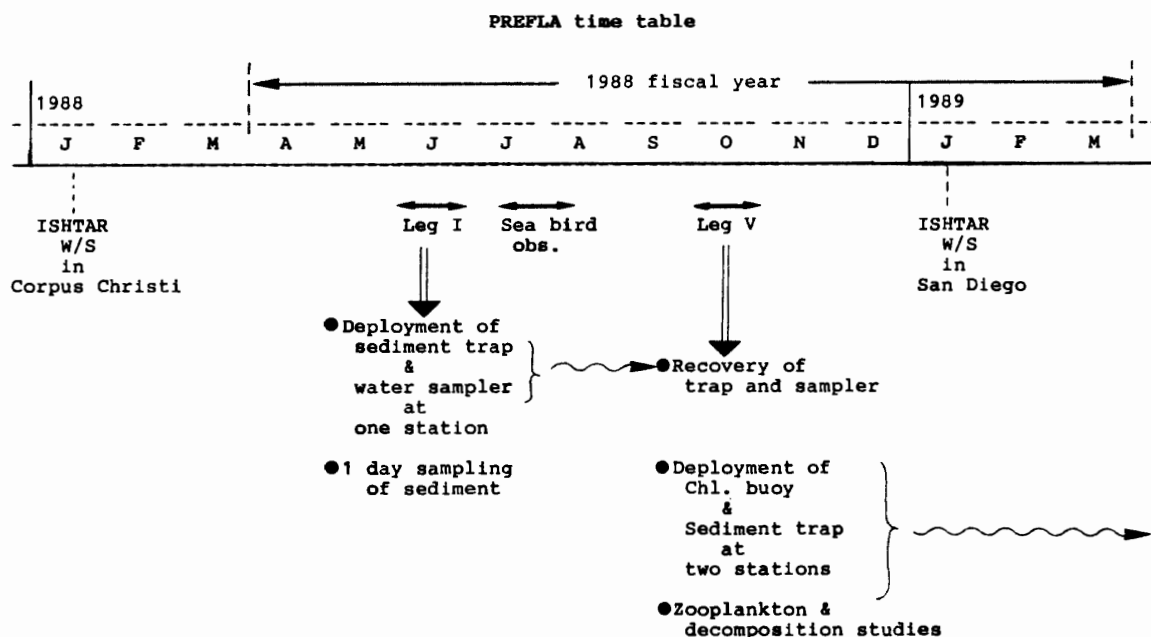


Fig. 3. "PREFLA" time table for 1988 field works.

ISHTAR Leg I). The long-term buoy (Sasaki-1, Fig. 4) was recovered in October on board R/V T. WASHINGTON, Scripps Institution of Oceanography, University of California, San Diego (1988 ISHTAR Leg V). Two sets of the other long-term moored system (Fukuchi-1 and -2, Fig. 5) were deployed on Leg V. The position of moored station on Leg I is almost identical to station 31 (Fukuchi-1) on Leg V. Concurrently, zooplankton samplings were made on these two legs, using two kinds of gears, Norpac net and NIPR-M sampler. Mooring stations and sites of plankton samplings are also shown in Fig. 6, which summarizes observations done on Leg V.

Time intervals of sediment trap samplings were 8 days for Sasaki-1 experiment and 15–60 days for Fukuchi-1 and -2, respectively. Fukuchi-1 and -2 are programmed

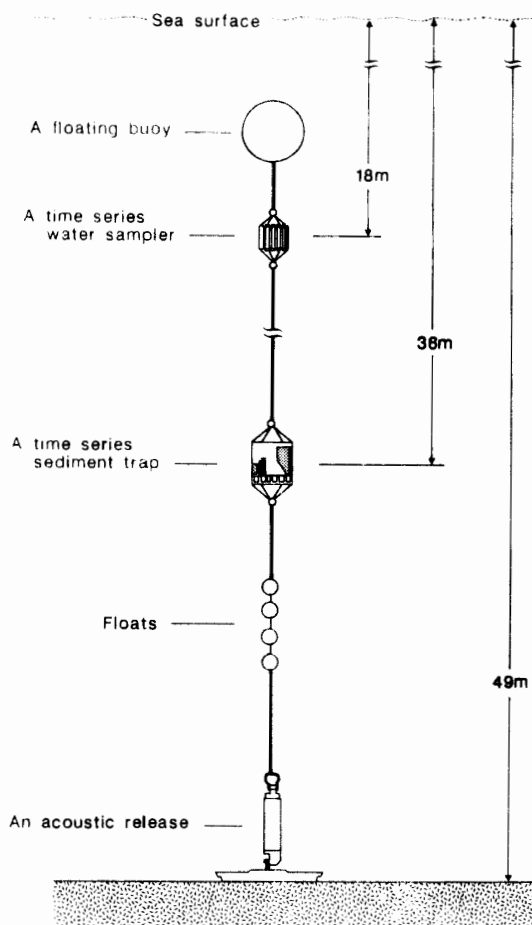


Fig. 4. A long-term mooring array, Sasaki-1, deployed on Leg I at $64^{\circ}58.62'N$ and $169^{\circ}10.08'W$ on 20 June and recovered on 6 October 1988.

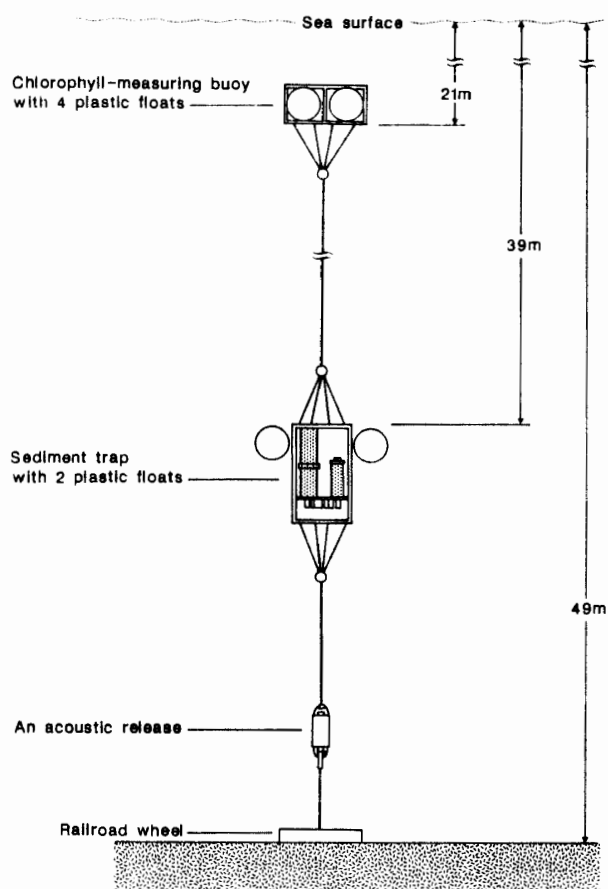


Fig. 5. A long-term mooring array of "Fukuchi-1 & -2", deployed at $64^{\circ}59.52'N$, $169^{\circ}08.35'W$ on 6 October and at $68^{\circ}19.84'N$, $168^{\circ}57.09'W$ on 9 October 1988.

to collect 2 samples per month in November, December, May, June and July and 1 sample per two months from January to April (Fig. 7). A time series water sampler attached to Sasaki-1 mooring collected about 50 ml of water sample 30 times at intervals of 3.5 days between June 20 and September 30, 1988. A chlorophyll-measuring buoy attached to Fukuchi-1 and -2 moorings is programmed to collect data (fluorescence intensity, water temperature, conductivity, light intensity and depth of buoy) at intervals of 2 hours.

Decomposition experiments of zooplankton and fecal pellets were carried out preliminarily on board of Leg V. Concurrently, a short-term culture experiment was made to collect fecal pellets produced by zooplankton.

Feeding activities of common murres and black-legged kittiwakes were observed in July–August at Bluff sea bird colony near Nome, Norton Sound.

Participants in the 1988 work are listed in Table 1.

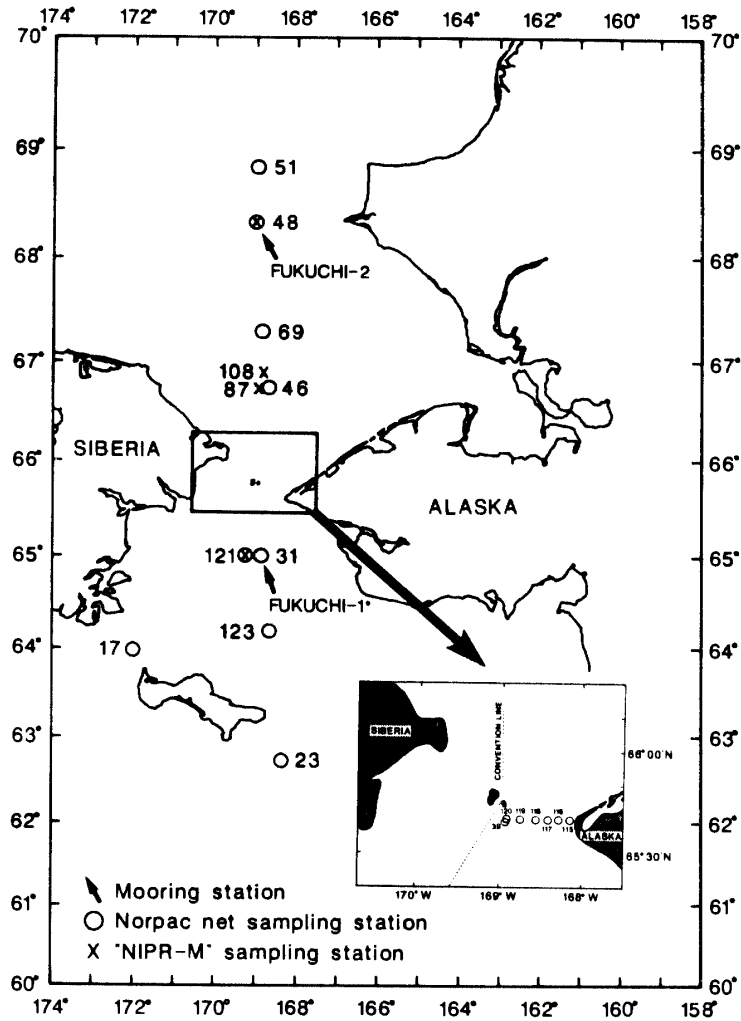


Fig. 6. Mooring stations and plankton samplings done on board R/V T. WASHINGTON in October 1988 (ISHTAR Leg V). Mooring experiment (Sasaki-1) on Leg I on board R/V T. G. THOMPSON in June 1988 was carried out at a location close to Stn. 31 (Fukuchi-1) of Leg V. Numerals indicate serial station number of ISHTAR CTD observation.

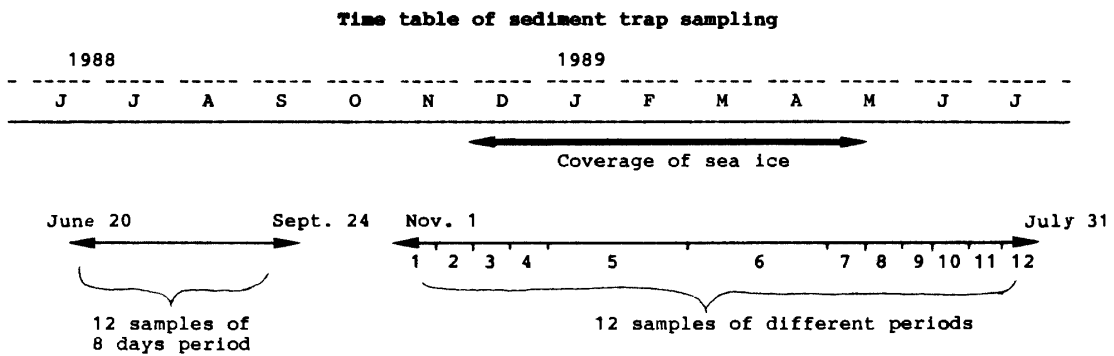


Fig. 7. Sampling interval of time series sediment trap.

Table 1. Participants in "PREFLA" program in 1988 and 1989.

| Title | 1988 ISHTAR workshop | ISHTAR cruise Leg I | Sea bird observation | ISHTAR cruise Leg V | 1989 ISHTAR workshop | 1990 ISHTAR workshop | ISHTAR cruise HX-128 | ISHTAR cruise HX-131 |
|-------|------------------------------------|----------------------------------|----------------------------------|---|---------------------------------|------------------------------|----------------------------------|----------------------------|
| Date | 13-15 January 1988 | 6-28 June 1988 | 18 July- 10 Aug. 1988 | 1-21 October 1988 | 17-19 January 1989 | 18-22 June 1989 | 17-30 July 1989 | 11-19 September 1989 |
| Place | Corpus Cristi, Texas, USA | Bering and Chukchi Seas | Bluff, Nome Alaska, USA | Bering and Chukchi Seas | San Diego California, USA | Fairbanks, Alaska, USA | Bering and Chukchi Seas | Bering Sea |
| Name | Y. NAITO M. FUKUCHI | H. SASAKI T. HOSHIAI* | Y. WATANUKI | M. FUKUCHI O. MATSUDA A. TANIMURA H. HATTORI | M. FUKUCHI | M. FUKUCHI | M. FUKUCHI H. HATTORI | M. FUKUCHI H. SASAKI |

* T.H. did not get on board but arranged cruise plan in Fairbanks and Seward, Alaska.

4. 1989 Field Observation

In January of 1989, one of the authors (M.F.) attended the ISHTAR workshop in San Diego, California, U.S.A., to discuss the 1989 research plan. The other ISHTAR workshop was also held in Fairbanks, Alaska, U.S.A., in June. And, two legs of ISHTAR cruises became available to the PREFLA program; one in July and the other in September.

In July, the long-term buoy (Fukuchi-2) in the Chukchi Sea was recovered on board R/V ALPHA HELIX, University of Alaska (HX-128 cruise) and zooplankton samplings with Norpac net were carried out (Fig. 8). However, the other buoy deployed in the Chirikov Basin (Fukuchi-1) could not be located.

In September, an attempt to recover the "Fukuchi-1" buoy was again made on board R/V ALPHA HELIX (HX-131 cruise) but only one of plastic floats attached to the buoy was recovered. The other trial to recover will be made in 1990. Zooplankton sampling with Norpac net, water sampling with Niskin bottles and dredging

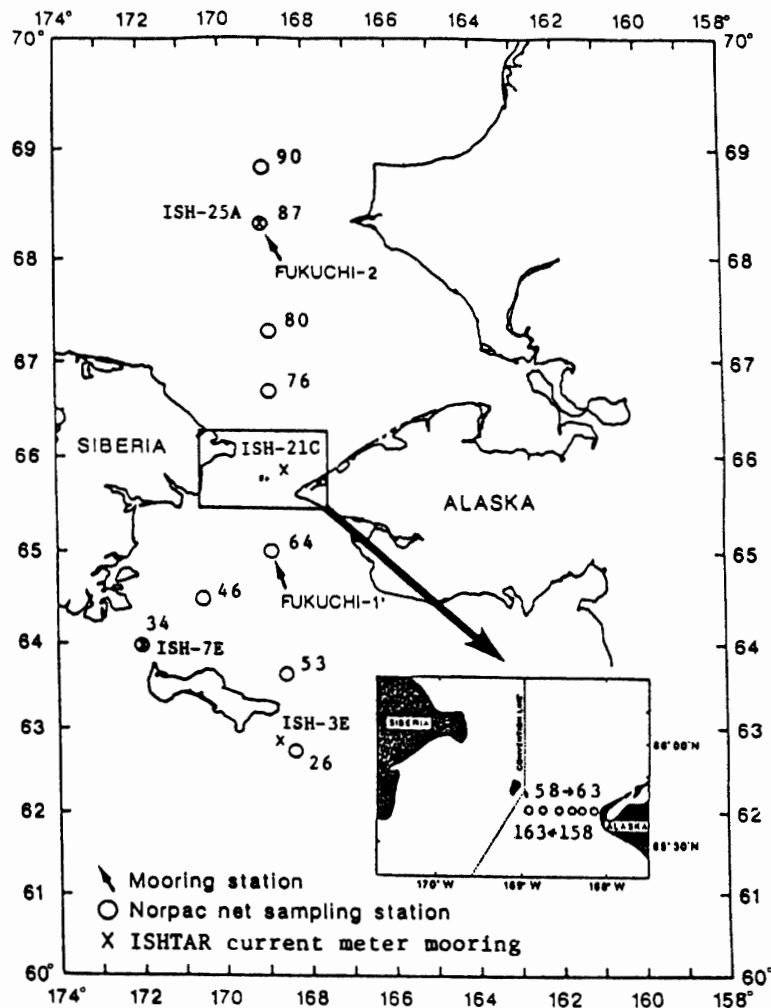


Fig. 8. Mooring stations and plankton samplings done on board R/V ALPHA HELIX in July 1989 (HX-128). Numerals indicate serial station number of ISHTAR CTD observation.

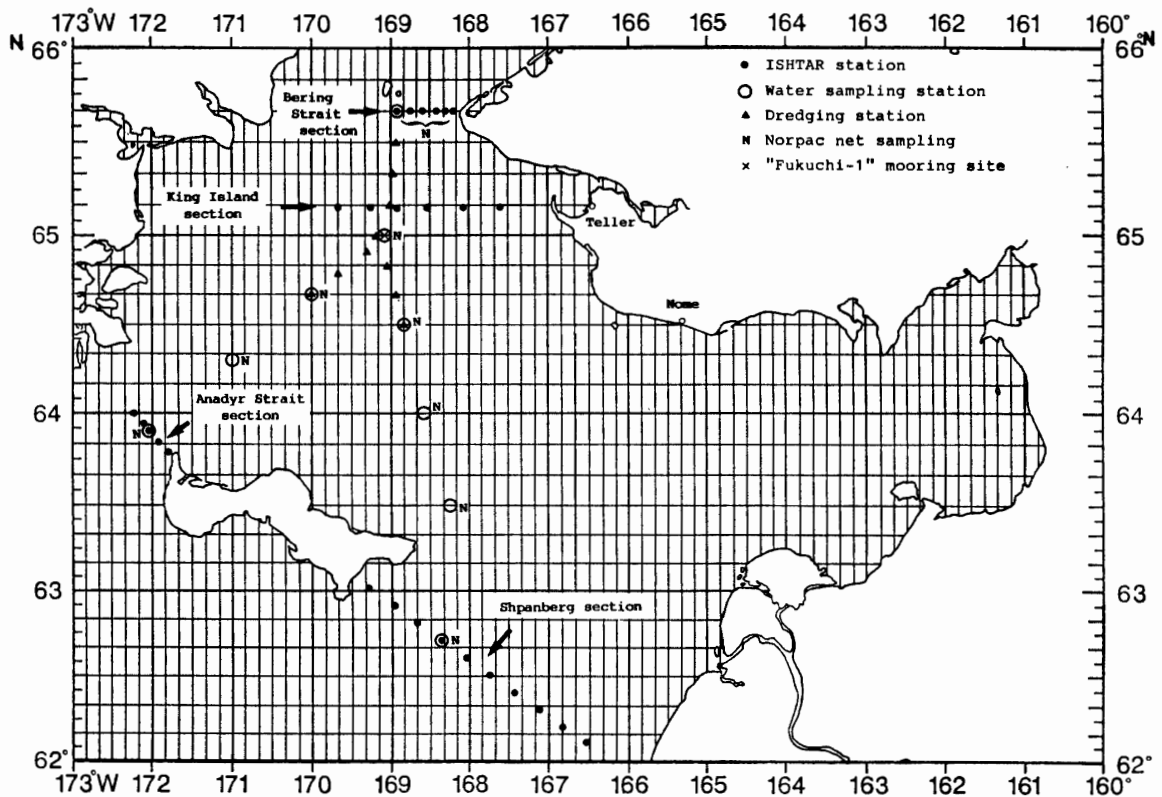


Fig. 9. Locations of observations done on board R/V ALPHA HELIX in September 1989.

of bottom sediment were carried out as seen in Fig. 7.

Participants in 1989 works are listed in Table 1.

5. Summary

Samples and data obtained from the 1988 and 1989 field works are now in process of analysis. The following is the list of preliminary reports from these works.

(1) ISHTAR Cruise Report, 1988

Field report of Japanese Arctic Program in 1988, "Temporal variability of primary production and energy flow in Arctic sea area", in cooperation with ISHTAR 1988 program (Tentative), 70-88.

(2) ISHTAR Progress Report, 1988

Temporal variability of primary production and energy flow in Arctic sea ice area (PREFLA program), 39 p.

(3) ISHTAR Cruise Report of HX-128

PREFLA carried out on R/V ALPHA HELIX cruise "HX-128" in July 1989. 6 p.

(4) ISHTAR Cruise Report of HX-131

ISHTAR cruise report of R/V ALPHA HELIX cruise "HX-131" 10-19 September 1989. 15 p.

(5) The Eleventh Symposium on Polar Biology, held at National Institute of Polar Research, Tokyo, 12-14 December 1988

Inner Shelf Transfer and Recycling (ISHTAR) program. HOSHIAI, T.

- Annual transport of phytoplankton and particles through Bering Strait. WIRICK, C. D.
- Temporal variability of primary production and energy flow in Arctic sea ice area (PREFLA project). FUKUCHI, M., HOSHIAI, T., NAITO, Y., TANIMURA, A., MATSUDA, O., HATTORI, H., ALEXANDER, V. and MCROY, P.
- Zooplankton investigation on ISHTAR 1988 Leg IV. TANIMURA, A., HATTORI, H., FUKUCHI, M., MATSUDA, O., NAITO, Y., HOSHIAI, T. and MCROY, P.
- Consecutive observations of downward flux and suspended particles in the northern Bering Sea in summer 1988. SASAKI, H., HATTORI, H., MATSUDA, O., TANIMURA, A., FUKUCHI, M., NAITO, Y., HOSHIAI, T., TRIPP, R. and MCROY, P.
- Daily activity patterns of common murre and black-legged kittiwakes at the breeding colony in Norton Sound, Alaska. WATANUKI, Y., NAITO, Y., MCROY, P. and SCHAUER, J.
- (6) The Twelfth Symposium on Polar Biology, held at National Institute of Polar Research, Tokyo, 6–8 December 1989
- Contribution of the Pacific Arctic to the global ocean carbon budget. MCROY, P. C.
- Time series change of chlorophyll-*a* under sea ice in Chukchi Sea, Arctic. FUKUCHI, M., HATTORI, H., MATSUDA, O., TANIMURA, A. and MCROY, P. C.
- Seasonal succession of microplankton community in the northern Bering shelf water during the period from June to September, 1988. YAMAZAKI, K., TANIGUCHI, A., SASAKI, H. and FUKUCHI, M.
- Distribution of copepods in the northern Bering Sea and the Chukchi Sea (Oct. 1988). HATTORI, H., TANIMURA, A., FUKUCHI, M. and MATSUDA, O.
- Variability in downward particulate flux in the northern Bering Sea in summer 1988, 1. Zooplankton fecal pellets. SASAKI, H., HATTORI, H., MATSUDA, O., TANIMURA, A. and FUKUCHI, M.
- Variability in downward particulate flux in the northern Bering Sea in summer 1988, 2. Sterol composition. YAMAGUCHI, T., SASAKI, H. and FUKUCHI, M.
- (7) The Fourth International Symposium on Okhotsk Sea and sea ice held by Okhotsk Sea and Cold Ocean Research Association, Mombetsu, Hokkaido, 5–7 February 1989
- Temporal variability of primary production and energy flow in Arctic sea ice area. FUKUCHI, M., HOSHIAI, T., NAITO, Y. and TANIMURA, A.
- (8) 1989 Spring Annual Meeting of the Oceanographical Society of Japan, 6–10 April 1989
- Time series observation of sinking and suspended particles in the northern Bering Sea (1988 summer). SASAKI, H., HATTORI, H., MATSUDA, O., TANIMURA, A., FUKUCHI, M., NAITO, Y., HOSHIAI, S., TRIPP, R. and MCROY, P.
- (9) 1989 Annual Meeting of American Society of Limnology and Oceanography, University of Alaska, Fairbanks, 18–22 June 1989
- Temporal variability of particulate flux in the northern Bering Sea. FUKUCHI, M., SASAKI, H., HATTORI, H., MATSUDA, O., TANIMURA, A., HANDA, N. and MCROY, P.

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