Jpn. J. Phycol. (Sôrui) 36: 221-229, September 20, 1988

Sub-ice microalgal strands in the Antarctic coastal fast ice area near Syowa Station

Kentaro WATANABE

National Institute of Polar Research, 9-10, Kaga 1-Chome, Itabashi-ku, Tokyo 173, Japan

WATANABE, K. 1988. Sub-ice microalgal strands in the Antarctic coastal fast ice area near Syowa Station. Jpn. J. Phycol. 36: 221-229.

Sub-ice microalgal strands, collected in the fast ice area near Syowa Station, Antarctica, are reported and described floristically. In mid-July, no strands were seen on the bottom of the ice. Strands 10-15 cm in length were observed hanging from the sea ice in early November which grew up to 50-60 cm in early December. The strands were mainly pennate diatoms, especially those that form long colonies, including *Amphiprora kufferathii*, *Berkeleya rutilans*, *Nitzschia lecointei*, *Nitzschia stellata*, *Nitzschia turgiduloides*, and several species of *Nitzschia* in a section *Fragiraliopsis* with a small abundance of a solitary cell species of *Navicula glaciei*. Cluster analysis performed on samples collected from a 10 m long sweep with a net under the ice suggests that the seasonal succession of the organisms composing strands from November to December was not significant.

Key Index Words: Antarctic—coastal fast ice—ice algae—ice diving—microalgal strands—sub-ice assemblage—Syowa Station.

Many types of ice algal assemblages have been reported from various sea ice areas (HORNER 1985). Among them, reports on a sub-ice assemblage, attached to the underside of the ice, forming strand colonies and extending into the water column, seem to be limited to those by CROSS (1982) from the Canadian Arctic, by SULLIVAN *et al.* (1982) from McMurdo Sound, by SASAKI and WATANABE (1984) from Lützow-Holm Bay and by McCONVILLE *et al.* (1985) from near Davis Station. The loss of this type of assemblage from core samples is likely to be the reason why it has been reported so rarely.

To investigate the sub-ice assemblage in the coastal fast ice area near Syowa Station (69°00'S, 39°35'E), underwater observations and collections were made, and the results of a floristic study of the sub-ice microalgal assemblage in November and December 1983 are described in this paper.

Materials and Methods

Under-ice diving was carried out for observation and collection of the sub-ice assemblage on July 14, November 5 and December 9 and 12 1983 at the same site, where the water was about 17 m deep, in Kita-noseto Strait near Syowa Station (Fig. 1). The equipment employed in the SCUBA diving was described earlier (WATANABE *et al.* 1982, 1986). Strands of ice algal assemblage (microalgal strands) hanging from the undersurface of undisturbed sea ice were collected on November 5 and December 9, using 50 ml plastic disposable syringes and a hand net with five openings arranged vertically (5 cm high × 20 cm wide mouth with 100 μm mesh net each). With the syringe, microalgal strands (samples Syr. 1 and 2 collected on November 5 and Syr. 3-5 on December 9) were sampled at several locations. The hand net was towed horizontally for about 10 m beneath the sea

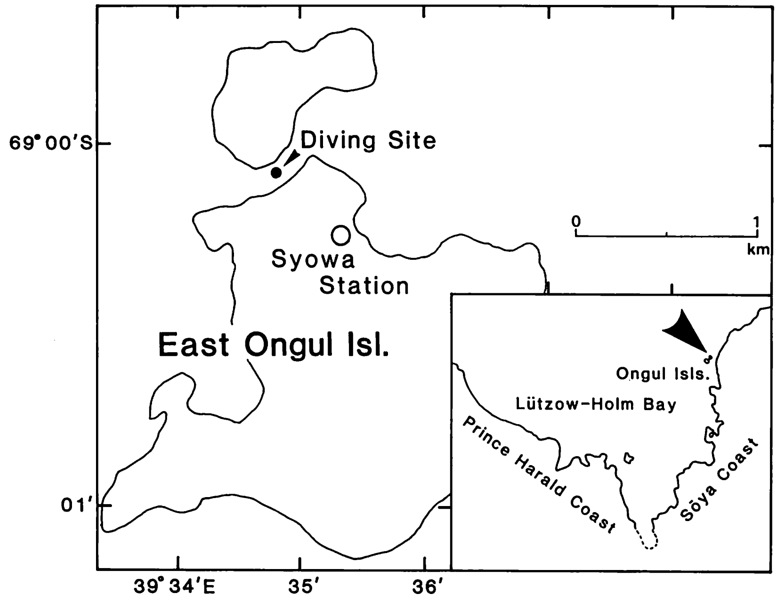


Fig. 1. Map showing under ice observation and collection site in the fast ice area near Syowa Station, 1983.

ice with the uppermost beam touching the bottom of the sea ice. Three hand net samples, H.N. 1, 2 and 3 in November and H.N. 4, 5 and 6 in December were collected from the microalgal strands in the layers of 0–5, 10–15 and 20–25 cm from the bottom of the sea ice, respectively. Samples were transported to a laboratory at Syowa Station and fixed with a formalin and acetic acid (1:1) mixture (HASLE 1978).

Species were identified using a JEOL T-100 scanning electron microscope (SEM) after being cleaned with distilled water or concentrated HCl and $KMnO_4$ mixture (SIMONSEN 1974), air dried and ion sputtered with gold. Two subsamples were taken from each sample to determine the relative abundance of selected species. 1200–2300 intact cells were counted in water mounted subsamples at a magnification of 400X or 200X, using a Nikon Diaphoto-TMD phase contrast inverted microscope. Species composition on the basis of relative abundance was compared between samples and Percent Similarity Index (PSI) by WHITTAKER (1952) was calculated as follows,

$$\mathrm{PSI}(\mathrm{sample}_{a,b}) = \sum_i \text{minimum } \% \ [\mathrm{species}_i(\mathrm{sample}_a, \mathrm{sample}_b)],$$

where $i=(1,2,\ldots n$ species) in a comparison of similarity between samples a and b. Percent Similarity Index was applied for cluster analysis and a dendrogram was drawn representing the single-linkage method.

Results and Discussion

No discoloration by ice algae was observed at the bottom surface of the sea ice around the diving hole on July 14 1983. On a second dive, made on November 5, microalgal strands were found hanging from the bottom of the sea ice which was then about 120 cm thick (Fig. 2). The length of the strands was mostly less than 15 cm. This agrees with the seasonal variation of standing crop in the fast ice area at Stn. I about 100 m away from the diving hole where the spring increase of chlorophyll *a* in the bottom layer of ice began in mid-August (WATANABE and SATOH 1987). As the strands were short, the amount of mi-

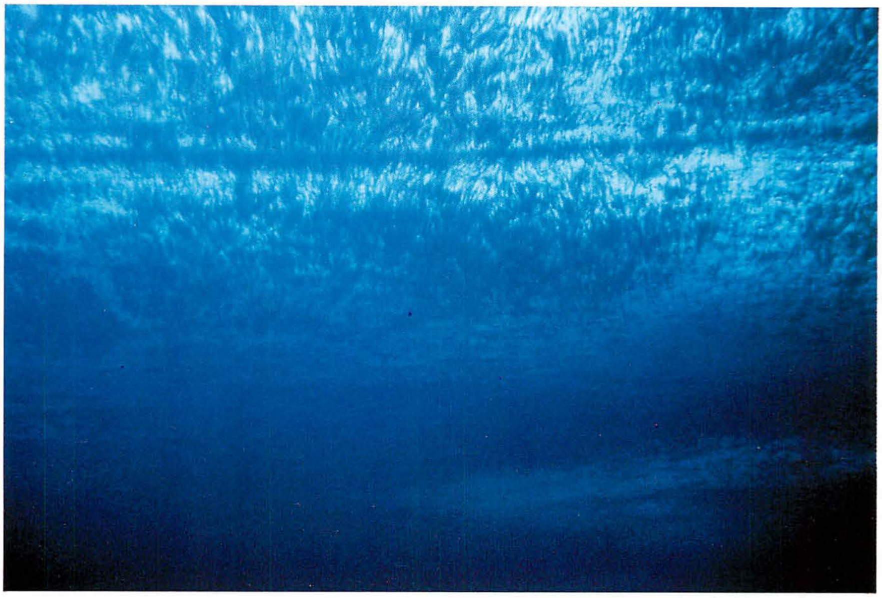
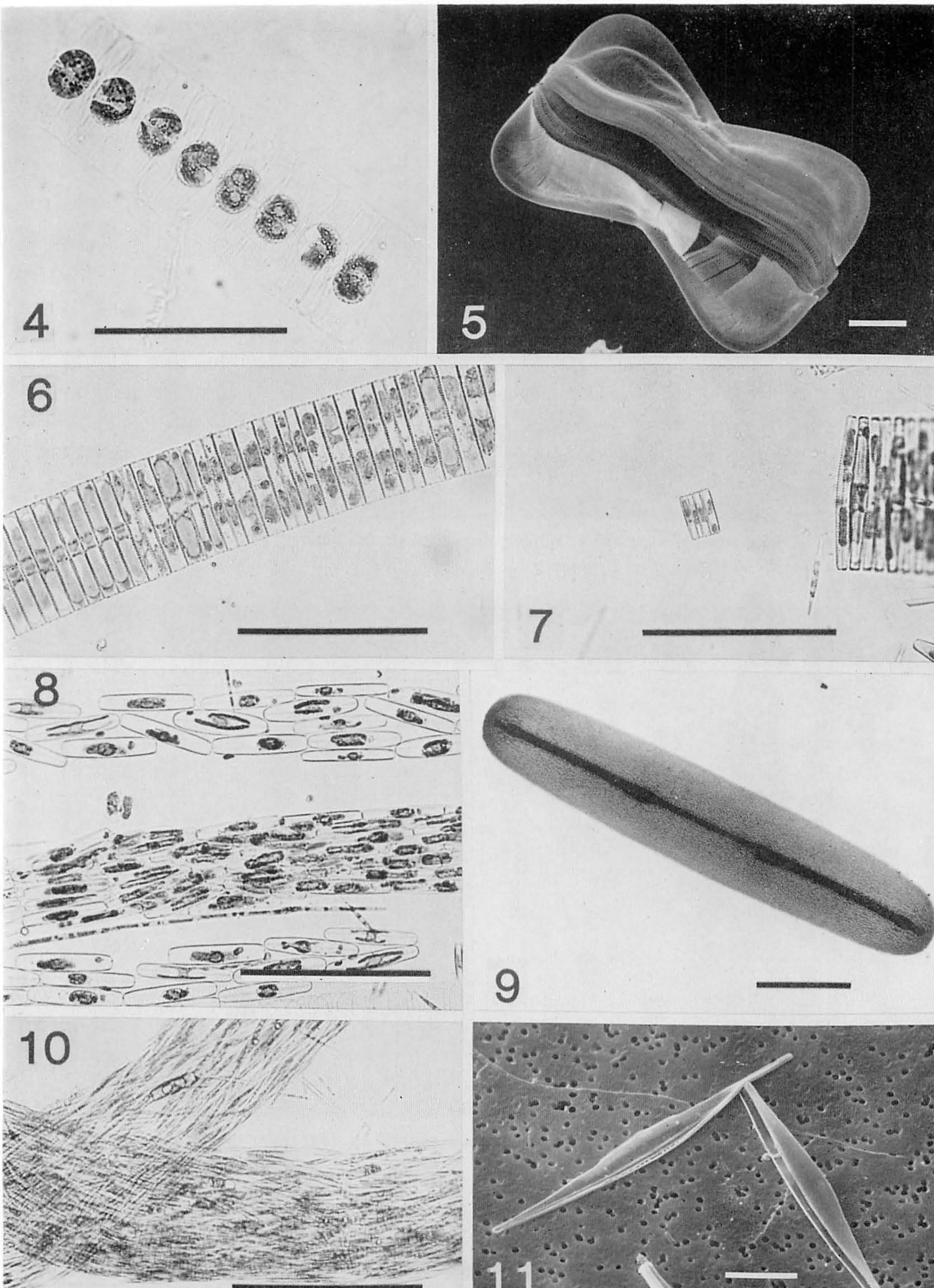


Fig. 2. Under-water photograph of sub-ice microalgal strands hanging from the fast ice in Kita-no-seto Strait near Syowa Station on November 5, 1983.

Fig. 3. Sub-ice microalgal strands extending about 50–60 cm into water column on December 12, 1983.

croalgae collected by the hand net from 20–25 cm beneath the ice in November (H.N. 3) was much less than that of H.N.1 (0–5 cm) and H.N.2 (10–15 cm). These microalgal strands appeared slightly different in their colony form and density on the ice from those reported from near Davis (Figs. 2 and 3 in McConville *et al.*, 1985). On November 5, strands were more densely distributed beneath a crack in the sea ice than


4
5
6
7
8
9
10
11

elsewhere. This unevenness of algal abundance was apparently due to the higher irradiance penetrating through the crack.

The strands were found to be longer (up to 50–60 cm) on December 9 and 12 (Fig. 3). The amount of microalgae in samples H.N.4, 5 and 6 did not differ greatly. On December 9, both short (Syr.3) and long (Syr.4) microalgal strands and globular colonies ca. 5 mm in diameter (Syr. 5), attached to the bottom of the sea ice, were collected from different locations. The strands were so fragile that they were often detached and broken by the water movement or by air bubbles exhausted from a diver. Therefore, it is presumed that the growth of sub-ice microalgal strands requires calm water. There were patches where no microalgal strands were found. This might reflect ice melting from the bottom surface which correlates with a marked decrease of ice algal standing crop in the fast ice area near Syowa Station in November and December (WATANABE and SATOH, 1987).

Most of the species appearing in the microalgal strand in this study were diatoms. Of the eleven selected taxa on which relative abundance were determined, seven formed colonies. The microalgal strands, hanging into water column, would possibly benefit zooplankton and micronekton which feed on ice algae because they are more easily accessible to grazers than microalgae inside the sea ice.

Amphiprora kufferathii MANGIN and *Nitzschia* spp. in group 1 and group 2 formed a ribbon-shaped colony (Figs. 4–7). Both groups of *Nitzschia* spp. belong to a section *Fragilariopsis* (HASLE 1972) forming similar colony in a water mount, but were distinguished on the basis of the fact that the former's valve costae were coarse enough to be seen in girdle view by light microscopy (LM) at a magnification of 200X, whereas the latter ones could hardly be seen at a magnification of 400X. By SEM examination of cleaned samples, *Nitzschia* spp. in group 1 and group 2 were found to include at least *N. obliquecostata* (VAN HEURCK) HASLE and *N. sublineata* HASLE, and *N. curta* (VAN HEURCK) HASLE and *N. cylindrus* (GRUNOW) HASLE, respectively. *Berkeleya rutilans* (TRENTEPOHL) GRUNOW and *Nitzschia lecointei* VAN HEURCK formed a tubular colony, in which cells were packed (Figs. 8–11). Sometimes, both species were found in the same tube. *B. rutilans* was abundant in the sub-ice assemblage of the coastal fast ice area near Davis (McCONVILLE *et al.* 1985). HASLE (1964) reported that *N. lecointei* occurred in great numbers in ice samples and that its proper habitat seems to be the under-surface of ice. *Nitzschia stellata* MANGUIN formed a stellate colony (Fig. 12) and *N. turgiduloides* Hasle formed short chains with cell ends overlapping (Fig. 13). *N. turgiduloides* has been reported to be abundant in the samples from the under-surface of pack-ice in the Atlantic Ocean (HASLE, 1965). The only centric diatom species *Porosira pseudodenticulata* (HUSTEDT) JOUSE, found, appeared in chains with valve faces connected to each other (Figs. 14, 15). It was the dominant species (96%) in the faintly colored bottom layer of sea ice 80 m off Langhovde in Lützow-Holm Bay (WATANABE 1982). Three other species, *Navicula glaciei* VAN HEURCK, *Nitzschia closterium* (EHRENBERG) W. SMITH and *Pleurosigma*

Figs. 4, 5. *Amphiprora kufferathii.* 4. Light micrograph (LM) showing the ribbon-shaped colony in a water mount. 5. Scanning electron micrograph (SEM) of a valve.

Fig. 6. A ribbon-shaped colony of *Nitzschia* species in group 1 in a water mount (LM).

Fig. 7. A short fragment of a colony of *Nitzchia* species in group 2 in a water mount in the center of this photograph (LM). Note that the valve costae cannot be seen in girdle view, while those of *Nitzschia* species in group 1 in the right are recognizable.

Figs. 8, 9. *Berkeleya rutilans.* 8. Tubular colony in a water mount (LM). 9. Transmission electron micrograph (TEM) of a valve.

Figs. 10, 11. *Nitzschia lecointei.* 10. Tubular colony fully packed with the cells in a water mount (LM). 11. SEM of two cells. (Scale bar: 100 μm for Figs. 4, 6, 7, 8 and 10; 10 μm for other figures.)

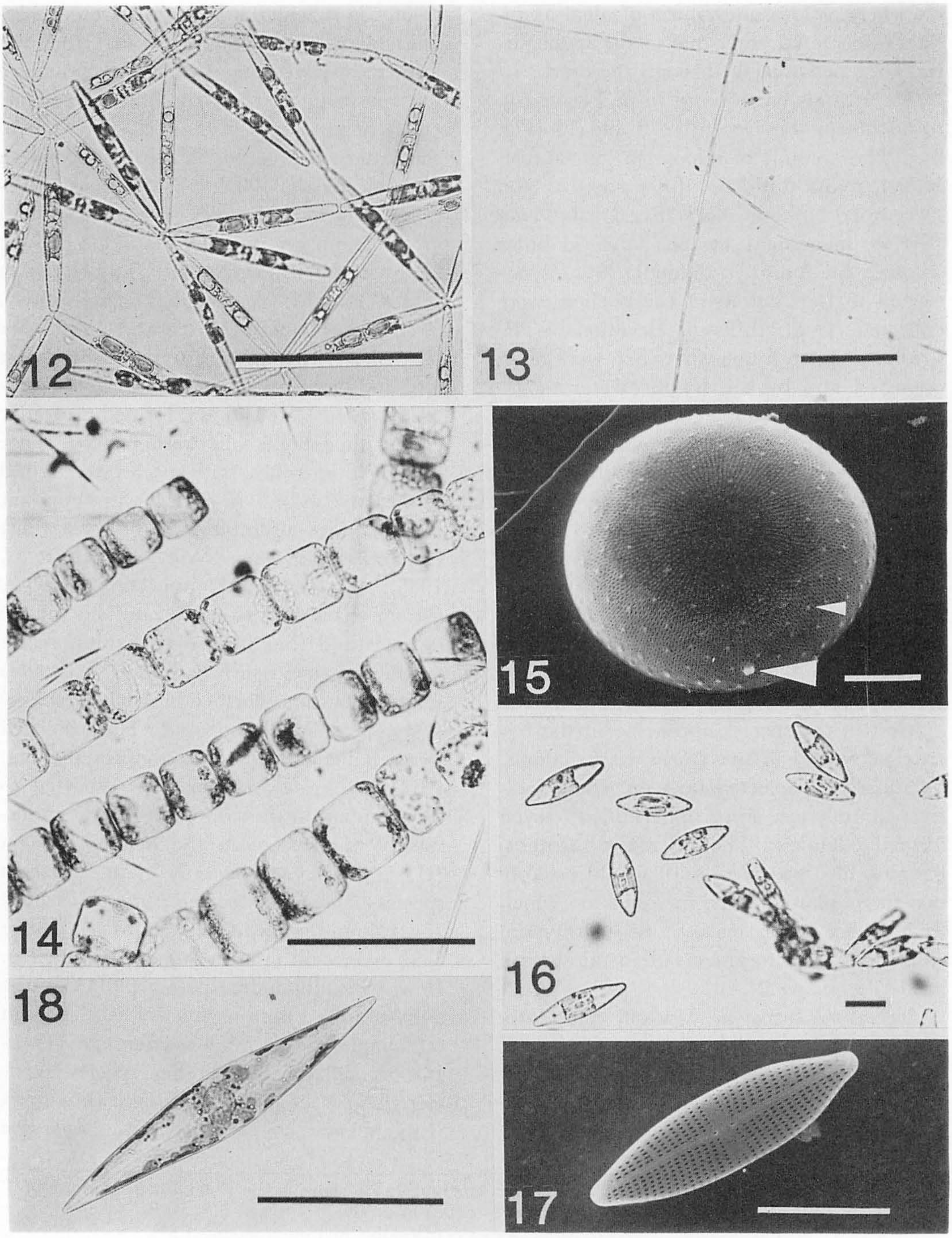


Fig. 12. *Nitzschia stellata*, forming characteristic stellate colonies in a water mount (LM).

Fig. 13. *Nitzschia turgiduloides*, forming a chain-shaped colony in a water mount (LM).

Figs. 14, 15. *Porosira pseudodenticulata*. 14. Chain-shaped colonies in a water mount (LM). 15. Valve view with a labiate process (large arrow) and strutted processes (small arrow) (SEM).

Figs. 16, 17. *Navicula glaciei*. 16. Cells in a water mount (LM). 17. SEM.

Fig. 18. *Pleurosigma directum* in a water mount (LM).

(Scale bar: 100 μm for Figs. 12, 13, 14 and 18; 10 μm for other figures.)

directum GRUNOW appeared as solitary cells (Figs. 16–18). Of these, *N. glaciei* was found to be abundant in the coastal tide-crack overflow region in Signy Is. (WHITAKER, 1977) and in Ongulkalven Is. near Syowa Station (WATANABE, unpublished), and *P. directum* was dominant (73%) in ice-algal assemblage in the off Prince Olav Coast as *Pleurosigma* sp. (WATANABE, 1982).

Species composition of the sub-ice samples are shown in Table 1. All samples were dominated by pennate diatoms (94.1–99.8%). The dominant taxa which appeared in more than 10% of samples were *Nitzschia lecointei, Amphiprora kufferathii, N. stellata, Berkeleya rutilans, Navicula glaciei, Nitzaxhia turgiduloides* and *Nitzschia* species in group 1. The results of a cluster analysis based on PSI (%), of the species composition of sub-ice samples are shown in Fig. 19. The globular sub-ice colony found on December 9 (Syr. 5), which was domi-

Table 1. Relative abundance (%) of selected taxa in sub-ice assemblages collected in Kita-no-seto Srait mear Syowa Station in 1983. Samples were collected with a syringe (Syr. samples) and with a hand net (H.N. samples). See text for more details.

Sampling Date	Nov. 5					Dec. 9					
Species/Samples	Syr. 1	Syr. 2	H.N. 1	H.N. 2	H.N. 3	Syr. 3	Syr. 4	Syr. 5	H.N. 4	H.N. 5	H.N. 6
Amphiprora kufferathii	6.6	11.4	13.4	12.5	13.2	2.5	4.7	45.0	11.6	16.2	20.1
Berkeleya rutilans	6.8	7.1	0.5	0.5	0.3	10.4	10.0	0.9	5.4	0	0
Navicula glaciei	0.7	11.5	17.8	16.3	4.7	1.2	4.9	2.8	6.3	15.0	16.6
Nitzschia closterium	0.5	0.6	0.8	0.4	0.2	2.0	1.3	2.6	2.2	1.4	1.7
N. lecointei	65.8	13.8	26.6	24.2	7.5	16.5	10.6	7.8	49.2	30.9	30.2
N. stellata	3.6	2.0	9.1	13.7	14.4	1.2	1.0	21.6	10.1	12.0	13.4
N. turgiduloides	4.5	10.7	0.6	1.8	1.1	11.0	3.4	0	0.3	0.6	0
N. spp. in group 1	2.3	35.4	10.0	21.3	53.7	35.0	42.9	5.9	7.7	4.0	4.6
N. spp. in group 2	1.1	0.8	0.1	0	1.4	1.1	3.4	0.1	0.7	1.8	0
Pleurosigma directum	1.9	0.3	0.7	0.2	0.3	0.1	0	5.5	0.3	0.9	0.7
Porosira pseudodenticulata	0.3	1.7	0.3	0.2	0.3	5.7	0.8	0	0.2	0.3	0.1
Pennales	99.5	98.3	99.7	99.7	99.7	94.1	98.8	99.1	99.8	99.6	99.4
Centrales	0.3	1.7	0.3	0.3	0.3	5.9	1.2	0.1	0.2	0.3	0.1

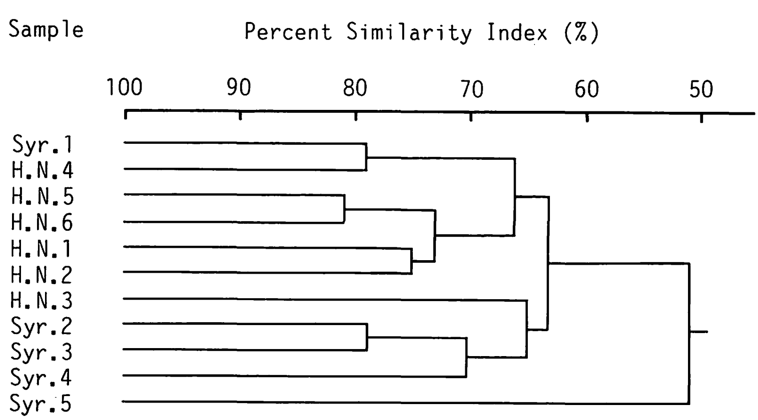


Fig. 19. A dendrogram showing the results of cluster analysis based on Percent Similarity Index (PSI) of the species composition of sub-ice samples. Samples were collected with a syringe (Syr. samples) and with a hand net (H.N. samples). Syr. 1 and 2 and H.N. 1–3 were collected on November 5 and Syr. 3–5 and H.N. 4–6 on December 9.

nated by *A. kufferathii* and *N. stellata*, has least similarity to others. However, samples from long and short strands collected on December 9 (Syr. 4 and Syr. 5, respectively) did not differ greatly (PSI=66.9%). They were dominated by *Nitzschia* species in group 1, *N. lecointei* and *Berkeleya rutilans*. As the hand net was towed for 10 m, samples collected by it represent averaged species composition in the area swept. Among hand net samples, H.N.5 and 6 collected on December 9 and H.N. 1 and 2 collected on November 5 had a high PSI; 79.6 and 74.0%, respectively. *Nitzschia lecointei, Navicula glaciei, Amphiprora kufferathii* and *Nitzschia stellata* dominated. H.N.3 sample had least similarity to other hand net samples. It contained *Nitzschia* species in group 1, *N. stellata* and *A. kufferathii*. These taxa which make long tubular or stellate colonies, may play an important role in forming long microalgal strands at an early stage of their development.

Acknowledgments

The author expresses his gratitude to Prof. T. HOSHIAI (N.I.P.R.) for his valuable advice during this study and critical reading of the manuscript. He is grateful to Dr. H.J. MARCHANT (Australian Antarctic Division) for reviewing the manuscript and helpful suggestions. He also thanks Prof. S. MAE (Univ. Hokkaido), the leader of the 24th Japanese Antarctic Research Expedition and the members of the party, especially Drs. H. KANDA (N.I.P.R.), H. SATOH (Tokyo Univ. Fish.) and E. TAKAHASHI (Univ. Kobe) for their helpful assistance in the ice diving operations.

References

CROSS, W.E. 1982. Under-ice biota at the Pond Inlet ice edge and in adjoining fast ice area during spring. Arctic **35**: 13–27.

HASLE, G.R. 1964. *Nitzschia* and *Fragilariopsis* species studied in the light and electron microscopes. I. Some marine species of the groups Nitzschiella and Lanceolatae. Skr. Norske Vidensk.-Akid. I. Mat.-Nat. Ki. N. S. **16**: 1–48.

HASLE, G.R. 1965. *Nitzschia* and *Fragilariopsis* species studied in the light and electron microscopes. II. The group Pseudonitzschia. Skr. Norske Vidensk.-Akid. I. Mat.-Nat. Ki. N. S. **18**: 1–45.

HASLE, G.R. 1972. *Fragilariopsis* HUSTEDT as a section of the genus *Nitzschia* Hassall. Nova Hedwig. Beihefte **39**: 111–119.

HASLE, G.R. 1978. Some specific preparations. Diatoms. *In*: SOURNIA, A. (ed.) Phytoplankton Manual, Paris, UNESCO Press.

HORNER, R.A. 1985. Ecology of Sea ice microalgae. *In*: HORNER, R.A. (ed.) Sea Ice Biota. CRC Press, Boca Raton.

MCCONVILLE, M.J., MITCHELL, C. and WETHERBEE, R. 1985. Patterns of carbon assimilation in a microalgal community from annual sea ice, east Antarctica. Polar Biol. **4**: 135–141.

SASAKI, H. and WATANABE, K. 1984. Underwater observations of ice algae in Lützow-Holm Bay, Antarctica. Nankyoku Shiryo (Antarct. Rec.) **81**: 1–8.

SIMONSEN, R. 1974. The diatom plankton of the Indian Ocean Expedition of R.V. "Meteor" 1964–65. Meteor Forschungsergeb. (D. Biol.), **19**: 1–66.

SULLIVAN, C.W., PALMISANO, A.C., KOTTMEIER, S. and MOE, R. 1982. Development of the sea ice microbial community in McMurdo Sound. Antarct. J. U. S. **17**: 155–157.

WATANABE, K. 1982. Centric diatom communities found in the Antarctic sea ice. Nankyoku Shiryo (Antarct. Rec.) **74**: 119–126.

WATANABE, K., NAKAJIMA, Y. and NAITO, Y. 1982. SCUBA ice diving along the coast of East Ongul Island, Antarctica. (in Japanese) Nankyoku Shiryo (Antarct. Rec.) **75**: 75–92.

WATANABE, K. and SATOH, H. 1987. Seasonal variations of ice algal standing crop near Syowa Station, East Antarctica, in 1983/84. Bull. Plankton Soc. Japan **34**: 143–164.

WATANABE, K., SATOH, H., KANDA, H. and TAKAHASHI, E. 1986. Report on the marine biological investigations near Syowa Station, 1983/84 (JARE-24) as a BIOMASS programme. (in Japanese) Nankyoku Shiryo (Antarct. Rec.) **30**: 48–65.

WHITAKER, T.M. 1977. Sea ice habitats of Signy Island (South Orkneys) and their primary productivity. *In* Llano, G. A. (ed.) Adaptations within Antarctic Ecosystems. Smithonian Institution, Washington D.C.

WHITTAKER, R.H. 1952. A summer study of foliage insect communities in the great Smokey Mountains. Ecol. Monogr. **22**: 1–44.

渡辺研太郎：南極昭和基地周辺定着氷下に見られたヒモ状微細藻類群体

南極昭和基地近くの定着氷下面に成長する微細藻類の太いヒモ状群体を海中から観察・採集し，種組成を調べた。7月中旬には海氷下面に群体は見られなかったが，11月上旬，10〜15 cm の長さの微細藻類から構成される太ヒモ状群体が海氷から水中へ垂れ下がっているのが観察され，12月上旬には50〜60 cm の長さに達するものが見られた。太ヒモ状群体を構成していたのは主に羽状目珪藻類，特に長い群体を形成する *Amphiprora kufferathii*, *Berkeleya rutilans*, *Nitzschia lecointei*, *Nitzschia stellata*, *Nitzschia turgiduloides*, section *Fragilariopsis* に属する *Nitzschia* 属の数種，および単独性の *Navicula glaciei* だった。海氷下面を手持ちネットで 10 m 区間採集したサンプルをクラスター分析したところ，11月と12月のサンプル間には顕著な種の遷移は認められなかった。（173 板橋区加賀1-9-10 国立極地研究所）

新 刊 紹 介

TRONO, G.C. & GANZON-FORTES, E.T.: Philippine Seaweeds, 328 pp, paperback, 1988, National Book Store, Inc., Manila, Price unknown.

著者達は Marine Science Inst., Univ. of Philippines 所属の海藻学者であり，開発途上国であるフィリピンでの海藻資源の研究をしている。

第1章は序論。第2章は pp. 6-196 で，総種数 141 についての線画とカラー写真を伴った記載であるが，写真は通常紙印刷のせいもあって明瞭でないものも少くない。緑藻は77種，褐藻は31種，紅藻は80種を掲載。種の記載は中程度の詳しさ。第3章は pp.197-204 で，海藻の現地での利用面を扱い，第4章は pp. 205-244 で，資源としての海藻を扱い，学名，地方名，利用区分，利用程度，野生と養殖の別から成る表（pp. 206-228），*Gracilaria*, *Eucheuma*, *Caulerpa*, *Porphyra* の海中や池中での養殖技術（pp. 229-236），収穫と市場価値（pp. 236-238），収穫物の処理（pp. 238-244）と寒天，カラゲナン，アルギン酸の製造法が述べられる。第5章（pp. 245-255）は海藻産業を扱い，輸出入，価額，問題点その他が述べられる。最後に，術語解，文献リスト（約200件），付録としての，食用海藻の調理法（12 pp.），海藻漁獲関連法令，標本作製法，*Eucheuma* と *Caulerpa* の海中と池中養殖の詳細（カラー写真多数），種名と件名索引が付いている。

浅海産の大型および普通種に限定されたので，名属又は科内のフィリピン産の全容を知ることはできぬ。現地人以外にとってはむしろ種の記載＋図よりも，現地独特の上記2属の養殖の現状が興味深いと思われる。ともあれ，東南アジアからこのような出版物が現われるようになったことは評価すべきと考える。

著者の訂正メモによれば，Figs 142 と 143 の説明が交換されてミスプリントとなっている。（191 日野市日野6498-4-103 赤塚伊三武）