Antantic Reseach Vol. 2, No. 1, 39—45, June 1991

ECOLOGICAL OBSERVATIONS ON COLOURED LAYER OF COASTAL FAST ICE IN GREAT WALL BAY, KING GEORGE ISLAND, ANTARCTICA

Lu Peiding[1], Zhang Kuncheng[1], Huang Fengpeng[1] and Kentaro Watanabe[2]

[1]*First Institute of Oceanography, S.O. A., Qingdao 266003*
[2]*National Institute of Polar Research, Japan*

Abstract Marine biological and environmental investigations were carried out on the coastatl waters off Great Wall Station (62°13′s, 58°58′W) on King George Island, Antarctica, from November 17, 1988, to March 3, 1989. Coastal fast ice covered inner part of Great Wall Bay until mid-December 1988, which allowed us to take ice core sampling and observations from mid-November to early December 1988. During this period, ice thickness ranged from 90 to 70cm with baout 20cm of snow cover. About 5cm brown layer occured in the middle part of fast ice core collected on November 20, 1988 at site 2, and two brown layers occured in the interior of ice core collected on November 17,20 and 26, 1988 at site 5.

In comparison to the water column, chlorophyll-a concentration in fast ice was higher, which ranged from 2.55 to 56.84mg/m^3, and most of them were concentracted in the interior layers of sea ice rather than in the bottom layer often observed in other sea ice areas, such as in Syowa, Davis, Casey Station and McMurdo Sound areas, etc. This might be a result of the difference in structure and formation procese of sea ice.

Meanwhile, temperature, transparency, nutrients and chlorophyll-*a* in water column were measured. Microalgal assemblages both in fast ice and water column of Great Wall Bay were reported.
Key words fast ice, coloured layer, ice algae.

1. Introduction

The importance of ice algae as a primary producer in the marine Antarctic ecosystem has been emphsaized since the 1960 s (Hoshiai, 1977). Ecological investigations on the colored layer formed by proliferation of such microorganisms as diatoms, flagellates and ciliates in the sea ice have been carried out mainly on the polar oceans (Horner, 1977; Bradford, 1978; Alexander, 1979; Hoshiai, 1981; Palmisano, *et al.*, 1983). Other than polar oceans, McRoy and Goering (1974) studied ice algae of the Bering Sea. Horner (1977) mentioned that the ice biota was also found in the Baltic Sea as well as in the Bering Sea. Dunbar (1979) has reported that chlorophyll-a was also detected in the sea ice of the Gulf of St. Lawrence, Canada. Hoshiai and Fukuchi (1981) reported that the coloration of sea ice by the ice algae was studied at Mombetsu on the Okhotsk coast of Hokkaido and Toetoko in a lagoon, Lake Saroma, Japan.

In order to improve our knowledge of ice communities, the present work was carried out in the Great Wall Bay, King George Island, Antarctica, from November to December, 1988. The results of a preliminary analysis of the data obtained from these observationz are reported in this paper.

2. Materials and Methods

Field study was conducted on the Great Wall Bay of King George Island, Antarctica, from November 17 to December 1, 1988. Two sites were set up in the inner part of Great Wall Bay (site 2 and 5). Locations for sampling are shown in Figure 1. Depth at site 2 and 5 was 25 m and 21 m respectively. In November and early December 1988 coastal fast ice covered the inner part of Great Wall Bay with its thickness from 70 to 90 cm and about 20 cm of snow cover. The ice was firm enough to allow us to carry out the field work on the sea ice.

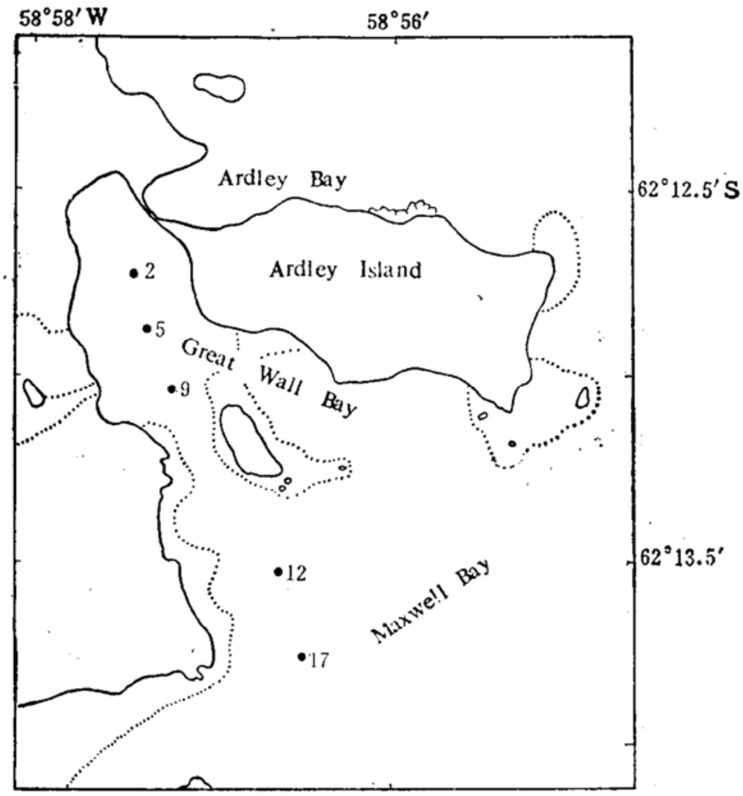

Fig. 1. Locations for sampling On Great Wall Bay of King George Island, Antarctica, from November to December 1988.

Ice samples were collected by using an ice auger with 7.5 cm diameter to obtain three or more ice cores at each site. Each ice core was placed in a plastic bag to protect them from high light and keep temperature less than 0°C, and transported to biological laboratory at Great Wall Station. In addition to ice core samples, ice–seawater interface water samples were collected by a 10–L PVC bucket through a 1×1 m^2 hole. Water column samples were collected at 5, 10, 15 and 20 or 21 m beneath the sea ice by using a water bottle through the same hole. One litre of water sample was filtered through a CN–CA microfiltration membrane for plant pigment determinations.

Plankton samples were also collected with four kinds of nets at each site by hauling vertically from near the bottom to the surface at a speed of 1m / s through the same hole as above. Net samples were preserved in 5% formalin seawater for biomass measurements and microscopic examinations.

Temperature of surface seawater was measured as usual, and the transparency of sea water was observed with a Secchi disc.

Ice cores from the bottom to surface were cut with a hand saw into setions 10 cm thick The ice core sections of same layer from each site were put into one container and allowed to thaw at room temperature (15°C) prior to analysis. The resulting ice core melt water was slowly mixed, and aliquots of melt water was used for determining plant pigments contained in the sea ice. The remainder melt water was used for measuring nutrients.

Chlorophyll *a* and phaeopigments were determined by the spectrophotometeric method (Jeffrey and Humphrey, 1975; Lorenzen 1967). Nutrient salts were analysed by the method of Strickland and Parsons (1968).

3. Results and Discussion

In November and December 1988, the fast ice around site 2 and 5 was firm, with its thickness of 0.7—0.9m, and snow cover is 0.2—0.3m thick. In order to understand the nature of colored layer occurred in the ice, field surveys were carried out at sites 2 and 5 from November 17 to December 1, 1988.

Two brown layers were found in the interior of sea ice cores obtained at site 5 on November 17, 20 and 26, 1988, i.e., the upper interior and the lower interior colored layers. Between these two layers, a light brown colour was recognized. No colour can be seen at the bottom layer (0—12cm) of sea ice, although the chlorophyll **a** can be deterted from the bottom layer of sea ice. Figure 2 a—b show the chlorophyll **a** profiles of sea ice collected at site 5 on November 17 and 26, 1988, which are consistent with the colored layers. The maximum chlorophyll **a** concentrations (50.59 and 56.84 mg / M^3) were detected in the upper interior layer of sea ice. In addition, a second highest value (33.59 and 33.92 mg / M^3)

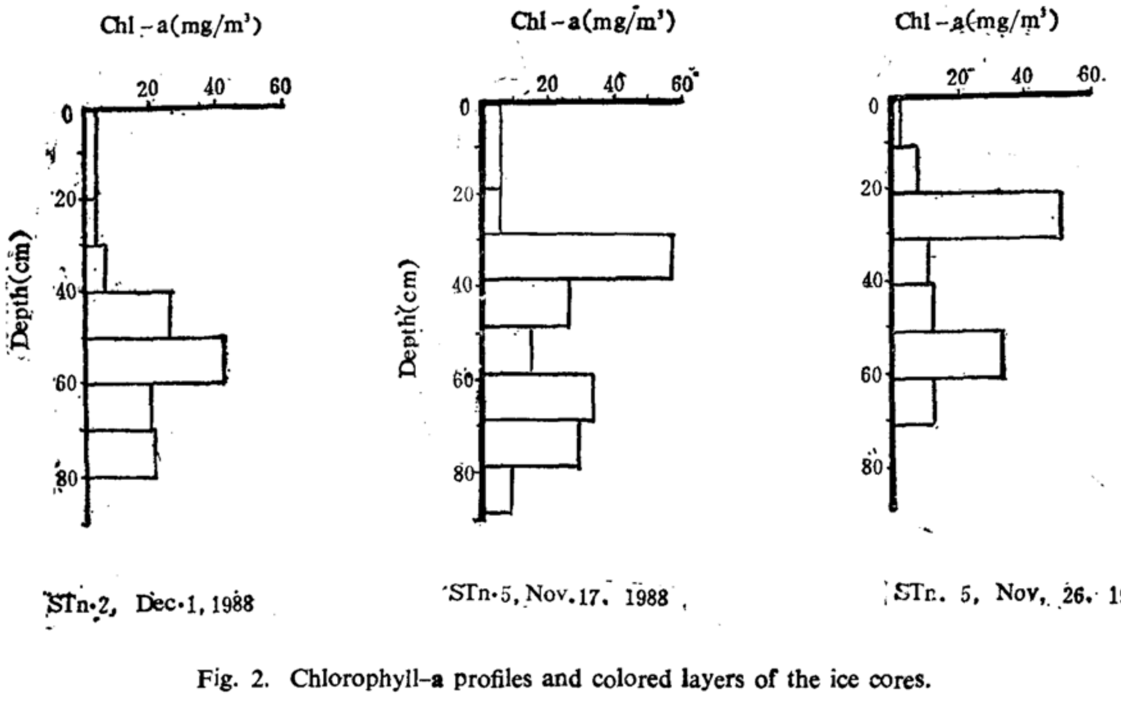

Fig. 2. Chlorophyll-a profiles and colored layers of the ice cores.

was found in the lower interior layer of sea ice. Dominant species were *Navicula glaciei* (in the upper colored layer), *Nitszchia cylindrus* and *N. lecointei* (in the lower interior colored layer), Microalgae communities in the water column at site 5 collected with plankton net were dominated by *Corethron criophilum* in midle and late November 1988 and by *Chaetoceros neglecta* and *C. socialis* in December 1988.

A brown colored layer was also found in the middle part of sea ice collected at site 2 on November 20 and December 1,1988. Figure 2–c shows a chlorophyll **a** profile of the sea ice from site 2 on December 1, 1988. It can be seen that most of chlorophyll **a** was concentrated in the lower internal part of sea ice with a maximum of 42.34 mg / M^3, rather than in the bottom layer often observed in the fast ice areas such as in Syowa Station (Hoshiai, 1977) Davis Station (Zhang and Lu, 1986), Casey Station (McConville and Wtherbee, 1983) and McMurdo Sound areas (Palmisane and Sullivan, 1983), etc. Micro–algae communities in the internal colored layer of sea ice at site 2 on December 1, 1988, were also dominated by pennate diatom species like *Navicula glaciei, Nitzschia cylindrus* and *N. lecointei.* (see Table 2.).

Chlorophyll–a concentrations in the sea ice exceeded that in water column at site 2 and site 5, while the standing crop was also higher in the sea ice than that in the water column (Table 1).

Phaeopigment concentrations in the sea ice and water column were also determined from November 17 to December, 1 1988, and the results were summarized in Table 1. It can be seen that the phaeopigment concentrations were very close to chlorophyll–a concentrations both in the sea ice and water column for each site and on same date, which indicates that most of sea ice algae cells were dead or unhealth. McConivlle and Wetherbee (1983) has reported that the presence of many empty diatom frustules in the sea ice suggests this was a residual population from the autumn ice algal bloom.

Fig. 3 a–c show phaeopigment profiles of the sea ice from same sites and date as chlorophyll–a profiles, which were also cosnistent with the colored layers of sea ice. It is nearly of

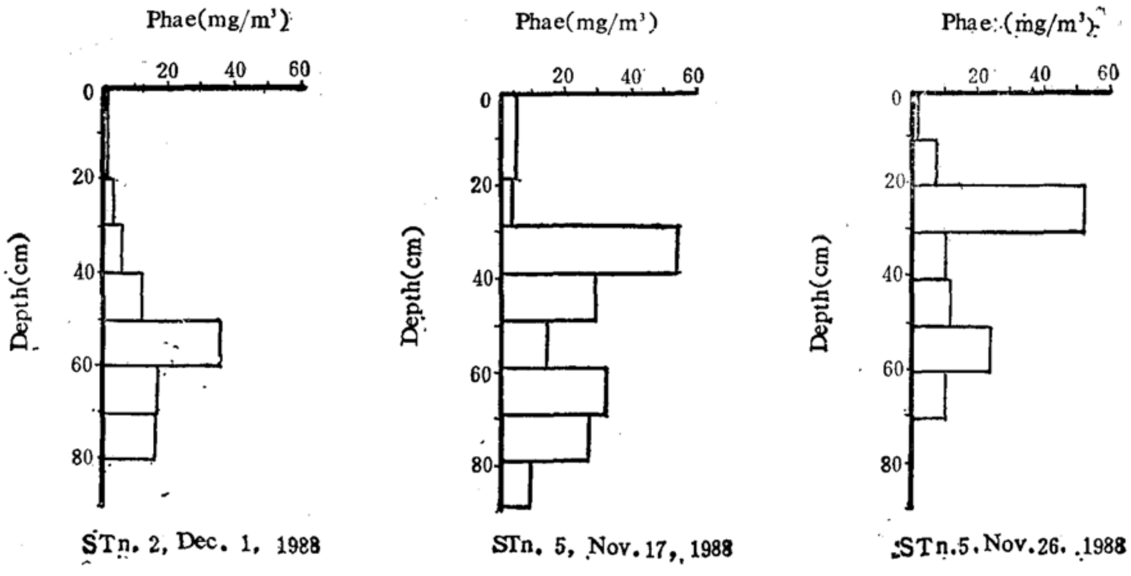

Fig. 3. Phaeopigment profiles and colored layers of the ice cores.

Table 1. Chlorophyll a, Phaeopigment and standing crop in sea ice and water column at site 2 and 5.

No. of site	Date	Depth (m)	Chlorophyll a (mg/m^3) Ice	Water	Phaeopigments (mg/m^3) Ice	Water	Standing Crop (mg/m^2) Ice	Water
5	17, Nov.	21	22.56	0.42	21.75	0.26	18.53	7.57
5	20,Nov.	21	18.88	0.60	20.30	0.75	14.16	12.58
5	26,Nov.	21	19.72	0.89	16.87	0.80	12.93	11.62
2	20,Nov.	25	40.73	0.60	41.10	0.35	32.99	(14.88)
2	1,Dec.	25	17.67	0.30	12.89	0.16	12.75	6.42

Table 2. Relative abundance of microalgae collected in the coaslal fast ice on King George Island.

Date	Nov.17, 88	–	–	–	Dec.1, 88	–	–
Location	Stn.5	–	–	–	Stn.2	–	–
Species / depth (cm)	snow 0–19	up int. 29–39	low int. 59–69	bottom 79–89	snow 0–20	interior 50–60	bottom 70–80
Actinocylus actinochilus		±					±
Corethron criophilum			±	±	±		±
Odontella weissflogii						±	±
Porosira sp.			±			±	±
Rhizosolenia alata	±		±	±		±	±
Stellarima microtrias						±	±
Thalassiosira antarctica	+	+	+	±	±	+	±
T. australis			±				
Amphiprora kufferathii		±	±	±		+	
Navicula glacisi	+ +	+ + +	±	+	+ +	+ +	+
Nitzschia closterium		±	±		±	+	+
N lecointei	+ +	±	+	+ + +	+	+ +	+
N. curta				+			
N. cylindrus	+	±	+ + +	+		+ + +	+ +
Phaeocystis pouchetii	+		+	+ +	+ +		+ + +

+ + + : dominant, + + : abundant, + : common, + : rare

the same types ae the chlorophyll a profiles.

Nutrient concentrations were also determined on the ice cores and water column. Phosphate–P concentration in the ice core varies in a range of 0.373–4.987 μg at / L, while in the water column varies in a range of 0.738 to 4.873 μg *at* / L. Fig. 4 a–b show the phosphate–P profiles for the ice at sites 5 and 2, there was no correlation between phosphate and chlorophyll a profiles but a maximum. Nitrite–N in the ice ranged from 0.01 to 0.199 μg *at*/L, while in the water from 0.64 to 0.273 μg at / L, there was also no correlation between nitrite and chlorophyll a profiles at all.

Water temperature ranged from —1.6 to —0.8°C ,and the transparency was 4 m at sites 2 and 5 from November 17 to December 1, 1988.

Many types of ice algae communities have been reported from various sea ice areas (Horner, 1985). There are three main types of ice algae communities, and thier formation

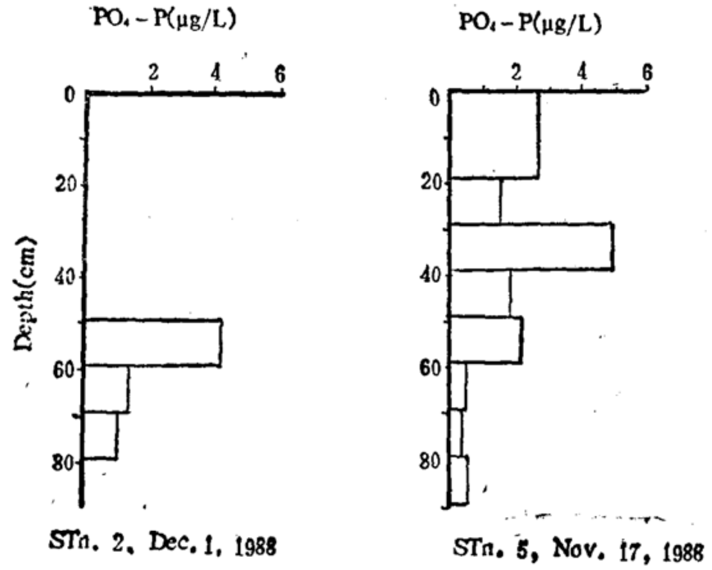

Fig. 4. Phosphate- P profiles for the ice cores.

and disintegration have been generally described, i. e. bottom ice algae, surface ice lagae and interior ice community. The upper interior colored layer found on the Great Wall Bay is similar to the surface ice community, according to their structure and formtion process, because the heavy snow cover (30 cm or more) is sufficient to depress the sea ice, and the sea water containing algal cells floods the snow–ice interface. It is porous with an irregular, granular structure. This layer is also disintegrated when warming from selective absorption of solar radiation by the algal cells weakens the ice in thermal process and causes separation from the rest of ice, and the cells rapidly release into the water column.

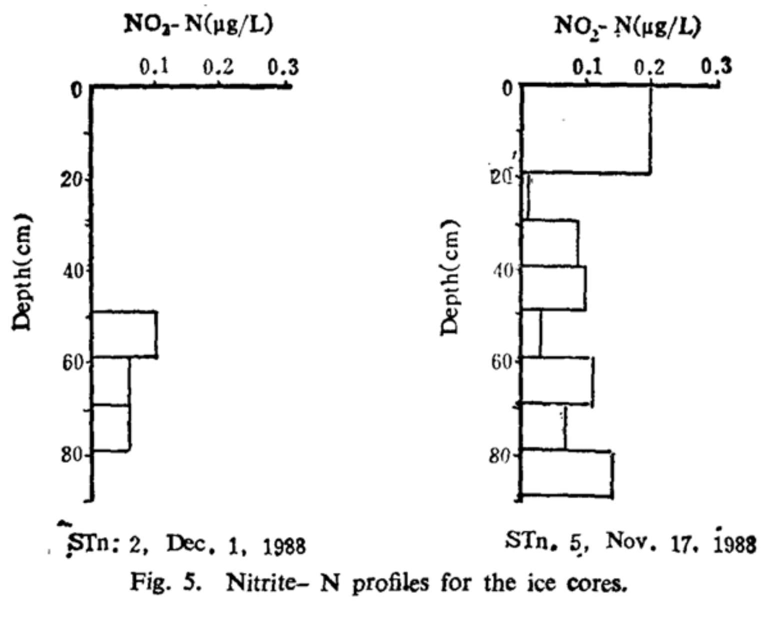

Fig. 5. Nitrite- N profiles for the ice cores.

The lower interior colored layer found in sea ice at site 5 was the same interior ice community as described by Ackley (1979) and Horner (1985). Ackley (1979) presumed that the interior community is a result of the upward transport of the summer population as the thickness of the ice increases and is therefore a remnant population. The interior community described by Hoshiai (1977) from Syowa Station and by McConville and Wetherbee (1983) from Casey Station was present in winter (May September), while Ackley et al (1979) found a similar community in the Weddell Sea in February-March, and the present authors found it on the Great Wall Bay in November–December. This community depends on air temperatures at or slightly below the freezing point to initiate brine drainge which also enriches the interior of the ice with nutrients, thus promoting algal growth. (Horner, 1985).

References

Ackley, S. F., Buck, K. R. & TAGUCHI, S. (1979): Standing crop of algae in the sea ice of Weddell Sea Region, *Deep-Sea Res.*, 26: 269—281.

Alexander, V. (1979): Interrelationships between the seasonal sea ice and biological regimes, *Cold. Reg. Sci Technol.*, 2, 157—178.

Bradford, J. M. (1978): Sea ice organisms and their importance to the Antarctic ecosystem (Review), *N. Z Antarctic Rec.* 1, (2) 43—50 .

Dunbar, M. J. (1979): Biological production in the Gulf of St. Lawrence, Marine productio production Mechanisms, ed. by M. J. DUNBAR, Cambridge Univ. Press, 151—157, (Int. Biol. Programme 20).

Horner, R. A. (1972): Ecological studies of Arctic sea ice organisms, Prog. Rep. Off. Nav. Res., Contrct No. 014–67–0317–0003, 1–79.

Horner, R. A. (1977): History and recent advances in the studies of ice biota, Polar Oceans, ed. by DUNBAR, M. J. Calgary, Alberta, Arctic Inst. Horth Am., 269—284.

Horner, R. A. (1985): Ecology of Sea Ice Microalgae , *in* Hovner, R. A. (ed.), Sea Ice Biota, CRC Press, Raton.

Hoshiar ,T. (1977): Seasonal change of ice communities in sea ice near Syowa Station, Antarctica, *in* DUNBAR, M. J. (ed.). Polar Oceans. Arctic Institute of North America, Calgary, Alberta, 307—317.

Hoshiai , T. (1969): Ecological observation of the colored layer of the sea ice at Syowa Station, *Antarctic Record,* 34, 60—72.

Hoshiai, T. (1981): Proliferation of ice algae in Syowa Station area, Antarctica, *Mem. Natl. Inst. Polar Res. Ser. E.* No. 34, p. 1—12.

Hoshial T., and Fuknchi ,M. (1981): Sea ice colored by algae in a lagoon, Lake Saroma, Hokkaido, Japan, *Antarctic Record,* No. 71, p. 113—120.

Jeffrey, S. W., Humphpey G. F. (1975): New spectrophotometric equtions for determing chlorophylls a, b, c_1 and c_2 in higher plants, algae and natural phytoplankton, Biochem. physiol. pflanz, Vol. 167, p. 191—194.

Lorenzen, C. J. (1967): Determination of chlorophyll and pheopigments spectrophometric equations, Limnol. Oceanorg., Vol. 12, p. 343—346.

McConvile M. J., Wetherbee, R. (1983): The bottom–ice microaglla community from annual ice in the inshore waters of East Antarctica, *J. Phycol.* 19, 431—439.

McRoy, C. P. and Goering J. J. (1974) The influence of ice on the primary productivity in the eastern Bering Sea, Biological Oceanography of the Northern North Pacific Ocean, ed. by Akenouti, A. Y. *et al.* Tokyo, Idemitsu Shoten, 199—216.

Meguro ,H. (1962): Plankton ice in the Antarctic Ocean, *Antractic Record,* 14, 1192—1199.

Meguro, H., Ito, K. and Fukushima, M. (1967): Bottom type plankton in the Arctic Ocean, *Antarctic Record,* 28, 2257—2271.

Palmisano, A. C., Sullivan, C. W. (1983): Sea ice microbial communities (SIMCOs) I. Distribution, abundance, and primary product on of microalgae in McMUrdo Sound in 1980, *Polar Biol.* 2, 171—177.

Strickland, J. D. H. and Parsons ,T. R. (1968): Appractical handbook of sea water analysis, *Fish, Res. Board Can., Bull.*, 167,1—311.

Sullivan, C. W., Palmisano, A. C. (1981): Sea ice microbial communities in McMurdo Sound, Antarctica, *Antarctic J. U. S.* 16; 126—127.

Whitaker, T. M. (1977): Sea ice habitats of Signy Island (South Orkneys) and their primary productivity, in Llano, G. A. (ed). Adaptations with Antarctic ecosystems, Gulf Publishing Co., Houston, p. 75—83.

Zhung, K. C., Lu, P. D. (1986). Some Ecological Observations on Antarctic Ice Algae. in: a collected of Antarctic scientific exploration, hinn Ocean Press, p. 49—59

(*Received Janurary, 1991*)