A Study of the Ice Biota of Frobisher Bay, Baffin Island 1979–1981

E. H. Grainger and Stephen I. C. Hsiao

Arctic Biological Station
Department of Fisheries and Oceans
Ste. Anne de Bellevue, Quebec H9X 3R4

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A STUDY OF THE ICE BIOTA OF FROBISHER BAY, BAFFIN ISLAND, 1979-1981

A report prepared for Esso Resources Canada Limited and Canterra Energy Limited (formerly Aquitaine Company of Canada Limited)

by

E. H. Grainger and Stephen I. C. Hsiao

Arctic Biological Station
Department of Fisheries and Oceans
555 St. Pierre Boulevard
Ste. Anne de Bellevue, Que.
H9X 3R4

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ABSTRACT

Grainger, E.H. and Stephen I. C. Hsiao. 1982. A study of the ice biota of Frobisner Bay, Baffin Island, 1979-1981. A report prepared for Esso Resources Canada Limited and Canterra Energy Limited (formerly Aquitaine Company of Canada Limited). Can. MS Rep. Fish. Aquat. Sci. 1647: ix + 128 p.

A total of 227 species in 48 genera of microalgae were identified from annual shore-fast sea ice samples collected in Frobisher Bay, Baffin Island, between 1979 and 1981. The diatoms were represented by 213 species (25 centric and 188 pennate), the dinoflagellates by 4 species, the green algae and chrysophytes by 3 species each, the blue-green algae and euglenoids by 2 species each.

As the sea ice microalgae developed in the fall, grew slowly through the winter months, increased dramatically in spring, and reached a maximum just before the beginning of the spring thaw, the numbers of species and cells increased as did the number of dominant species. Then, as ice melting occurred, the microalgae declined rapidly. Most of the sea ice microalgal blooms occurred in the bottom of the ice, while Nitzschia grunowii and N. frigida also occurred elsewhere in the ice. Several species were found unique to specific depths of the ice and to the underlying waters with many having a seasonal occurrence.

The standing stock of microalgae expressed as per unit volume was greatest at the bottom of the ice, where it was one or two orders of magnitude larger than in other parts of the ice column. It was 7 to 72 times greater than that of phytoplankton in the underlying water, when expressed as per unit volume, but it was 2 to 13 times smaller when compared on a per unit area basis.

There were at least 20 species of animals found within the sea ice of Frobisher Bay. Nematode worms were the most abundant (nearly 3×10^5 per m^2), followed by copepods, larvae of polychaete worms, and larvae of pelecypod molluscs. At least 13 species were reported here for the first time from within arctic sea ice.

Among animals, many ice inhabitants, generally the most abundant ones, were found in far greater concentrations in the ice than in the water below. In a few copepods, this ratio changed significantly during the ice season. Several forms were consistently rare in the ice, although they reached large numbers in the water below, and there were a number of plankters not found at all in the ice. All ice-inhabiting animals were taken in the plankton.

Plant cells were shown to be the primary food of all the ice-dwelling animals about which information on feeding is available. The sea ice as a feeding and sheltering area was discussed, along with the accessibility of the lower surface of the ice to possible ice-seeking (surface-seeking) zooplankton, many of which belong to primarily benthic animal groups.

Key words: Arctic sea ice microalgae, phytoplankton, species composition, vertical distribution, abundance, community structure, standing stock, sea ice fauna, zooplankton, sea ice salinity, nutrients, chlorophyll.

RESUME

Grainger, E.H. and Stephen I. C. Hsiao. 1982. A study of the ice biota of Frobisher Bay, Baffin Island, 1979-1981. A report prepared for Esso Resources Canada Limited and Canterra Energy Limited (Formerly Aquitaine Company of Canada Limited). Can. MS Rep. Fish. Aquat. Sci. 1647: ix + 128 p.

Entre 1979 et 1981, un total de 227 espèces réparties entre 48 genres d'algues microscopiques ont été identifiées à partir d'échantillons de glace prélevés à même la banquise côtière annuelle dans la baie de Frobisher, Terre de Baffin. Les diatomées y sont représentées par 213 espèces (25 de forme centrique et 188 de forme pennée), les dinoflagellées par 4 espèces, les algues vertes et les chrysophytes par 3 espèces chacune, les algues bleues et les euglèniens par 2 espèces chacune.

Pendant que les algues microscopiques de la banquise se développent à l'automne, s'accroissent d'abord lentement au cours des mois d'hiver puis de façon dramatique au printemps pour atteindre un maximum au début du dégel du printemps, le nombre d'espèces et de cellules augmente de même que le nombre d'espèces dominantes. Par la suite, lors de la fonte des glaces, les algues microscopiques subissent un déclin rapide. La plupart des blooms d'algues microscopiques de la banquise se déroulent dans la partie inférieure de la glace; le bloom des espèces Nitzschia grunowii et N. frigida ne se limite pas à ce seul niveau mais prend aussi place ailleurs dans la glace. Plusieurs espèces sont associées à des niveaux spécifiques de la glace et aux eaux sous-jacentes. Parmi ces espèces, un grand nombre d'entre elles ne sont présentes que de manière saisonnière.

Exprimée par unité de volume, la biomasse des algues microscopiques

est plus élevée dans la couche inférieure de la glace dépassant par un ou deux ordres de grandeur les valeurs obtenues pour les autres parties de la colonne de glace. La biomasse est de 7 à 72 fois supérieure à celle du phytoplancton présent dans les eaux sous-jacentes lorsqu'exprimée par unité de volume mais de 2 à 13 fois moins élevée lorsque la comparaison est faite par unité de surface.

On a constaté la présence d'au moins 20 espèces d'animaux vivant à même la banquise de la baie de Frobisher. En ordre d'abondance, les nématodes figurent au premier rang (près de 3×10^5 par m^2) suivis des copépodes, des larves de polychètes et des larves de mollusques pélécypodes. Des espèces animales rapportées ici, au moins 13 d'entre elles n'avaient jamais été trouvées vivant à même la glace. Parmi les nombreux animaux qui habitent la glace, pour les espèces retrouvées en abondance, on observe généralement de plus fortes concentrations dans la glace que dans la colonne d'eau sous-jacente. Dans le cas de quelques copépodes, ce rapport change de façon significative au cours de la saison des glaces. Plusieurs espèces ne sont retrouvées que rarement dans la glace et ceci de façon constante même si elles atteignent des nombres élevés dans la colonne d'eau. Certaines espèces du plancton n'ont jamais été observées dans la glace. Tous les animaux habitant la glace sont également présents dans le plancton.

De tous les animaux résidant dans la glace pour lesquels des renseignements sont disponibles quant à leurs habitudes alimentaires, il a été démontré que les cellules végétales constituaient la principale source de nourriture. La possibilité de trouver nourriture et abri à même la banquise est discutée de même que la facilité d'accès de sa surface inférieure à la fraction du zooplancton qui recherche un support (la glace) et dont plusieurs espèces appartiennent à des groupes d'animaux avant tout benthiques.

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THE FLORA OF THE SEA ICE

Stephen I. C. Hsiao

INTRODUCTION

Microalgae within seasonal shore-fast ice in Frobisher Bay lasts eight to nine months a year, starting from newly formed sea ice in late October that thickens through the winter months to 2 metres by early June (Hsiao 1980). Microalgal cells are present in the ice from the time it forms, but they are few in number and scattered through the entire thickness of the ice so that no visible layer of organisms is present. By late March a relatively large population exists in the ice and by late April or May a thin layer of coloured bands ranging from brownish-green, greenish-brown, yellow-brown, brown, dark brown to red develop in the arctic sea ice particularly in the bottom layers (Gran 1904, Apollonio 1961, Bursa 1961, Meguro et al. 1967, Alexander et al. 1974, McRoy and Goering 1976, Grant and Horner 1976, Hsiao 1980). These bands are caused by the pigments of microalgae containing different proportions of diatoms, green flagellates, dinoflagellates, blue-green algae and chrysophytes growing on or trapped within the ice. The ice communities and standing stock of Frobisher Bay consists mainly of diatoms with a great majority of pennate forms (Hsiao 1980). Dinoflagellates, flagellates and chrysophytes occur in relatively low numbers. No blue-green algae have been observed. Large numbers of species and cells of microalgae form at the bottom of the sea ice. It has been recognized that sea ice microalgae play an important role as primary producers in the arctic marine ecosystem (Meguro et al. 1967, Horner and Alexander 1972, Alexander 1974, McRoy and Goering 1974, Clasby et al. 1976). They may provide a major food source for ice-associated fauna and cod, which in turn are the food source for many of the large whales, seals, fishes and birds (Horner 1976, McConnaughey and McRoy 1979).

The composition of ice flora in the Canadian arctic was studied as early as 1878 by Dickie in the region between Smith Sound and Robeson Channel, by Cleve (1896) in Baffin Bay and Davis Strait and by Gran (1904) in the Arctic Ocean. All of this information was obtained from drifting, broken ice-floes or samples taken from ice upturned in the path of ice-breakers. None of it was quantitatively evaluated from species composition. Recently, Dunbar and Acreman (1980) used a SIPRE ice corer to take samples from solid, unbroken sea ice at Hudson Bay, Robeson Channel, Barrow Strait and Austin Channel, and quantitatively analyzed the samples from the 20 cm of the ice core for species composition and standing stock of diatoms. Hsiao (1980) comprehensively investigated the quantitative composition, vertical distribution, community structure and standing stock of microalgae in the Canadian arctic sea ice of the Eskimo Lakes, Eclipse Sound and Frobisher Bay, and examined some environmental factors controlling their distribution. It is necessary to undertake further studies on the variations in species composition, vertical distribution, community structure and standing stock of sea ice microalgae under the present relatively undisturbed conditions prior to resource development, and to compare them with the phytoplankton in the underlying waters.

MATERIALS AND METHODS

The sea ice microalgal samples were collected with a 7.6 cm SIPRE ice corer from the top to the bottom of the ice at station 1 in Frobisher Bay during late fall and early summer of the years 1979 to 1981 (Fig. 1). The total length of the ice core was measured, and was cut into 3 equal portions with a fine-toothed meat saw. An additional 5-cm sample was taken from another ice core. All ice samples were placed in plastic containers, and thawed in the field laboratory at room temperature. The methods of preservation, species identification and enumeration for sea ice microalgae were described by Hsiao (1980). Chlorophyll a was analyzed with a spectrophotometric technique following the method of Strickland and Parsons (1972), and was calculated from the Jeffrey-Humphrey equations (Jeffrey and Humphrey 1975).

The total cell counts and chlorophyll a were used to estimate the standing stock of sea ice microalgae. The integrated standing stock was used as the standard value for seasonal and regional comparisons.

RESULTS

Species composition, distribution and abundance.

A total of 227 species in 48 genera of sea ice microalgae was identified from Frobisher Bay (Table 1). Among them, the diatoms were represented by 213 species (25 centric and 188 pennate), the dinoflagellates by 4 species, the green algae and chrysophytes by 3 species each, the blue-green algae and euglenoids by 2 species each. The species composition, vertical distribution, and abundance of sea ice microalgae in Frobisher Bay are presented in detail in Tables 5 - 18. The diatoms were ubiquitous and always the most important group. They dominated in numbers of species and cells.

Most species of microalgae were scattered throughout the entire thickness of the sea ice, but 8 species (Buddulphia aurita, Chaetoceros atlanticus, C. compressus, Distephanus speculum, Navicula cincta var. heufleri, Nedium iridis var. ampliatum, Synedra acus var. radian and Thalassiosira bioculata) occurred only at the top of the ice; another 6 species (Coscinodiscus kuetzingii, Melosira binderana, Navicula radiosa, Nitzschia diaphana, Oscillatoria sp. and Thalassiosira kryophila) were found exclusively in the middle of the ice; and remarkably there were 80 species found only at the bottom of the ice (Table 1).

The numbers of species and vertical distribution of sea ice microalgae increased from February through March-April and reached a maximum in May in the entire ice column (Table 2). Greater numbers of species slightly decreased at the top, middle and bottom 5 cm of the ice, while they increased at the bottom of the sea ice.

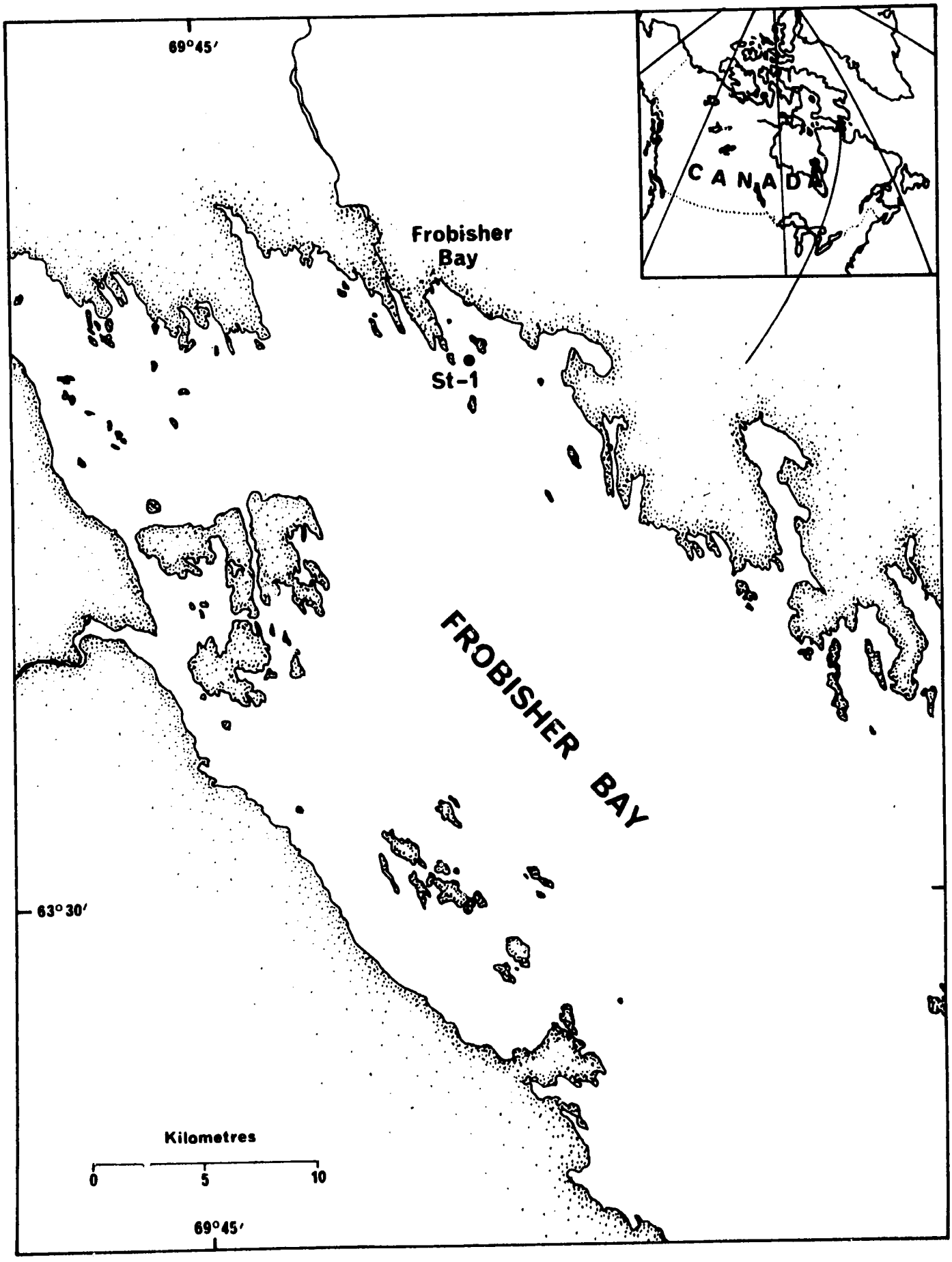
69°45′
CANADA
Frobisher
Bay
St-1
FROBISHER BAY
63°30′
Kilometres
0
5
10
69°45′

Table 1. Species composition, occurrence and vertical distribution of sea ice microalgae in Frobisher Bay. T, t, M, m, B, b, B5 and b5 indicate the top, middle, bottom and bottom 5 cm of the sea ice. Capital letters indicate dominant species (more than 100,000 cells per litre), while lower case letters simply show presence in particular layers. An asterisk (*) indicates the species also occurring in the water beneath the sea ice.

Sea ice microalgae	December				February				March				May				June			
	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5
Bacillariophyta (diatoms)																				
Centrales																				
*Biddulphia aurita (Lyngbye) Brébisson et Godey													t							
Chaetoceros atlanticus Cleve													t							
*C. borealis Bailey									t		b									
C. compressus Lauder													t							
*C. fragilis Meunier					t				t	m	b		t					m	b	
*C. furcellatus Bailey	t	m	b	b5	t	m	b		t	m	b		t	m	b	b5	t	m	b	b5
*C. karianus Grunow in Cleve et Grunow	t	m			t	m	b		t	m	b		t	m	b	b5	t	m	b	
*C. septentrionalis Oestrup		m	b		t	m	b		t	m		b5	t	m	b	b5	t	m	b	b5
*Coscinodiscus kuetzingii Schmidt														m						
*C. lacustris Grunow in Cleve et Grunow													t	m	b	b5		m	b	b5
*C. lacustris var. septentrionalis (Grunow) Rattray					t	m	b	b5	t	m	b	b5	t	m	b	b5			b	
*C. polyacanthus Grunow in Cleve et Grunow																b5			b	b5
*Cyclotella comta var. oligactis (Ehrenberg) Grunow in Van Heurck																			b	
*Melosira arctica (Ehrenberg) Dickie in Pritchard									t	m	b	b5	t	m	b		t		b	
M. binderana Kuetzing																		m		
Rhizosolenia Ehrenberg							b		t					m			t		b	
*Thalassiosira aestivalis Gran et Angst														m		b5	t	m	b	b5
*T. baltica (Grunow in Cleve et Grunow) Oestenfeld														m	b				b	b5
*T. bioculata (Grunow) Oestenfeld																	t			
*T. bioculata var. exigua (Grunow) Hustedt																		m	b	
T. gravida Cleve																b5			b	
T. hyalina (Grunow in Cleve et Grunow) Gran																			b	
*T. kryophila (Grunow) E. Joergensen																		m		
*T. nordenskioldii Cleve	t	m		b5	t	m	b	b5	t	m	b	b5	t	m		B5	t	m	b	b5
*T. oestrupii (Oestenfeld) Proschkina-Lavrenko ex Hasle					t	m		b5	t	m	b	b5	t	m	b	b5	t	m	b	b5
Pennales																				
*Achnanthes clevei Grunow in Cleve et Grunow																			b	
*A. curta (A. Cleve) A.Berg ex Cleve-Euler																	t		b	
*A. delicatula (Kuetzing) Grunow in Cleve et Grunow																	t			b5
*A. hauckiana Grunow in Cleve et Grunow														m					b	b5
*A. lemmermannii Hustedt																b5				
*A. marginulata Grunow in Cleve et Grunow																			b	

Table 1. (Continued)

Sea ice microalgae	December				February				March				May				June			
	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5
*A. taeniata Grunow in Cleve et Grunow				b5	t	m	b	b5	t	m	B	B5	t	m	b	B5	t	m	B	b5
*Amphiprora concilians Cleve							b	b5				b5	t	m	b	B5	t	m	b	b5
*A. gigantea var. septentrionalis (Grunow in Cleve et Grunow) Cleve					t	m	b	b5		m	b		t	m	b	b5	t	m	b	b5
A. kjellmanii Cleve in Cleve et Grunow													t	m	b		t	m	b	b5
A. kjellmanii var. kariana (Grunow in Cleve et Grunow) Cleve				b5	t	m	b		t	m	b	b5	t	m	b	b5	t		b	b5
A. kjellmanii var. striolata (Grunow in Cleve et Grunow) Cleve															b	b5			b	
A. kryophila Cleve						m	b	b5		m	b	b5	t	m	b	b5			b	
A. paludosa Wm. Smith													t		b					
A. paludosa var. hyperborea (Grunow in Cleve et Grunow) Cleve														m						
*Amphora coffeaeformis (Agardh) Kuetzing													t		b	B5	t	m	b	b5
*A. exigua Gregory																			b	
*A. exsecta Grunow in Schmidt et al.	m	b		b5	t	m	b	b5	t	m	b	B5	t	m	b	b5			b	
*A. laevis Gregory														m	b		t	m	b	b5
*A. laevis var. laevissima (Gregory) Cleve					t	m		b5	t	m	b	b5			b	B5		m	b	b5
A. laevis var. minuta Cleve															b					b5
A. laevissima var. minuta Cleve																				b5
A. proteus Gregory													t			b5				
Bacillaria paradoxa Gmelin in Linneaeus																B5				b5
Caloneis kryophila (Cleve) Cleve							b	b5				b5		m	b	b5				
*Cocconeis californica (Grunow in Cleve et Moeller) Grunow in Van Heurck																			b	
*C. costata Gregory	t			b5	t	m	b	b5	t		b	b5	t	m	b	b5	t		b	b5
*C. diminuta Pantocsek																			b	
*C. scutellum Ehrenberg									t				t			b5	t		b	b5
*C. scutellum var. stauroneiformis Rabenhorst										m		b5			b	b5	t		b	
*C. thumensis Mayer															b					b5
*Cylindrotheca closterium (Ehrenberg) Reimann et Lewin	m	b		b5	t	m	b	b5	t	m	B	B5	t	m	b	B5	t	m	B	b5
*Diatoma elongatum (Lyngbye) Agardh																				b5
Diploneis contigua (Schmidt in Schmidt et al.) Cleve																b5			b	
*D. didyma (Ehrenberg) Ehrenberg													t		b	b5			b	b5
*D. lineata (Donkin) Cleve														m	b		t		b	
*D. litoralis (Donkin) Cleve													t	m	b	B5	t	m	b	b5
*D. litoralis var. arctica Cleve	t		b		t	m	b	b5	t	m	b	B5	t	m	b	B5	t	m	b	b5
*D. litoralis var. clathrata (Oestrup) Cleve				b5	t	m	b	b5	t	m	b	B5	t	m	b	b5				b5
*D. smithii (Brébisson in Wm. Smith) Cleve																				b5
*Fragilaria brevistriata Grunow in Van Heurck																b5				b5
F. crotonensis Kitton																			b	
*F. pinnata Ehrenberg													t			b5				

Table 1. (Continued)

Sea ice microalgae	December				February				March				May				June			
	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5
*F. virescens Ralfs																			b	b5
F. virescens var. subsalina Grunow in Van Heurck																			b	
*Fragilariopsis nana (Steemann-Nielsen) Paasche																	t			b5
*Gomphonema exiguum Kuetzing	m				t		b		t		b		t	m		B5				b5
*G. exiguum var. pachycladum (Brébisson in Brébisson et Godey) Cleve		b			t	m		b5	t	m	b	b5	t	m		B5			b	
G. groenlandicum Oestrup							b	b5									t			
*G. kamtschaticum Grunow														m		b5	t	m	b	b5
Gyrosigma fasciola (Ehrenberg) Griffith et Henfrey																b5				
G. glaciale (Cleve) Cleve													t	m	b	B5	t	m	b	b5
*G. lineare (Grunow in Cleve et Grunow) Cleve														m	b	b5	t	m	b	b5
Licmophora gracilis (Ehrenberg) Grunow													t			b5				
*L. gracilis var. anglica (Kuetzing) Peragallo et Peragallo		b	b5		t					m	b		t	m	b	b5				
*Navicula algida Grunow						m	b	b5	t	m	b	b5	t	m	b	b5		m	b	b5
N. ammophila f. minuta (Grunow in Cleve et Grunow) Oestrup																	t			b5
N. areschougiana Grunow																			b	b5
N. aucklandica Grunow																				b5
*N. avenacea (Brébisson in Brébisson et Godey) Cleve																			b	
N. brasiliensis Grunow																b5				
*N. cancellata var. retusa (Brébisson) Cleve																b5				
*N. cincta (Ehrenberg) Ralfs in Pritchard																			b	
*N. cincta var. heufleri (Grunow) in Van Heurck																	t			
N. clementis Grunow																b5				b5
*N. cluthensis var. pagophila Grunow			b5					b5	t					m					b	
*N. comoides (Dillwyn) Peragallo et Peragallo													t				t	m		
N. corymbosa (Agardh) Cleve															b	b5				
*N. crassirostris Grunow in Cleve et Grunow								b5						m	b	B5		m	b	b5
*N. creuzburgensis Krasske																b5				
*N. crucigera (Wm. Smith) Cleve																B5				b5
*N. crucigeroides Hustedt							b	b5	t			b5	t	m	b	b5	t	m	b	b5
*N. cryptocephala Kuetzing											b		t	m	b					b5
*N. digitoradiata (Gregory) Ralfs in Pritchard	t	b				m	b	b5		m		b5	t	m	b	b5	t	m	b	b5
*N. directa (Wm. Smith) Ralfs in Pritchard		b	b5			m	b	B5	t	m	B	B5	t	m	b	B5	t	m	b	B5
N. directa var. cuneata Oestrup																b5				
*N. distans (Wm. Smith) Ralfs in Pritchard																B5				
*N. forcipata Greville												b5	t		b	b5		m	b	B5
*N. gastrum (Ehrenberg) Kuetzing											b									
*N. gelida Grunow		b			t	m	b	b5	t	m	b	B5	t	m	b	B5	t	m	b	b5
*N. gelida var. curta (Cleve) Cleve-Euler															b					b5

Table 1. (Continued)

Sea ice microalgae	December				February				March				May				June			
	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5
*N. glacialis (Cleve) Grunow								b5							b	b5				
*N. gracilis Ehrenberg															b	b5		m	b	b5
N. granulata J. W. Bailey																				b5
*N. hyalosira Cleve in Cleve et Moeller																				b5
*N. imperfecta Cleve															b	b5			b	b5
*N. kariana Grunow in Cleve et Grunow													t	m	b	B5	t	m	b	B5
N. kariana var. detersa Grunow in Cleve et Moeller																			b	
*N. kjellmanii (Cleve in Cleve et Grunow) Cleve																b5				b5
N. kryokonites Cleve																		m	b	
*N. kryokonites var. subprotracta Cleve													t	m	b	b5			b	b5
*N. marina Ralfs in Pritchard													t	m	b	b5			b	b5
*N. novadecipiens Hustedt					t		b	b5						m		b5		m	b	b5
N. obtusa (Cleve in Cleve et Moeller) Cleve																			b	
*N. oestrupi Cleve										b	b5		t		b	b5				
N. pellucida Karsten																				b5
*N. peregrina (Ehrenberg) Kuetzing																B5	t		b	b5
*N. peregrina var. meniscus (Schumann) Grunow in Heurck													t	m		b5		m	b	b5
N. perlucens Oestrup	m																			
*N. placentula (Ehrenberg) Kuetzing													t	m	b	B5	t	m	b	b5
*N. placentula f. lanceolata (Grunow) Hustedt																			b	b5
*N. pseudotenelloides Krasske															b					
*N. pygmaea Kuetzing														m	b	b5	t	m	b	b5
*N. radiosa Kuetzing														m						
N. recurvata Gran		b	b5				b	b5				b5				b5				
*N. rhynchocephala Kuetzing													t	m	b	b5			b	b5
*N. salinarum Grunow in Cleve et Moeller											b									
N. siberica (Grunow in Cleve et Moeller) Cleve																b5				
*N. solitaria Cleve																b5		m	b	b5
N. spicula (Hickie) Cleve											b	b5								
*N. subinflata Grunow in Cleve et Moeller																	t	m	b	
*N. superba Cleve														m		B5			b	b5
N. transfuga var. septentrionalis Oestrup																b5				b5
*N. transitans Cleve	m	b	b5		t	m	b	b5	t	m	B	B5	t	m	b	B5	t	m	b	b5
N. transitans var. asymmetrica (Cleve) Cleve													t	m						
*N. transitans var. derasa (Grunow in Cleve et Grunow) Cleve							b	b5			b		t	m	b	B5		m	b	b5
N. transitans var. erosa (Cleve) Cleve																				b5
*N. transitans var. incudiformis (Grunow in Cleve) Cleve						m	b	b5	t		b	B5	t	m	b	B5	t	m	b	b5
*N. trigonocephala Cleve							b	b5			b	b5	t	m	b	B5		m	b	b5
*N. trigonocephala var. contracta Oestrup																b5				
N. trigonocephala var. depressa Oestrup							b	b5			b	b5			b	b5				b5
N. trigonocephala f. minor Oestrup																b5			b	

Table 1. (Continued)

Sea ice microalgae	December				February				March				May				June			
	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5
*N. ulvacea (Kuetzing) Van Heurck														m	b	b5			b	b5
*N. valida Cleve et Grunow				b5	t	m		B5	t	m	b	B5	t	m	b	B5	t		b	b5
*N. valida var. minuta Cleve					t		b	b5		m	b	b5		m	b	B5	t	m	b	
*N. vanhoeffenii Gran													t			b5				b5
*N. vulpina Kuetzing																				
Nedium binodis (Ehrenberg) Hustedt																				b5
N. iridis var. ampliatum (Ehrenberg) Cleve																	t			
Nitzschia acicularis (Kuetzing) Wm. Smith							b				b		t	m	b	b5				b5
N. angularis Wm. Smith												b5				b5			b	b5
N. brebissonii Wm. Smith														m		B5				b5
N. brebissonii var. borealis Grunow in Cleve et Moeller				b5	t	m	b	b5	t	m	b	b5	t		b	B5	t			
*N. cryophila Cleve																		m	b	b5
*N. cylindrus (Grunow) Hasle							b	b5	t	m	b	b5	t	m	b	B5	t	m	b	b5
N. diaphana Cleve														m						
*N. distans Gregory																b5			b	b5
N. distans var. erratica Cleve				b5		m	b	b5		m	b	b5		m	b	B5	t	m	b	
*N. frigida Grunow in Cleve et Grunow		m	b	b5	t	m	b	B5	t	m	B	B5	t	m	B	B5	T	M	B	b5
*N. frustulum (Kuetzing) Grunow in Cleve et Grunow																			b	
N. gelida Cleve et Grunow in Cleve et Moeller						m													b	b5
*N. grunowii Hasle	t	m	b	B5	t	m	b	B5	t	m	B	B5	t	m	B	B5	T	M	B	
*N. hybrida Grunow in Cleve et Grunow					t				t	m		b5	t	m	b	b5	t	m	b	b5
*N. laevissima Grunow in Cleve et Moeller			b	b5	t		b	b5	t		b	B5			b	B5	t	m	b	b5
*N. lecointei Van Heurck				b5						m	b	b5	t	m	b	b5	t	m	B	b5
N. linearis (Agardh) Wm. Smith						m			t	m	B	B5	t	m	b	B5	t	m	b	
*N. longissima (Brébisson in Kuetzing) Grunow							b			m	b	b5	t	m	b	B5	t	m	b	b5
*N. obtusa Wm. Smith																b5			b	
*N. polaris Grunow in Cleve et Moeller		m							t				t	m	b	B5				b5
*N. seriata Cleve					t		b						t			B5				b5
N. sigma (Kuetzing) Wm. Smith												b5								
*N. socialis Gregory															b	b5	t		b	b5
*N. socialis var. kariana Grunow in Cleve et Grunow																				b5
*N. tergestina (Kuetzing) Ralfs in Pritchard			b	b5	t	m	b	B5	t	m	B	B5	t	m	B	B5	t	m	b	
*N. vitrea Norman																				b5
*Pinnularia ambigua Cleve								b5								b5			b	b5
*Parva (Ehrenberg) Gregory																b5				
*P. quadratarea (Schmidt) Cleve					t	m	b	b5	t	m	b	b5	t	m	b	B5	t	m	b	b5
*P. quadratarea var. bicontracta (Oestrup) Heiden in Schmidt et al.					t	m	b	b5	t	m	b	b5	t	m	b	B5	t	m	b	b5
P. quadratarea var. bicuneata Heiden et Kolbe														m		b5				
*P. quadratarea var. capitata Heiden in Schmidt et al.								b5	t	m	b	b5	t	m	b	b5		m	b	b5

Table 1. (Continued)

Sea ice microalgae	December				February				March				May				June			
	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5
*P. quadratarea var. constricta (Oestrup) Heiden in Schmidt et al.					t	m	b	b5		m	b	b5	t	m	b	b5		m	b	b5
*P. quadratarea var. cuneata Oestrup in Schmidt et al.																b5	t	m	b	b5
*Plagiogramma staurophorum (Gregory) Heiberg																b5				
*Pleurosigma antarcticum Heiden et Kolbe		b	b5		t	m	b	b5	t	m	b	B5	t	m	b	B5	t		b	b5
*P. clevei Grunow in Cleve et Grunow	m	b	b5		t		b	b5	t	m	b	b5	t	m	b	B5		m	b	b5
P. cuspidatum (Cleve) H. Peragallo															b				b	
P. elongatum Wm. Smith																				
*P. elongatum var. kariana (Grunow in Cleve et Grunow) Cleve	m		b5		t		b	b5	t		b	b5	t		b	b5				
P. longum Cleve																b5				
P. stuxbergii Cleve et Grunow																B5				
P. stuxbergii var. minor Grunow															b	b5				
*P. stuxbergii var. rhomboides (Cleve in Cleve et Grunow) H. Peragallo													t	m	b	B5			b	b5
Pseudonitzschia delicatissima (Cleve) Heiden in Heiden et Kolbe																B5				
*Rhabdonema arcuatum (Lyngbye) Kuetzing																			b	
Stauroneis quadripedis (Cleve-Euler) Hendey								b5		m	B	b5	t	m	b	B5	t	m	b	
Stenoneis inconspicua (Gregory) Cleve																b5				
*S. inconspicua var. baculus (Cleve in Cleve et Moeller) Cleve							b	b5			b	b5	t	m	b	b5			b	b5
*Surirella ovata Kuetzing																			b	
*Synedra acus var. radians (Kuetzing) Hustedt																	t			
*S. camtschatica Grunow																			b	
S. hyperborea var. rostellata Grunow																			b	
*S. pulchella (Ralfs) Kuetzing	m	b	b5					b5	t	m	b	b5	t	m	b	b5	t		b	b5
*S. tabulata (Agardh) Kuetzing							b	b5	t		b	b5	t	m	b	b5	t		b	
*S. tabulata var. fasciculata (Kuetzing) Hustedt									t	m	b	b5			b	b5		m	b	
*Tabellaria flocculosa (Roth) Kuetzing	m								t		b		t	m		b5	t		b	b5
Tropidoneis maxima (Gregory) Cleve														m		b5				
*T. vitrea (Wm. Smith) Cleve													t		b	b5		m	b	b5
Chlorophyta (green algae)																				
*Carteria Diesing					t	m	b													
*Unidentified green filaments				b5						m									b	
*Unidentified green flagellates	t	m	b	B5	t	m	b	B5	t	m	B	B5	t	m	b	B5	t	m	B	
Chrysophyta (chrysophytes)																				
Dinobryon balticum (Schuett) Lemmermann															b	b5				
Distephanus speculum (Ehrenberg) Haeckel									t											
Phaeocystis pouchetii (Hariot) Lagerheim										m	b								b	

Table 1. (Continued)

Sea ice microalgae	December				February				March				May				June			
	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5	Top	Mid	Bot	Bot5
Cyanophyta (blue-green algae)																				
Oscillatoria Vaucher														m						
*Unidentified Cyanophyceae	t	m			t				t	m	b		t	m					b	
Euglenophyta (euglenoids)																				
*Euglena proxima Dangeard	t	m			t	m	b	b5	t		b	b5	t	m		b5		m	b	
*Euglena Ehrenberg	t	m	b	b5						m	b		t	m				m	b	
Pyrrophyta (dinoflagellates)																				
*Goniaulax Diesing											b	b5								
*Gymnodinium Stein	t	m	b	b5	t	m	b	b5	t		b	b5		m	b	b5		m	b	
*Peridinium Ehrenberg			b		t		b				b		t			b5				
*Prorocentrum ovalis Rampi					t	m	b		t	m	b								b	b5

Table 2. Numbers of species of sea ice microalgae occurring in the ice column during 1979 - 1981 ice seasons at Station 1 in Frobisher Bay. The figures in the bracket incidate the numbers of dominant species.

	December	February	March	May	June
Top	12	44	54	88	69(2)
Middle	21	40	52	94	70(2)
Bottom	23	56	69(9)	97(3)	133(6)
Bottom 5 cm	29(2)	55(6)	62(17)	137(48)	111(3)

Of those dominant species whose cell numbers exceeded 10^5 per litre, 52 occurred at the bottom of the sea ice, especially in the bottom 5 cm (Table 1). The seven most frequently encountered were Achnanthes taeniata, Cylindrotheca closterium, Navicula directa, Nitzschia frigida, N. grunowii, N. tergestina and unidentified green flagellates. The greatest number of dominant species occurred in this layer through the spring months and peaked in May. Nitzschia grunowii and a species of unidentified green flagellates bloomed as early as December, and extended through February, March, May and June to the end of the ice season. In June Nitzschia grunowii and N. frigida bloomed throughout the entire ice column.

The highest counts in the top of the ice were obtained for the diatom Nitzschia grunowii with 2.7×10^5 cells/L in late June, a species of unidentified green flagellates with 3.2×10^4 cells/L in late June, a species of unidentified blue-green Cyanophyceae with 2.5×10^4 cells/L in May, the euglenoid Euglena sp. with 1.0×10^3 cells/L in May, the dinoflagellate Prorocentrum ovalis with 360 cells/L in February and the chrysophyte Distephanus speculum with 40 cells/L in March. The greatest numbers of cells in the middle of the ice were found to be Nitzschia grunowii comprising 2.4×10^5 cells/L in June, a species of unidentified green flagellates with 2.9×10^4 cells/L in late June, an unidentified Cyanophyceae with 2.9×10^4 cells/L in May, Peridinium sp. and Prorocentrum ovalis of the dinoflagellates each with 4,353 cells/L in June, Euglena sp. with 3,120 cells/L in December, and the chrysophyte Phaeocystis pouchetii with 200 cells/L in March. The most abundant of the ice flora occurred at the bottom of the sea ice, particularly at the bottom 5 cm: Nitzschia frigida had highest counts, reaching 40×10^5 cells/L in March; a species of unidentified green flagellates with 9.1×10^5 cells/L in early May, Phaeocystis pouchetii with 1.4×10^4 cells/L in March; Peridinium sp. with 5.0×10^4 cells/L in May, Euglena sp. with 4.0×10^4 cells/L in March; and an unidentified Cyanophyceae with 1.4×10^4 cells/L in May.

Community structure

The ice flora of Frobisher Bay consisted mainly of diatoms which were largely composed of pennate forms (Table 3). Green algae, blue-green algae, dinoflagellates, euglenoids and chrysophytes were fewer in numbers of species and cells. The greatest diatom community, in terms of numbers of species and cells, was found downward to the bottom of the sea ice throughout all of the ice season particularly during the months of May and June, when it reached a maximum. Smaller communities of the green algae, dinoflagellates and euglenoids frequently occurred at the lower parts of the ice during the early part of the ice season from December to March, then declined rapidly in early- and mid-May, and eventually disappeared in late May and early June. The blue-green algae usually formed a small community except in a single instance when they composed 72% of the total

Table 3. Standing stock and community structure of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay.

Date	Sea ice thickness (cm)	Sample type	Chl. a mg/m³	Cell Numbers x 10⁴/litre	Diatoms % *	Diatoms No. **	Green Algae %	Green Algae No.	Chryso-phytes %	Chryso-phytes No.	Blue-Green Algae %	Blue-Green Algae No.	Euglenoids %	Euglenoids No.	Dino-flagellates %	Dino-flagellates No.
10 Mar 79	154	Ice core (cm)														
		Top 0-5	0.20	1.6	70.2(C17.1 | P53.1)	29(C3 P26)	25.1	spp	0	0	0	0	0	0	4.7	1+spp
		Middle 75-80	0.20	3.0	59.3(C11.4 | P47.8)	29(C6 P23)	32.5	spp	0.7	1	2.5	spp	2.9	spp	2.2	1+spp
		Bottom 149-154	25.08	1 021.6	92.6(C 0.8 | P91.8)	41(C4 P37)	5.5	spp	0.1	1	0.1	spp	0.5	spp	0.1	1+spp
		Sea water (m)														
		0	0.29	1.1	3.2(C 0 | P 3.2)	5(C0 P 5)	52.3	spp	0	0	43.1	spp	0	0	1.4	spp
		10	0.20	1.1	6.4(C 1.1 | P 5.3)	3(C1 P 2)	47.6	spp	0	0	44.4	spp	0.8	spp	0.8	spp
		40	0.31	1.2	0 (C 0 | P 0)	0(C0 P 0)	48.4	spp	0	0	50.6	spp	0	0	1.0	spp
7 May 79	171	Ice core (cm)														
		Top 0-5	0.81	8.5	98.8(C10.7 | P88.2)	19(C3 P16)	0.6	spp	0.6	spp	0	0	0	0	0	0
		Middle 83-88	0.59	6.8	85.3(C 4.4 | P80.9)	20(C2 P18)	0	0	0	0	14.7	spp	0	0	0	0
		Bottom 166-171	47.6	1 379.0	99.5(C 2.6 | P96.9)	43(C3 P41)	0	0	0	0	0	0	0	0	0.5	spp
		Sea water (m)														
		0	0.31	1.5	66.6(C33.3 | P33.3)	8(C2 P 6)	0	0	0	0	0	0	0	0	0	0
		10	0.20	3.0	66.7(C 0 | P66.7)	2(C0 P 2)	0	0	0	0	0	0	0	0	0	0
		35	0.29	1.0	100.0(C50 | P50)	6(C2 P 4)	0	0	0	0	0	0	0	0	0	0
16 Jun 79	142	Ice core (cm)														
		Top 0-137	0.52	1.6	100.0(C 0 | P100)	17(C0 P17)	0	0	0	0	0	0	0	0	0	0
		Bottom 137-142	1.67	23.7	99.5(C 6.9 | P92.6)	29(C3 P26)	0	0	0	0	0	0	0	0	0.5	0
		Sea water (m)														
		0	0.44	0.9	100.0(C55.6 | P44.4)	11(C3 P 8)	0	0	0	0	0	0	0	0	0	0
		10	0.87	3.7	98.6(C46.6 | P52.0)	8(C4 P 4)	1.4	spp	0	0	0	0	0	0	0	0
		33	0.42	1.9	100.0(C31.6 | P68.4)	12(C6 P 6)	0	0	0	0	0	0	0	0	0	0
12 Dec 79	62	Ice core (cm)														
		Top 0-20	1.05	1.7	38.0(C 8.0 | P30.0)	8(C3 P 5)	44.6	spp	0	0	4.3	spp	5.5	1+spp	7.6	spp
		Middle 20-41	0.91	3.9	42.8(C13.1 | P29.7)	17(C4 P13)	32.5	spp	0	0	6.3	spp	8.6	1+spp	9.8	spp
		Bottom 41-62	1.94	22.6	57.7(C 3.9 | P53.8)	19(C2 P17)	34.6	spp	0	0	0	0	2.6	spp	5.1	spp
		Bottom 57-62	-	49.0	65.9(C 3.7 | P62.2)	25(C2 P23)	29.0	spp	0	0	0	0	0.7	spp	4.4	spp
		Sea water (m)														
		0	0.26	2.4	4.1(C 1.5 | P 2.6)	21(C2 P19)	94.5	spp	0	0	1.4	spp	0	0	0	0
		10	0.95	2.6	9.5(C 3.5 | P 6.0)	24(C3 P21)	89.6	spp	0	0	0.9	spp	0	0	0	0
		24	1.13	2.6	9.3(C 2.6 | P 6.7)	25(C2 P23)	88.7	spp	0	0	2.0	spp	0	0	0	0
12 Mar 80	137	Ice core (cm)														
		Top 0-45	1.06	2.9	21.3(C 9.0 | P12.3)	23(C8 P15)	4.6	spp	0	0	71.9	spp	2.2	spp	0	0
		Middle 45-91	0.21	3.0	68.9(C10.2 | P58.7)	27(C7 P20)	11.4	spp	0	0	19.6	spp	0.1	spp	0	0
		Bottom 91-137	7.06	134.2	91.3(C 2.7 | P88.7)	34(C4 P30)	6.5	spp	0	0	0.3	spp	0.8	spp	1.1	spp
		Bottom 132-137	-	175.4	96.5(C 2.0 | P94.5)	36(C2 P34)	3.0	spp	0	0	0	0	0.3	spp	0.2	spp
		Sea water (m)														
		0	0.12	0.9	27.7(C17.3 | P10.4)	21(C2 P19)	15.6	spp	0	0	56.7	spp	0	0	0	0
		10	0.09	0.7	63.4(C32.6 | P30.8)	48(C3 P45)	36.6	spp	0	0	0	0	0	0	0	0
		40	0.28	0.7	71.3(C29.7 | P41.6)	40(C4 P36)	28.7	spp	0	0	0	0	0	0	0	0

Table 3. (Continued)

Date	Sea ice thickness (cm)	Sample type	Chl. a mg/m³	Cell Numbers x 10⁴/litre	Diatoms %	Diatoms No.**	Green Algae %	Green Algae No.	Chryso-phytes %	Chryso-phytes No.	Blue-Green Algae %	Blue-Green Algae No.	Euglenoids %	Euglenoids No.	Dino-flagellates %	Dino-flagellates No.
6 May 80	162	Ice core (cm)														
		Top 0-54	0.38	4.1	90.8(C 3.9	P86.9) 30(C5 P25)	7.1	spp	0	0	0.8	spp	1.2	spp	0.1	spp
		Middle 54-108	1.04	4.2	95.5(C 5.2	P90.3) 35(C5 P30)	4.2	spp	0	0	0	0	0.3	spp	0	0
		Bottom 108-162	21.97	105.5	94.5(C 1.4	P93.1) 37(C1 P36)	5.5	spp	0	0	0	0	0	0	0	0
		Bottom 157-162	-	1 403.8	92.9(C 0.9	P92.0) 36(C2 P34)	6.5	spp	0	0	0	0	0.3	spp	0.3	spp
		Sea water (m)														
		0	0.13	2.9	11.0(C 8.6	P 2.4) 22(C3 P19)	19.1	spp	0	0	67.0	spp	0.3	spp	2.6	spp
		10	0.15	1.0	35.4(C14.2	P21.2) 16(C4 P12)	55.0	spp	0	0	9.6	spp	0	0	0	0
		40	0.22	1.0	39.4(C23.9	P15.5) 29(C3 P26)	60.6	spp	0	0	0	0	0	0	0	0
6 Jun 80	152	Ice core (cm)														
		Top 0-50	1.23	29.2	96.5(C 8.0	P88.5) 20(C4 P16)	3.0	spp	0	0	0	0	0	0	0.5	spp
		Middle 50-101	0.84	19.3	94.0(C 8.3	P85.7) 19(C5 P14)	5.2	spp	0	0	0	0	0.8	spp	0	0
		Bottom 101-152	1.57	140.4	92.2(C 4.4	P87.8) 29(C6 P23)	6.2	spp	0.8	1	0	0	0.5	spp	0.3	spp
		Sea water (m)														
		0	0.95	3.9	44.4(C22.0	P22.4) 47(C4 P43)	53.8	spp	0	0	0	0	0	0	1.8	spp
		10	1.65	1.2	45.5(C41.5	P 3.9) 7(C2 P 5)	54.6	spp	0	0	0	0	0	0	0	0
		40	4.05	0.4	57.1(C42.9	P14.2) 16(C2 P14)	42.9	spp	0	0	0	0	0	0	0	0
13 Jun 80	158	Ice core (cm)														
		Top 0-53	0.63	48.5	93.1(C 6.6	P86.5) 19(C4 P15)	6.0	spp	0	0	0.3	spp	0	0	0.6	spp
		Middle 53-105	0.83	36.3	91.6(C 4.8	P86.8) 25(C6 P19)	5.6	spp	0	0	0.4	spp	0	0	2.4	1+spp
		Bottom 105-158	1.73	241.6	91.1(C 3.8	P87.3) 35(C4 P31)	8.1	spp	0	0	0	0	0.3	spp	0.5	spp
		Sea water (m)														
		0	0.42	7.6	34.1(C 5.2	P28.9) 71(C8 P63)	60.5	spp	0	0	5.1	spp	0.1	spp	0.2	spp
		10	1.63	1.2	9.1(C 5.4	P 3.7) 15(C3 P12)	86.9	spp	0	0	4.0	spp	0	0	0	0
		40	1.25	1.5	25.7(C10.0	P15.7) 29(C3 P26)	68.5	spp	0	0	5.8	spp	0	0	0	0
20 Jun 80	100	Ice core (cm)														
		Top 0-33	0.76	63.4	94.5(C 6.9	P87.6) 24(C6 P18)	5.0	spp	0	0	0	0	0	0	0.5	spp
		Middle 33-66	0.94	59.8	93.9(C 5.1	P88.8) 24(C6 P18)	4.9	spp	0	0	0	0	0.2	0	1.0	spp
		Bottom 66-100	1.63	305.4	93.9(C 2.4	P91.5) 32(C5 P27)	5.6	spp	0	0	0	0	0	0	0.5	spp
		Sea water (m)														
		0	0.36	7.0	46.4(C14.1	P32.3) 77(C12P65)	51.2	spp	0	0	2.4	spp	0	0	0	0
		10	0.58	3.2	8.7(C 2.6	P 6.1) 21(C4 P17)	86.4	spp	0	0	4.9	spp	0	0	0	0
		40	0.75	2.9	40.8(C 9.2	P31.6) 51(C5 P46)	54.5	spp	0	0	4.7	spp	0	0	0	0
14 Feb 81	123	Ice core (cm)														
		Top 0-41	0.33	4.2	77.2(C33.0	P44.2) 38(C7 P31)	20.4	spp	0	0	0.3	spp	0.9	spp	1.3	spp
		Middle 41-82	0.23	2.0	80.6(C23.2	P57.4) 41(C6 P35)	17.3	spp	0	0	0	0	0.6	spp	1.5	1+spp
		Bottom 82-123	5.43	19.5	85.0(C 4.0	P81.0) 60(C6 P54)	13.5	spp	0	0	0	0	0.3	1+spp	1.2	1+spp
		Bottom 118-123	-	286.9	89.3(C 5.1	P84.2) 59(C6 P53)	9.1	spp	0	0	0	0	0.3	spp	1.4	1+spp
		Sea water (m)														
		0	0.19	1.1	26.0(C11.0	P15.0) 9(C4 P 5)	67.1	spp	0	0	0	0	2.7	spp	4.2	spp
		10	0.17	1.1	22.7(C11.0	P11.7) 8(C3 P 5)	67.8	spp	0	0	0	0	6.8	spp	2.7	spp
		42	0.19	1.3	31.9(C 6.0	P25.9) 11(C3 P 8)	65.3	spp	0	0	0	0	2.8	spp	0	0

Table 3. (Continued)

Date	Sea ice thickness (cm)	Sample type	Chl. a mg/m³	Cell Numbers x 10⁴/litre	Diatoms % *	Diatoms No. **	Green Algae %	Green Algae No.	Chryso-phytes %	Chryso-phytes No.	Blue-Green Algae %	Blue-Green Algae No.	Euglenoids %	Euglenoids No.	Dino-flagellates %	Dino-flagellates No.
24 Mar 81	142	Ice core (cm)														
		Top 0-47	0.48	2.1	72.0(C16.8 P55.2)	22(C5 P17)	19.9	spp	0.2	1	0	0	1.5	1+spp	6.4	1+spp
		Middle 47-94	0.42	2.0	90.2(C25.6 P64.6)	24(C5 P19)	7.6	spp	0	0	0	0	1.0	spp	1.2	1+spp
		Bottom 94-142	3.88	5.6	83.6(C15.5 P68.1)	53(C6 P47)	14.6	spp	0	0	0	0	0.4	spp	1.4	spp
		Bottom 137-142	-	846.5	93.8(C 2.2 P91.6)	52(C5 P47)	5.3	spp	0	0	0	0	0.5	spp	0.4	spp
		Sea water (m)														
		0	0.13	1.0	63.5(C41.4 P22.1)	12(C6 P 6)	29.3	spp	0	0	0	0	2.8	1+spp	4.4	spp
		10	0.16	1.5	54.8(C32.8 P22.0)	13(C4 P 9)	41.8	spp	0	0	0	0	1.8	1+spp	1.6	spp
		40	0.13	1.8	66.2(C32.7 P33.5)	19(C5 P14)	29.4	spp	0	0	0.7	spp	1.3	spp	2.4	spp
1 May 81	145	Ice core (cm)														
		Top 0-48	0.51	9.2	91.7(C11.4 P80.3)	42(C8 P34)	5.6	spp	0	0	1.1	spp	1.4	1+spp	0.2	spp
		Middle 48-96	0.73	10.6	93.3(C 6.9 P86.4)	42(C6 P36)	6.0	spp	0	0	0.2	spp	0.3	1+spp	0.2	spp
		Bottom 96-145	2.94	18.7	82.1(C 2.7 P79.4)	51(C5 P46)	16.3	spp	0.2	1	0	0	0.6	spp	0.8	spp
		Bottom 140-145	-	203.8	91.3(C 5.1 P86.2)	52(C5 P47)	8.5	spp	<0.1	1	0	0	<0.1	1+spp	<0.1	spp
		Sea water (m)														
		0	0.20	1.1	37.3(C18.3 P19.0)	11(C4 P 7)	57.6	spp	1.1	spp	0	0	2.2	spp	1.8	spp
		10	0.28	0.7	35.7(C25.6 P 9.8)	6(C3 P 3)	60.0	spp	1.4	spp	0	0	1.4	spp	1.8	spp
		40	0.12	1.1	35.9(C15.9 P20.0)	10(C3 P 7)	59.2	spp	0.8	spp	0	0	3.0	spp	1.1	spp
27 May 81	148	Ice core (cm)														
		Top 0-49	1.30	86.7	97.1(C11.7 P85.4)	23(C4 P19)	0	0	0	0	2.9	spp	0	0	0	0
		Middle 49-98	2.09	63.1	95.4(C12.6 P82.8)	47(C4 P43)	0	0	0	0	4.6	spp	0	0	0	0
		Bottom 98-148	4.80	99.0	99.3(C 7.4 P91.9)	50(C4 P46)	0	0	0	0	0	0	0	0	0.7	spp
		Bottom 143-148	391.79	1 342.0	100.0(C 7.0 P93)	81(C3 P78)	0	0	0	0	0	0	0	0	0	0
		Sea water (m)														
		0	0.48	0.5	100.0(C21.2 P78.8)	37(C2 P35)	0	0	0	0	0	0	0	0	0	0
		10	0.24	0.4	100.0(C39.8 P60.2)	30(C4 P26)	0	0	0	0	0	0	0	0	0	0
		40	0.50	0.9	100.0(C51.1 P48.9)	45(C6 P39)	0	0	0	0	0	0	0	0	0	0
19 Jun 81	137	Ice core (cm)														
		Top 0-46	0.51	83.8	100.0(C 6.9 P93.1)	46(C5 P41)	0	0	0	0	0	0	0	0	0	0
		Middle 46-92	1.14	86.3	100.0(C 8.0 P92.0)	47(C5 P42)	0	0	0	0	0	0	0	0	0	0
		Bottom 92-137	1.94	248.8	99.8(C10.1 P89.7)	103(C8 P95)	0	0	0	0	0	0	0	0	0.2	0
		Bottom 132-137	21.34	648.9	100.0(C 7.2 P92.8)	96(C7 P89)	0	0	0	0	0	0	0	0	0	0
		Sea water (m)														
		0	5.43	195.9	39.6(C 2.1 P37.5)	118(C8 P110)	57.3	spp	0	0	3.1	spp	0	0	0	0
		10	0.09	2.7	63.2(C13.1 P50.2)	65(C5 P60)	36.8	spp	0	0	0	0	0	0	0	0
		40	0.29	2.1	93.9(C18.5 P75.4)	101(C9 P92)	6.1	spp	0	0	0	0	0	0	0	0

* Percentage of total population
** Number of species
†C Centric diatoms
§P Pennate diatoms

microalgal populations in the top of the ice. Chrysophytes were sparse and represented the smallest community, never exceeding 0.8% of the total populations.

Standing stock

The standing stock results, as measured by both chlorophyll a and cell counts, are presented in Table 3. In the top of the ice it increased from 1.6 x 10^4 cells/L with chlorophyll a of 0.2 mg/m^3 in early March to 86.7 x 10^4 cells/L with chlorophyll a of 1.3 mg/m^3 in late May; in the middle of the ice it increased from 2.0 x 10^4 cells/L with chlorophyll a of 0.23 mg/m^3 in mid-February to 86.3 x 10^4 cells/L with chlorophyll a of 1.14 mg/m^3 in mid-June; in the bottom of the ice it increased from 5.6 x 10^4 cells/L with chlorophyll a of 3.88 mg/m^3 in late March to 248.8 x 10^4 cells/L with chlorophyll a of 1.94 mg/m^3 in mid-June; and in the bottom 5 cm of the ice cell counts increased from 49.0 x 10^4 cells/L in mid-December to 1403.8 x 10^4 cells/L in early May, and chlorophyll a increased from 25.08 mg/m^3 in early March to 391.79 mg/m^3 in late May. The greatest numbers of cells and concentrations of chlorophyll a were found in the bottom 5 cm of the ice. The average standing stock of the whole ice column increased from 9.4 x 10^4 cells/L with chlorophyll a of 1.3 mg/m^3 in mid-December to 464.8 x 10^4 cells/L with chlorophyll a of 16.3 mg/m^3 in early May.

Integrated standing stock, in terms of cell numbers and chlorophyll a per square meter over the whole ice column, showed that the standing stock started to build up from the time of ice formation in late fall. From initial values of 3.37 x 10^7 cells/m^2 with chlorophyll a of 0.51 mg/m^2, there was a progressive increase through the winter months, followed by a dramatic increase in early spring to the maximum level of 399.31 x 10^7 cells/m^2 with a chlorophyll a value of 20.74 mg/m^2 in late spring, and thereafter a rapid decline as ice melting occurred in early summer (Figs. 2 and 3).

Maximum standing stock of sea ice microalgae was found during late spring and early summer, and was composed mostly of pennate diatoms, mainly Navicula and Nitzschia. Each of the following species, Achnanthes taeniata, Cylindrotheca closterium, Navicula directa, Nitzschia frigida, N. grunowii, N. longissima and N. tergestina, had cell numbers greater than 1 million per litre. In general, the standing stock increased with ice thickness and the approach of summer just prior to ice melting.

DISCUSSION

The sea ice microalgae consisted of 227 species, while the phytoplankton in the underlying water column beneath the sea ice comprised 118 species. The ice microalgae were represented by 213 species of diatoms (25 centric and 188 pennate), 4 dinoflagellates,

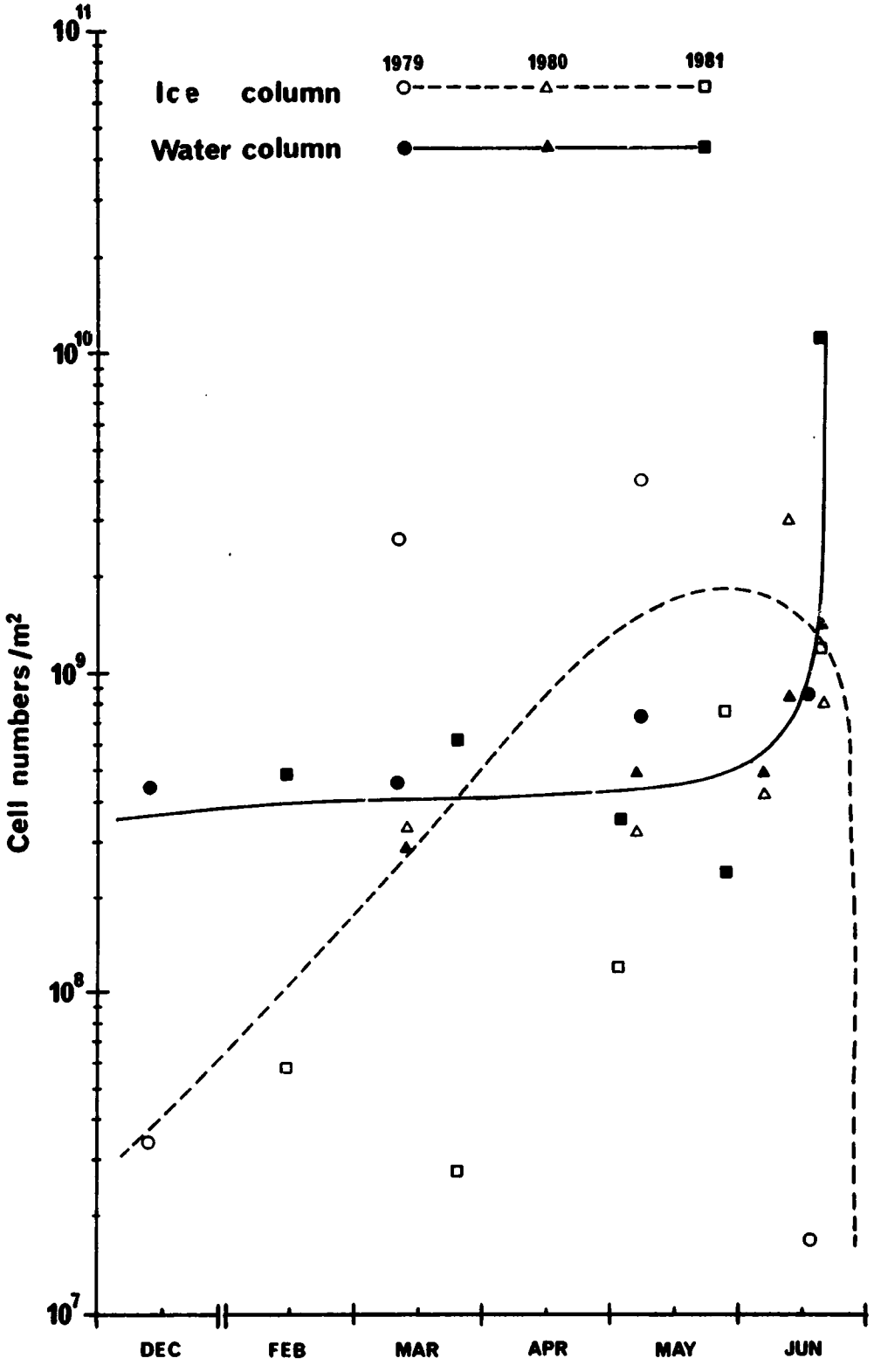

Fig. 2. Seasonal changes of standing stock (expressed as cell numbers per square meter) of sea ice microalgae and phytoplankton in the water beneath the sea ice in Frobisher Bay.

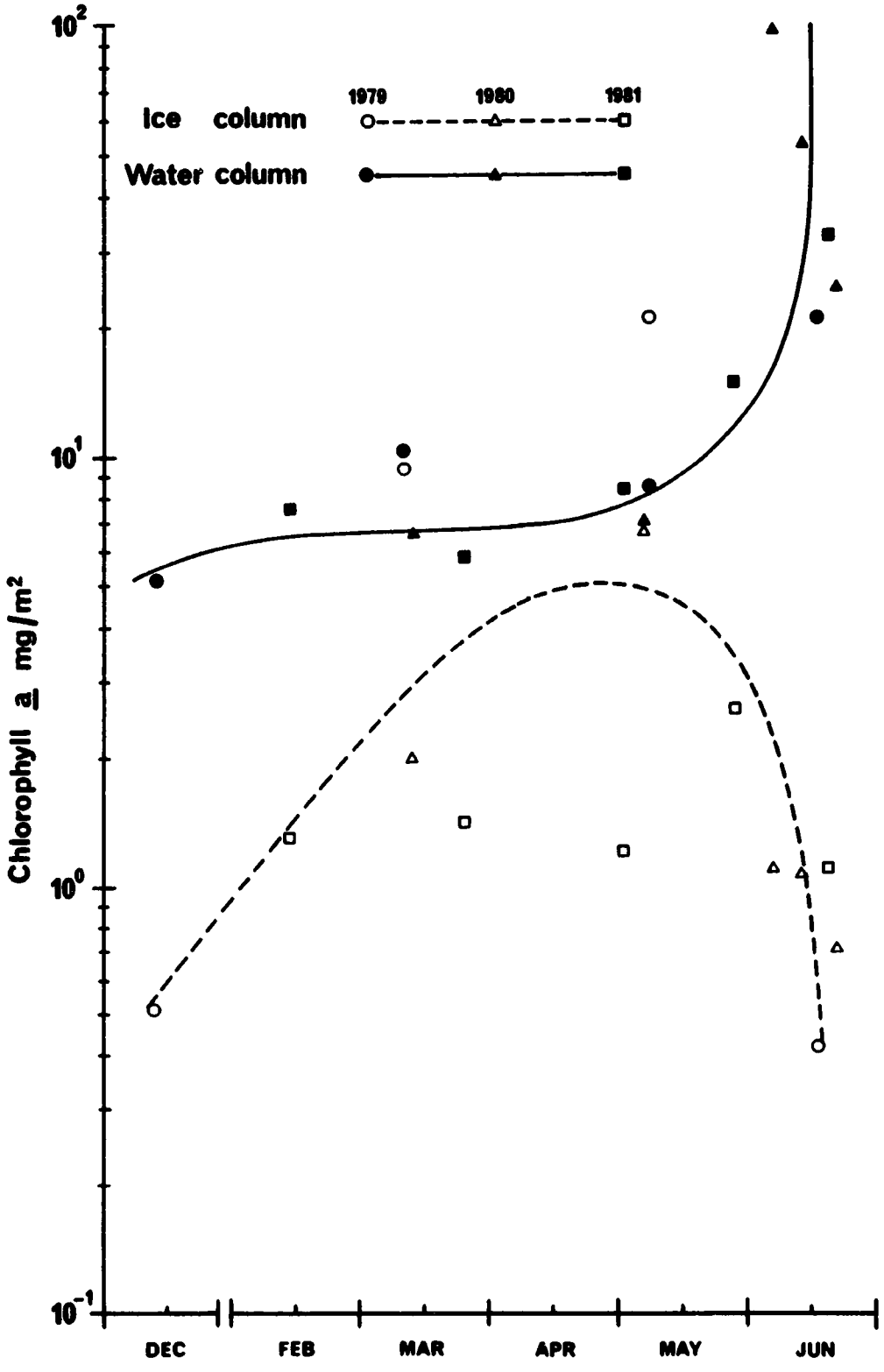

Fig. 3. Seasonal changes of standing stock (expressed as chlorophyll a concentration mg per square meter) of sea ice microalgae and phytoplankton in the water beneath the sea ice in Frobisher Bay.

3 green algae, 3 chrysophytes, 2 blue-green algae and 2 euglenoids, while the underlying phytoplankton were represented by 117 species of diatoms (7 centric and 110 pennate), and 1 blue-green alga. The ice diatoms that have been found include 24 species more than that in the previous studies made in 1971 to 1978 (Hsiao 1980). Oscillatoria sp. and a species of unidentified Cyanophyceae of blue-green algae, Carteria sp. and a species of unidentified green filaments of green algae, and Dinobryon balticum and Distephanus speculum of chrysophytes in the sea ice were first recorded in Frobisher Bay. The groups other than the species mentioned above remained the same. There were 71 species taken only in the sea ice and 118 species found only in the water column (Table 4), while 156 species commonly occurred in both the ice and the water (Table 1).

Usachev (1949) designated 24 diatom species (3 centric and 21 pennate) as typical cryophiles from the ice in the Kara and Laptev Seas. All these cryophiles except Fragilaria islandica were also found in the Frobisher Bay sea ice. Meguro et al. (1967) listed 24 species of pennate diatoms, but no other algae, in the bottom of sea ice off Point Barrow, Alaska. Twenty-one of them, except Gomphonema exiguum var. arctica, Navicula gracilis var. inaequalis, Nitzschia lavuensis, also occurred commonly in the sea ice of Frobisher Bay. The pennate diatoms, Nitzschia frigida and Navicula directa were the most abundant species in the ice microalgal community in the Chukchi Sea at Barrow (Horner and Alexander 1972, Clasby et al. 1976), but were not found in areas farther from shore (Meguro et al. 1967). These species commonly occurred in this study. Other dominant species are listed in Table 1, which includes all species found by Horner and Alexander (1972), and Dunbar and Acreman (1980).

During the ice season the diatom community overwhelmingly exceeded the green algae, blue-green algae, dinoflagellates, euglenoids and chrysophytes. In the communities in the underlying waters most of the time the green algae were more abundant than the diatoms except on two occasions (March and May) when the blue-green algae were slightly more numerous. On only one occasion did the green algal community out number the diatoms. They were 6.8% more numerous in the top of the ice in mid-December. On only one occasion did the blue-green algae out number (by 50.6%) the diatoms in the top of the ice. This occurred in mid-March. The diatom community consisted mostly of pennate species in the ice, while centric diatoms in the underlying waters were in a few instances 2 to 37.6% more numerous than pennates.

Allen (1971) reported that extremely dense growth of microalgae, principally small pennate diatoms, developed in the ice at high latitude. Horner and Alexander (1972) found only pennate diatoms occurring the Chukchi Sea ice. Later, Horner (1976) observed several species of Chaetoceros and Thalassiosira, centric diatoms, occurring in an ice community dominated by pennate diatoms and small flagellates, in the ice at Barrow. Grant and Horner (1976) collected Coscinodiscus

Table 4. Phytoplankton taxa found only in the water column beneath the sea ice in Frobisher Bay.

Bacillariophyta (diatoms)
  Centrales
    Chaetoceros neogracile Van Landingham
    C. socialis Lauder
    Cyclotella bodanica Eulenstein in Grunow
    Melosira roeseana Rabenhorst
    Stephanodiscus astraea (Ehrenberg) Grunow in Van Heurck
    Thalassiosira eccentrica (Ehrenberg) Cleve
    Triceratium arcticum Brightwell
  Pennales
    Achnanthes brevipes Agardh
    A. exilis Kuetzing
    A. flexella (Kuetzing) Brun
    A. groenlandica (Cleve) Grunow in Cleve et Grunow
    A. hauckiana var. rostrata Schulz
    A. kriegeri Krasske
    Amphipleura rutilans (Trentepohl) Cleve
    Amphora costata Wm. Smith
    A. holsatica Hustedt
    A. ovalis var. libyca (Ehrenberg) Cleve
    A. terroris Ehrenberg
    Caloneis brevis (Gregory) Cleve
    C. silicula (Ehrenberg) Cleve
    C. silicula var. minuta (Grunow in Van Heurck) Cleve
    Cocconeis distans Gregory
    C. finnmarchica Grunow in Cleve et Grunow
    C. interrupta Grunow
    C. pediculus Ehrenberg
    C. pellucida Grunow ex Hantzsch
    C. placentula var. euglypta (Ehrenberg) Grunow
    C. placentula var. lineata (Ehrenberg) Van Heurck
    C. pseudomarginata Gregory
    Cymbella angustata (Wm. Smith) Cleve
    C. cesatii (Rabenhorst) Grunow in Schmidt
    C. cymbiformis Agardh
    C. naviculiformis Auerswald in Rabenhorst
    C. parva (Wm. Smith) Wolle
    C. tumida var. fossilis (Cleve et Grunow) Cleve
    C. ventricosa Agardh
    Diatoma hiemale (Lyngbye) Heiberg
    Diploneis incurvata (Gregory) Cleve
    D. interrupta (Kuetzing) Cleve
    D. marginestriata Hustedt
    D. oculata (Brébisson in Desmazières) Cleve
    D. parca (Schmidt in Schmidt et al.) Boyer
    D. puella (Schumann) Cleve
    D. reichardtii var. tschuktschorum (Cleve) Heiden in Heiden et Kolbe

Table 4. (Continued)

Eunotia arcus Ehrenberg
E. bigibba Kuetzing
E. bigibba var. pumila Grunow in Van Heurck
E. cristagallii Cleve
E. exigua (Brébisson in Kuetzing) Rabenhorst
E. exigua var. compacta Hustedt
E. glacialis Meister
E. lunaris (Ehrenberg) Brébisson in Rabenhorst
E. monodon var. major (Wm. Smith) Hustedt
E. pectinalis var. minor (Kuetzing) Rabenhorst
E. pectinalis var. ventralis (Ehrenberg) Hustedt
E. praerupta Ehrenberg
Fragilaria capucina Desmazières
F. construens (Ehrenberg) Grunow
F. lapponica Grunow in Van Heurck
F. vaucheriae (Kuetzing) Petersen
F. virescens var. elliptica Hustedt
Frustulia rhomboides var. saxonica (Rabenhorst) De Toni
F. rhomboides var. saxonica f. capitata (Mayer) Hustedt
Gomphonema aestuarii Cleve
Grammatophora angulosa Ehrenberg
G. arctica Cleve
G. arcuata Ehrenberg
Gyrosigma acuminatum (Kuetzing) Rabenhorst
G. prolongatum (Wm. Smith) Griffith et Henfrey
Licmophora hyalina (Kuetzing) Grunow
Navicula ammophila Grunow
N. anglica var. subsalsa (Grunow) Cleve
N. cancellata Donkin
N. cancellata var. apiculata (Gregory) Peragallo et Peragallo
N. cancellata var. subapiculata Grunow in Cleve et Grunow
N. cincta var. leptocephala (Brébisson) Grunow in Van Heurck
N. exigua (Gregory) Grunow in Van Heurck
N. explanata Hustedt
N. fortis (Gregory) Ralfs in Pritchard
N. gregaria Donkin
N. insociabilis Krasske
N. jamalinensis Cleve in Cleve et Grunow
N. longa (Gregory) Ralfs in Pritchard
N. minima Grunow in Van Heurck
N. minuscula Grunow in Van Heurck
N. monilifera Cleve
N. palpebralis Brébisson
N. placentula var. jenisseyensis (Grunow in Cleve et Grunow) Meister
N. pseudoscutiformis Hustedt in Schmidt et al.
N. rotaeana (Rabenhorst) Grunow in Van Heurck
N. ruttneri Hustedt
N. viridula var. slesvicensis (Grunow in Van Heurck) Grunow in Cleve et Moeller

Table 4. (Continued)

Nitzschia acuminata (Wm. Smith) Grunow
N. angustata var. acuta Grunow in Cleve et Grunow
N. commutata var. pamirensis (Hustedt) Cleve-Euler
N. denticula Grunow in Cleve et Grunow
N. frustulum var. perpusilla (Rabenhorst) Grunow in Van Heurck
Pinnularia appendiculata (Agardh) Cleve
P. divergens Wm. Smith
P. divergentissima (Grunow in Van Heurck) Cleve
P. divergentissima var. subrostrata A. Cleve
P. gibba Ehrenberg
P. gibba var. linearis Hustedt
P. interrupta Wm. Smith
P. mesolepta (Ehrenberg) Wm. Smith
P. obscura Krasske
P. viridis (Nitzsch) Ehrenberg
Rhabdonema minutum Kuetzing
Stauroneis anceps Ehrenberg
S. gracilis Ehrenberg
S. phoenicenteron (Nitzsch) Ehrenberg
S. prominula (Grunow in Cleve et Moeller) Hustedt
Synedra affinis var. rostrata Juhlin-Dannfelt
S. cyclopum Brutschy
S. pulchella var. lanceolata O'Meara
Tabellaria fenestrata (Lyngbye) Kuetzing
Trachyneis aspera (Ehrenberg) Cleve

Cyanophyta (blue-green algae)
Spirulina Turpin

lacustris from ice in the nearshore Beaufort Sea. Recently, Dunbar and Acreman (1980) found that more than 96% of ice diatoms were pennate species during studies in Hudson Bay, Robeson Channel, Barrow Strait and Austin Channel. Of the diatoms identified in the sea ice samples from Frobisher Bay, the order of importance of the genera of pennate diatoms, in terms of standing stock, were Nitzschia, Navicula and Achnanthes. Centric diatom genera were of lesser importance and included Thalassiosira and Chaetoceros. Next to the diatoms in abundance and importance were the green algae represented by an unidentified species of green flagellates, the blue-green algae by an unidentified species of Cyanophyceae, the euglenoids by Euglena proxima, the dinoflagellates by Gymnodinium sp., and the chrysophytes by Phaeocystis pouchetii. This sequence is slightly different from the previous studies made in 1971 to 1978 (Hsiao 1980). In other arctic areas, species other than diatoms were not found commonly (Horner and Alexander 1972). In the Antarctic, most of the sea ice microalgae were diatoms (Bunt and Wood 1963, Buinitsky 1968).

The development time of sea ice microalgal communities was similar to that observed in previous studies in Frobisher Bay (Hsiao 1980), extending from late fall at the time of ice formation through the winter, and increasing rapidly in spring until the ice disappeared. The microalgae differed in numbers of species and cells during the ice season depending upon varying preference for such factors as light, temperature, oceanographical conditions and available nutrients. The various depths of the ice and snow cover show some differences in these respects. The period of most abundant species and cell counts was in May-June. The periodicity of the three most important groups may be especially mentioned. The species and cell development of diatoms reached a maximum in late spring and early summer (May-June) in the entire ice column but they were most concentrated in the bottom 5 cm. The green flagellates were relatively abundant during the ice season from December to June and were particularly concentrated in the bottom 5 cm of the ice. The blue-green algae were less numerous and of sporadic occurrence in the top of the ice in March.

The species of microalgae that occurred in the bottom of the ice differed from those found in the top and middle parts. Most of the dominant species occurred in the bottom layers where the shade-adapted microalgae grew vigorously in the very small amount of light energy reaching the bottom of the sea ice after being almost completely absorbed by snow cover, sea ice and flora lying above (Tsurikov and Vedernikov 1979). The communities developed to maximum size just prior to the thaw period when the melting fast ice started to promote the growth of microalgae by increasing the available light, nutrients and low salinity water (McRoy and Goering 1974, Grainger 1977, Tsurikov and Vedernikov 1979). The growth was inhibited by higher light intensities in the upper layers as a result of photo-oxidation of photosynthetic algal pigments, particularly as the overlying snow melted (Apollonio 1961, Bunt 1964, 1968, Burkholder and Mandelli 1965, Tsurikov and Vedernikov 1979).

The standing stock of sea ice microalgae ranged from 1.6 x 10^4 cells/L with chlorophyll a of 0.2 mg/m^3 in March in the top of the ice to 1403.8 x 10^4 cells/L with chlorophyll a of 391.79 mg/m^3 in the bottom of the ice in May. In the underlying phytoplankton it varied from 0.7 x 10^4 cells/L with chlorophyll a of 0.09 mg/m^3 in March to 195.9 x 10^4 cells/L with chlorophyll a of 5.43 mg/m^3 in June. This shows that the standing stock of the sea ice microalgae per unit volume of melted ice samples was 7 to 72 times greater than that of the phytoplankton in the underlying waters. Concentrations varied greatly depending upon the time of year and the portion of the ice core sampled. They were low in late fall through winter, increased in early spring, bloomed in late spring and early summer, and then declined as the snow cover and sea ice started to melt. The largest standing stock occurred at the bottom of the ice particularly in the bottom 5 cm. The standing stock of phytoplankton in the underlying waters was relatively high in late fall, decreased through the winter months as the ice thickened and snow accumulated above, then increased in early spring as day length increased, and reached a peak level in the surface water as melting of the snow cover and the bottom of the sea ice occurred.

The integrated standing stock found in the sea ice increased in quantity from 3.4 x 10^7 cells/m^2 with chlorophyll a of 0.51 mg/m^2 in mid-December to 399.3 x 10^7 cells/m^2 with chlorophyll a of 20.7 mg/m^2 in early May, while in the underlying phytoplankton it increased from 45.4 x 10^7 cells/m^2 in mid-December to 1065 x 10^7 cells/m^2 in mid-June, and chlorophyll a increased from 5.2 mg/m^2 in mid-December to 98.5 mg/m^2 in early June. These results of cell counts were 3 to 9 times lower than that of previous work done from 1971 to 1978 (Hsiao 1980), but the present chlorophyll a level was 3 to 22 times greater than was found in the earlier work. This was probably due to the fact that the communities contained a different species composition and were sampled at different times of the year. The chlorophyll content of the algae would have higher concentrations at lower light intensities. The integrated standing stock was comparable to the amount found in the arctic sea ice of Jones Sound, N.W.T. (Apollonio 1961, 1965), at Point Barrow, Alaska (Meguro et al. 1967, Alexander et al. 1974), in the Bering Sea (McRoy and Goering 1974), in the Bering Sea (McRoy and Goering 1974), in Robeson Channel, Hudson Bay, Barrow Strait and Austin Channel (Dunbar and Acreman 1980), and in the Antarctic fast ice (Buinitsky 1977), but it was higher than that of phytoplankton blooms in some productive seas of the northern hemisphere (Bursa 1961, Thórdardóttir 1973, Throndsen and Heimdal 1976, Hsiao et al. 1977, Hsiao and Trucco 1980). However, the integrated standing stock in the ice was 3 to 13 times smaller than that of phytoplankton in the underlying waters. This resulted in the total volumes of melted ice column samples containing far less microalgae than that of in a square meter of the water column beneath the ice, although the sea ice contained more concentrated cells on a per unit volume basis.

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Table 5. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 10 March 1979.

Sea ice thickness (cm) 154

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-5	Middle 75-80	Bottom 149-154	0	10	40
Total sea ice microalgae or phytoplankton (cells/litre)	15 480	30 440	10 215 776	11 240	10 640	12 240
Bacillariophyta	10 880	18 040	9 462 506	360	680	0
Centrales	2 640	3 480	86 088	-	120	-
Chaetoceros	1 440	1 760	50 218	-	120	-
C. borealis	-	-	14 348	-	120	-
C. fragilis	-	1 040	28 696	-	-	-
C. furcellatus	1 440	360	7 174	-	-	-
C. septentrionalis	-	360	-	-	-	-
Coscinodiscus	-	-	7 174	-	-	-
C. lacustris var. septentrionalis	-	-	7 174	-	-	-
Melosira	-	440	-	-	-	-
M. arctica	-	440	-	-	-	-
Rhizosolenia	40	-	-	-	-	-
R. spp.	40	-	-	-	-	-
Thalassiosira	1 080	1 280	14 348	-	-	-
T. nordenskioldii	520	360	-	-	-	-
T. oestrupii	560	920	-	-	-	-
T. spp.	-	-	14 348	-	-	-
Unidentified	80	-	14 348	-	-	-
Pennales	8 240	14 560	9 376 418	360	560	-
Achnanthes	-	-	1 119 144	-	-	-
A. taeniata	-	-	1 119 144	-	-	-
Amphiprora	80	200	-	-	-	-
A. gigantea var. septentrionalis	-	200	-	-	-	-
A. kjellmanii var. kariana	80	-	-	-	-	-

Table 5. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-5	Middle 75-80	Bottom 149-154	0	10	40
Amphora	160	80	7 174	-	-	-
A. laevis var. laevissima	160	80	7 174	-	-	-
Cocconeis	600	-	7 174	80	-	-
C. costata	480	-	7 174	80	-	-
C. scutellum	120	-	-	-	-	-
Cylindrotheca	120	40	200 872	-	-	-
C. closterium	120	40	200 872	-	-	-
Diploneis	80	440	50 218	-	-	-
D. litoralis var. arctica	80	320	50 218	-	-	-
D. litoralis var. clathrata	-	120	-	-	-	-
Gomphonema	840	-	71 740	-	-	-
G. exiguum	-	-	64 566	-	-	-
G. exiguum var. pachycladum	840	-	7 174	-	-	-
Grammatophora	-	-	-	40	-	-
G. angulosa	-	-	-	40	-	-
Licmophora	-	160	28 696	-	-	-
L. gracilis var. anglica	-	160	28 696	-	-	-
Navicula	1 480	2 600	803 488	+	40	-
N. algida	80	520	7 174	-	-	-
N. crucigeroides	40	-	-	-	-	-
N. digitoradiata	-	80	-	-	-	-
N. directa	640	360	322 830	+	+	-
N. gastrum	-	-	7 174	-	-	-
N. gelida	240	1 000	71 740	-	-	-
N. oestrupi	-	-	28 696	-	-	-
N. transitans	200	520	129 132	-	-	-
N. transitans var. derasa	-	-	7 174	-	-	-
N. transitans var. incudiformis	-	-	28 696	-	-	-
N. trigonocephala	-	-	7 174	-	-	-
N. trigonocephala var. depressa	-	-	14 348	-	-	-

Table 5. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-5	Middle 75-80	Bottom 149-154	0	10	40
N. valida	80	-	71 740	-	-	-
N. valida var. *minuta*	-	-	43 044	-	-	-
N. spp.	200	120	64 566	-	40	-
Nitzschia	4 200	9 360	6 628 776	240	240	-
N. acicularis	-	-	7 174	-	-	-
N. brebissonii var. *borealis*	40	-	28 696	-	-	-
N. cylindrus	120	560	-	-	-	-
N. frigida	840	960	3 967 222	-	-	-
N. grunowii	1 720	5 320	1 822 196	-	-	-
N. hybrida	160	40	-	-	-	-
N. laevissima	360	-	50 218	-	-	-
N. linearis	-	-	35 870	-	-	-
N. tergestina	760	2 240	595 442	-	-	-
N. spp.	200	240	121 958	240	240	-
Pinnularia	120	160	86 088	-	-	-
P. quadratarea	-	40	21 522	-	-	-
P. quadratarea var. *bicontracta*	40	80	43 044	-	-	-
P. quadratarea var. *capitata*	80	40	7 174	-	-	-
P. quadratarea var. *constricta*	-	-	14 348	-	-	-
Pleurosigma	240	40	179 350	-	-	-
P. antarcticum	80	-	57 392	-	-	-
P. clevei	-	40	71 740	-	-	-
P. elongatum var. *kariana*	160	-	35 870	-	-	-
P. spp.	-	-	14 348	-	-	-
Stauroneis	-	840	114 784	-	-	-
S. quadripedis	-	840	114 784	-	-	-
Stenoneis	-	-	7 174	-	-	-
S. inconspicua var. *baculus*	-	-	7 174	-	-	-

Table 5. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-5	Middle 75-80	Bottom 149-154	0	10	40
Synedra	200	520	50 218	+	80	-
S. pulchella	80	80	50 218	+	80	-
S. tabulata var. *fasciculata*	120	440	-	-	-	-
Unidentified	120	120	21 522	+	200	-
Chlorophyta	3 880	9 880	559 572	5 880	5 080	5 920
Unidentified green flagellates	3 880	9 760	559 572	5 400	3 280	3 040
Unidentified green filaments	-	120	-	480	1 800	2 880
Chrysophyta	-	200	14 348	-	-	-
Phaeocystis	-	200	14 348	-	-	-
P. pouchetii	-	200	14 348	-	-	-
Cyanophyta	-	760	14 348	4 840	4 720	6 200
Unidentified Cyanophyceae	-	760	14 348	4 840	4 720	6 200
Euglenophyta	-	880	50 218	-	80	-
Euglena	-	880	50 218	-	80	-
E. spp.	-	880	50 218	-	80	-
Pyrrophyta	720	680	114 784	160	80	120
Gymnodinium	-	-	14 348	-	80	-
G. spp.	-	-	14 348	-	80	-
Peridinium	-	-	7 174	-	-	-
P. spp.	-	-	7 174	-	-	-
Prorocentrum	360	280	43 044	-	-	-
P. ovalis	360	280	43 044	-	-	-
Unidentified	360	400	50 218	160	-	120

Table 6. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 7 May 1979.

Sea ice thickness (cm)			171			
	Ice core (cm)			Seawater depth (m)		
Sample type	Top 0-5	Middle 83-88	Bottom 166-171	0	10	35
Total sea ice microalgae or phytoplankton (cells/litre)	84 500	68 000	13 790 000	15 000	30 000	10 000
Bacillariophyta	83 500	58 000	13 720 000	10 000	20 000	10 000
Centrales	9 000	3 000	360 000	5 000	-	5 000
Chaetoceros	1 500	-	-	5 000	-	-
C. fragilis	500	-	-	-	-	-
C. furcellatus	1 000	-	-	5 000	-	-
C. spp.	+	-	-	-	-	-
Coscinodiscus	-	+	20 000	-	-	-
C. kuetzingii	-	+	-	-	-	-
C. polyacanthus	-	-	20 000	-	-	-
Melosira	5 000	-	-	-	-	-
M. arctica	5 000	-	-	-	-	-
Thalassiosira	-	1 000	160 000	+	-	-
T. gravida	-	-	50 000	-	-	-
T. nordenskioldii	-	1 000	110 000	+	-	-
Unidentified	2 500	2 000	180 000	-	-	5 000
Pennales	74 500	55 000	13 360 000	5 000	20 000	5 000
Achnanthes	-	-	30 000	-	-	-
A. taeniata	-	-	30 000	-	-	-
Amphiprora	-	3 000	60 000	-	-	-
A. concilians	-	-	40 000	-	-	-
A. gigantea var. septentrionalis	-	-	10 000	-	-	-
A. kjellmanii	-	-	10 000	-	-	-
A. paludosa var. hyperborea	-	3 000	-	-	-	-

Table 6. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-5	Middle 83-88	Bottom 166-171	0	10	35
Amphora	500	1 000	60 000	-	-	-
A. laevis	-	1 000	20 000	-	-	-
A. proteus	500	-	40 000	-	-	-
Bacillaria	-	-	290 000	-	-	-
B. paradoxa	-	-	290 000	-	-	-
Caloneis	-	-	30 000	-	-	-
C. spp.	-	-	30 000	-	-	-
Cocconeis	500	-	-	+	-	+
C. costata	-	-	-	+	-	+
C. scutellum	500	-	-	-	-	-
Diatoma	-	-	-	-	-	+
D. hiemale	-	-	-	-	-	+
Diploneis	-	5 000	920 000	-	-	-
D. litoralis	-	5 000	920 000	-	-	-
Gomphonema	1 000	1 000	310 000	5 000	-	-
G. exiguum	1 000	1 000	310 000	5 000	-	-
Gyrosigma	-	-	30 000	-	-	-
G. fasciola	-	-	30 000	-	-	-
Licmophora	500	-	20 000	-	-	-
L. gracilis	500	-	20 000	-	-	-
Navicula	24 500	16 000	3 670 000	+	5 000	+
N. clementis	-	-	10 000	-	-	-
N. crucigera	-	-	120 000	+	-	-
N. directa	+	2 000	1 300 000	-	-	+
N. distans	-	-	100 000	-	-	-
N. gelida	-	2 000	180 000	-	-	-
N. kariana	-	-	40 000	-	-	-
N. marina	+	+	+	-	-	-
N. siberica	-	-	80 000	-	-	-

Table 6. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-5	Middle 83-88	Bottom 166-171	0	10	35
N. superba	-	1 000	180 000	-	-	-
N. transitans	500	2 000	270 000	-	-	-
N. trigonocephala	-	-	140 000	-	-	-
N. valida	-	-	260 000	-	-	-
N. vanhoeffenii	21 000	-	-	+	-	-
N. spp.	3 000	9 000	990 000	+	5 000	-
Nitzschia	43 500	16 000	5 260 000	+	15 000	+
N. angularis	-	-	90 000	-	-	-
N. brebissonii	-	1 000	160 000	-	-	-
N. cylindrus	1 500	2 000	240 000	-	5 000	-
N. distans var. *erratica*	-	2 000	30 000	-	-	-
N. frigida	34 000	2 000	770 000	-	-	-
N. laevissima	-	-	190 000	-	-	-
N. lecointei	2 500	1 000	-	-	-	-
N. linearis	1 000	-	10 000	-	-	-
N. longissima	500	3 000	3 000 000	+	-	-
N. polaris	3 000	5 000	530 000	+	5 000	+
N. seriata	1 000	-	240 000	-	-	-
N. spp.	-	-	-	+	5 000	-
Pinnularia	500	1 000	670 000	-	-	-
P. quadratarea	500	1 000	670 000	-	-	-
Pleurosigma	+	+	240 000	-	-	-
P. clevei	-	-	20 000	-	-	-
P. longum	-	-	10 000	-	-	-
P. stuxbergii	-	-	210 000	-	-	-
P. spp.	+	+	-	-	-	-
Pseudonitzschia	-	-	120 000	-	-	-
P. delicatissima	-	-	120 000	-	-	-
Stauroneis	-	-	120 000	-	-	-
S. quadripedis	-	-	120 000	-	-	-

Table 6. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-5	Middle 83-88	Bottom 166-171	0	10	35
Synedra	-	-	110 000	-	-	-
S. tabulata	-	-	110 000	-	-	-
Tropidoneis	-	1 000	20 000	-	-	-
T. maxima	-	1 000	20 000	-	-	-
Unidentified	3 500	11 000	1 400 000	-	-	5 000
Chlorophyta	500	-	-	-	-	-
Unidentified	500	-	-	-	-	-
Chrysophyta	500	-	-	-	-	-
Unidentified	500	-	-	-	-	-
Cyanophyta	-	10 000	-	-	-	-
Oscillatoria	-	10 000	-	-	-	-
O. spp.	-	10 000	-	-	-	-
Pyrrophyta	-	-	70 000	-	-	-
Gymnodinium	-	-	20 000	-	-	-
G. spp.	-	-	20 000	-	-	-
Peridinium	-	-	50 000	-	-	-
P. spp.	-	-	50 000	-	-	-
Unidentified cysts	1 000	-	-	5 000	10 000	-

Table 7. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 16 June 1979.

Sea ice thickness (cm)	142				
Sample type	Ice core (cm) Top 0-137	Ice core (cm) Bottom 137-142	Seawater depth (m) 0	Seawater depth (m) 10	Seawater depth (m) 35
Total sea ice microalgae or phytoplankton (cells/litre)	15 500	236 500	9 000	36 500	19 000
Bacillariophyta	15 500	235 250	9 000	36 000	19 000
Centrales	-	16 250	5 000	17 000	6 000
Chaetoceros	-	5 000	3 000	16 000	3 500
C. fragilis	-	-	3 000	8 500	1 000
C. furcellatus	-	2 500	-	-	2 000
C. neogracile	-	-	-	3 000	500
C. septentrionalis	-	2 500	-	-	-
C. socialis	-	-	-	4 500	-
Coscinodiscus	-	-	-	-	+
C. kuetzingii	-	-	-	-	+
C. polyacanthus	-	-	-	-	+
Melosira	-	-	1 000	-	-
M. arctica	-	-	1 000	-	-
Thalassiosira	-	11 250	1 000	1 000	2 500
T. nordenskioldii	-	11 250	1 000	1 000	2 500
Pennales	15 500	219 000	4 000	19 000	13 000
Amphiprora	500	7 500	-	-	-
A. kjellmanii	500	7 500	-	-	-
Bacillaria	-	2 500	-	-	-
B. paradoxa	-	2 500	-	-	-
Cocconeis	-	-	-	+	+
C. costata	-	-	-	+	+
Diploneis	-	5 000	-	-	-
D. litoralis var. arctica	-	5 000	-	-	-

Table 7. (Continued)

Sample type	Ice core (cm) Top 0-137	Ice core (cm) Bottom 137-142	Seawater depth (m) 0	Seawater depth (m) 10	Seawater depth (m) 35
Gomphonema	1 500	22 500	500	-	-
G. exiguum	1 500	22 500	500	-	-
Navicula	6 000	74 000	1 500	7 500	3 500
N. clementis	-	5 000	-	-	-
N. crucigera	500	11 250	-	-	-
N. directa	1 000	18 750	+	+	-
N. gelida	-	6 250	-	-	-
N. kariana	+	-	-	-	-
N. kjellmanii	-	+	-	-	-
N. marina	+	+	-	-	-
N. pygmaea	-	+	-	-	-
N. superba	-	2 500	-	-	-
N. transitans	1 500	7 500	-	-	-
N. trigonocephala	500	+	-	-	-
N. valida	2 000	-	-	-	-
N. vanhoeffenii	-	22 750	1 500	-	+
N. spp.	500	-	-	7 500	3 500
Nitzschia	5 500	83 750	1 000	11 500	9 500
N. acicularis	500	8 750	-	-	-
N. brebissonii	1 000	+	-	-	-
N. cylindrus	1 000	12 500	-	-	1 000
N. distans	+	5 000	-	-	-
N. frigida	-	27 500	-	-	-
N. laevissima	+	7 500	-	-	-
N. lecointei	-	+	-	-	-
N. longissima	1 500	-	-	10 500	6 000
N. polaris	1 500	15 000	500	1 000	1 000
N. seriata	-	7 500	500	-	1 500

Table 7. (Continued)

Sample type	Ice core (cm) Top 0-137	Ice core (cm) Bottom 137-142	Seawater depth (m) 0	Seawater depth (m) 10	Seawater depth (m) 35
Pinnularia	2 000	15 000	-	-	-
P. quadratarea	2 000	15 000	-	-	-
P. quadratarea var. *constricta*	-	+	-	-	-
Pleurosigma	+	8 750	-	-	-
P. spp.	+	8 750	-	-	-
Synedra	-	-	1 000	-	-
S. pulchella	-	-	1 000	-	-
Tabellaria	-	-	+	-	-
T. fenestrata	-	-	+	-	-
T. flocculosa	-	-	+	-	-
Chlorophyta	-	-	-	500	-
Unidentified green flagellates	-	-	-	500	-
Pyrrophyta	-	1 250	-	-	-
Peridinium	-	1 250	-	-	-
P. spp	-	1 250	-	-	-

Table 8. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 12 December 1979.

Sea ice thickness (cm)				62			
Sample type	Ice core (cm)				Seawater depth (m)		
	Top	Middle	Bottom	Bottom			
	0-20	20-41	41-62	57-62	0	10	24
Total sea ice microalgae or phytoplankton (cells/litre)	16 760	38 600	226 356	489 645	23 560	26 440	25 800
Bacillariophyta	6 360	16 520	130 590	322 803	960	2 520	2 400
Centrales	1 400	5 040	8 706	18 135	360	920	680
Biddulphia	-	-	-	-	-	40	-
B. aurita	-	-	-	-	-	40	-
Chaetoceros	1 000	2 840	4 353	3 627	+	+	+
C. furcellatus	360	1 160	2 902	3 627	-	-	-
C. karianus	280	1 360	-	-	-	-	-
C. septentrionalis	-	160	1 451	-	-	-	-
C. spp.	360	160	-	-	+	+	+
Coscinodiscus	-	-	-	-	+	40	+
C. lacustris	-	-	-	-	+	40	+
Thalassiosira	160	1 640	-	3 627	-	+	-
T. eccentrica	-	-	-	-	-	+	-
T. nordenskioldii	160	1 640	-	3 627	-	-	-
T. oestrupii	-	-	-	-	-	+	-
Unidentified	240	560	4 353	10 881	360	840	680
Pennales	4 960	11 480	121 884	304 668	600	1 600	1 720
Achnanthes	-	-	-	36 270	-	40	+
A. brevipes	-	-	-	-	-	40	-
A. groenlandica	-	-	-	-	-	-	+
A. taeniata	-	-	-	36 270	-	-	-

Table 8. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-20	Middle 20-41	Bottom 41-62	Bottom 57-62	0	10	24
Amphiprora	-	-	-	3 627	-	-	-
A. kjellmanii var. kariana	-	-	-	3 627	-	-	-
Amphora	-	80	2 902	3 627	-	120	+
A. costata	-	-	-	-	-	+	-
A. exigua	-	-	-	-	-	-	+
A. exsecta	-	80	2 902	3 627	-	80	-
A. terroris	-	-	-	-	-	40	+
Cocconeis	120	320	-	3 627	40	240	320
C. californica	-	-	-	-	-	+	200
C. costata	120	320	-	3 627	40	120	40
C. diminuta	-	-	-	-	-	+	+
C. interrupta	-	-	-	-	-	+	+
C. scutellum	-	-	-	-	+	40	40
C. scutellum var. stauroneiformis	-	-	-	-	-	80	40
Cylindrotheca	160	640	7 255	25 389	200	40	160
C. closterium	160	640	7 255	25 389	200	40	160
Diploneis	80	-	1 451	3 627	+	-	+
D. incurvata	-	-	-	-	-	+	-
D. litoralis	-	-	-	-	+	-	-
D. litoralis var. arctica	80	-	1 451	-	+	-	-
D. litoralis var. clathrata	-	-	-	3 627	-	-	-
D. reichardtii var. tschuktschorum	-	-	-	-	-	-	+
D. smithii	-	-	-	-	-	-	+
Fragilaria	-	-	-	-	-	+	+
F. construens	-	-	-	-	-	+	-
F. pinnata	-	-	-	-	-	+	+
F. virescens	-	-	-	-	-	-	+
Gomphonema	-	120	1 451	-	-	+	-
G. aestuarii	-	-	-	-	-	+	-
G. exiguum	-	120	-	-	-	-	-
G. exiguum var. pachycladum	-	-	1 451	-	-	-	-

Table 8. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-20	Middle 20-41	Bottom 41-62	Bottom 57-62	0	10	24
Gyrosigma	-	-	-	-	+	-	-
G. acuminatum	-	-	-	-	+	-	-
Licmophora	-	-	1 451	7 254	-	-	-
L. gracilis var. anglica	-	-	1 451	7 254	-	-	-
Navicula	80	360	11 608	21 762	40	40	80
N. cluthensis var. pagophila	-	-	-	3 627	-	-	-
N. crucigeroides	-	-	-	-	+	-	-
N. digitoradiata	80	-	1 451	-	-	-	-
N. directa	-	-	5 804	3 627	+	-	-
N. forcipata	-	-	-	-	-	-	+
N. gelida	-	-	1 451	-	-	-	-
N. imperfecta	-	-	-	-	-	-	40
N. oestrupi	-	-	-	-	+	-	-
N. peregrina var. meniscus	-	-	-	-	-	-	+
N. perlucens	-	40	-	-	-	-	-
N. placentula	-	-	-	-	+	-	-
N. recurvata	-	-	1 451	3 627	-	-	-
N. superba	-	-	-	-	+	-	-
N. transitans	-	200	1 451	3 627	+	-	-
N. valida	-	-	-	3 627	+	-	-
N. spp.	-	120	-	3 627	40	40	40
Nitzschia	4 280	8 840	91 413	174 096	40	+	+
N. brebissonii var. borealis	-	-	-	3 627	-	-	-
N. cylindrus	-	-	-	-	+	+	-
N. distans var. erratica	-	-	-	3 627	-	-	-
N. frigida	-	1 840	21 765	21 762	-	-	-
N. frustulum var. perpusilla	-	-	-	-	-	-	+
N. grunowii	4 080	6 680	46 432	105 183	-	-	-
N. laevissima	-	-	1 451	7 254	-	-	-
N. lecointei	-	-	-	3 627	-	-	-
N. polaris	-	80	-	-	-	-	-
N. socialis var. kariana	-	-	-	-	-	-	+
N. tergestina	-	-	11 608	21 762	+	-	-

Table 8. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-20	Middle 20-41	Bottom 41-62	Bottom 57-62	0	10	24
N. spp.	200	240	10 157	7 254	40	-	-
Pinnularia	-	-	-	-	+	-	-
P. quadratarea var. *bicontracta*	-	-	-	-	+	-	-
P. quadratarea var. *constricta*	-	-	-	-	+	-	-
Plagiogramma	-	-	-	-	-	+	+
P. staurophorum	-	-	-	-	-	+	+
Pleurosigma	-	160	2 902	14 508	+	-	-
P. antarcticum	-	-	1 451	7 254	-	-	-
P. clevei	-	80	1 451	3 627	-	-	-
P. elongatum var. *kariana*	-	80	-	3 627	-	-	-
P. stuxbergii var. *rhomboides*	-	-	-	-	+	-	-
Rhabdonema	-	-	-	-	-	+	+
R. arcuatum	-	-	-	-	-	+	+
R. minutum	-	-	-	-	-	+	-
Synedra	-	120	1 451	10 881	40	120	80
S. camtschatica	-	-	-	-	+	-	-
S. pulchella	-	120	1 451	10 881	-	-	-
S. tabulata	-	-	-	-	40	120	80
Tabellaria	-	80	-	-	+	+	+
T. flocculosa	-	80	-	-	+	+	+
Unidentified	240	760	-	-	240	1 000	1 080
Chlorophyta	7 480	12 560	78 354	141 453	22 280	23 680	22 880
Carteria	-	-	-	-	3 240	3 200	1 760
C. spp.	-	-	-	-	3 240	3 200	1 760
Unidentified green filaments	-	-	-	10 881	-	80	-
Unidentified green flagellates	7 480	12 560	78 354	130 572	19 040	20 400	21 120
Cyanophyta	720	2 440	-	-	320	240	520
Unidentified Cyanophyceae	720	2 440	-	-	320	240	520

Table 8. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-20	Middle 20-41	Bottom 41-62	Bottom 57-62	0	10	24
Euglenophyta	920	3 320	5 804	3 627	-	-	-
Euglena	920	3 320	5 804	3 627	-	-	-
E. proxima	200	200	-	-	-	-	-
E. spp.	720	3 120	5 804	3 627	-	-	-
Pyrrophyta	1 280	3 760	11 608	21 762	-	-	-
Gymnodinium	80	240	1 451	3 627	-	-	-
G. spp.	80	240	1 451	3 627	-	-	-
Peridinium	-	-	4 353	-	-	-	-
P. spp.	-	-	4 353	-	-	-	-
Unidentified	1 200	3 520	5 804	18 135	-	-	-

Table 9. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 12 March 1980.

Sea ice thickness (cm)	137						
Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-45	Middle 45-91	Bottom 91-137	Bottom 132-137	0	10	40
Total sea ice microalgae or phytoplankton (cells/litre)	28 514	30 204	1 341 990	1 753 570	9 240	6 880	7 400
Bacillariophyta	6 080	20 800	1 225 926	1 693 300	2 560	4 360	5 280
Centrales	2 560	3 080	36 270	34 440	1 600	2 240	2 200
Chaetoceros	1 680	1 200	14 08	-	+	80	80
C. borealis	120	-	-	-	-	-	-
C. fragilis	520	-	-	-	-	-	-
C. furcellatus	440	680	-	-	-	-	-
C. karianus	600	400	14 508	-	-	-	-
C. septentrionalis	-	120	-	-	-	-	-
C. spp.	-	-	-	-	+	80	80
Coscinodiscus	200	200	-	22 960	-	-	-
C. lacustris var. septentrionalis	200	200	-	22 960	-	-	-
Melosira	200	320	7 254	-	-	-	+
M. arctica	200	320	7 254	-	-	-	-
M. roeseana	-	-	-	-	-	-	+
M. spp.	-	-	7 254	-	-	-	-
Thalassiosira	480	1 240	7 254	5 740	+	40	+
T. aestivalis	-	-	-	-	+	+	-
T. eccentrica	-	-	-	-	-	+	+
T. kryophila	-	-	-	-	-	-	+
T. nordenskioldii	200	720	3 627	-	-	-	-
T. oestrupii	160	520	3 627	5 740	+	+	+
T. spp.	120	-	-	-	-	40	-
Unidentified	-	120	-	5 740	1 600	2 120	2 120
Pennales	3 520	17 720	1 189 656	1 658 860	960	2 120	3 080
Achnanthes	-	-	72 540	246 820	40	+	+
A. clevei	-	-	-	-	+	+	+
A. curta	-	-	-	-	-	-	+

Table 9. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-45	Middle 45-91	Bottom 91-137	Bottom 132-137	0	10	40
A. delicatula	-	-	-	-	-	-	+
A. lemmermannii	-	-	-	-	40	+	+
A. taeniata	-	-	72 540	246 820	+	-	-
Amphiprora	80	760	14 508	14 350	-	-	-
A. kjellmanii var. kariana	80	760	14 508	14 350	-	-	-
Amphora	-	-	-	8 610	-	+	40
A. laevis var. laevissima	-	-	-	8 610	-	-	-
A. terroris	-	-	-	-	-	+	40
Caloneis	-	-	-	-	-	+	-
C. silicula var. minuta	-	-	-	-	-	+	-
Cocconeis	160	120	-	5 740	200	320	440
C. californica	-	-	-	-	-	-	+
C. costata	160	-	-	2 870	120	80	160
C. diminuta	-	-	-	-	+	160	80
C. interrupta	-	-	-	-	-	+	+
C. pediculus	-	-	-	-	-	-	+
C. placentula var. euglypta	-	-	-	-	-	40	-
C. pseudomarginata	-	-	-	-	-	+	+
C. scutellum	-	-	-	-	40	+	40
C. scutellum var. stauroneiformis	-	120	-	2 870	+	+	+
C. thumensis	-	-	-	-	40	-	40
C. spp.	-	-	-	-	-	40	120
Cylindrotheca	-	120	39 897	8 610	80	80	160
C. closterium	-	120	39 897	8 610	80	80	160
Diploneis	-	1 080	32 643	22 960	+	+	40
D. incurvata	-	-	-	-	-	+	-
D. litoralis var. arctica	-	480	18 135	14 350	-	+	-
D. litoralis var. clathrata	-	600	14 508	8 610	-	-	-
D. puella	-	-	-	-	+	-	40
D. reichardtii var. tschuktschorum	-	-	-	-	-	+	+
D. smithii	-	-	-	-	-	-	+

Table 9. (Continued)

Sample type	Ice core (cm) Top 0-45	Middle 45-91	Bottom 91-137	Bottom 132-137	Seawater depth (m) 0	10	40
Eunotia	-	-	-	-	+	+	+
E. arcus	-	-	-	-	+	-	+
E. exigua	-	-	-	-	-	+	-
Fragilaria	-	-	-	-	-	80	40
F. pinnata	-	-	-	-	-	80	40
Gomphonema	-	-	-	-	+	+	80
G. aestuarii	-	-	-	-	+	+	+
G. kamtschaticum	-	-	-	-	-	-	80
Licmophora	-	-	-	-	-	+	+
L. gracilis var. anglica	-	-	-	-	-	+	-
L. hyalina	-	-	-	-	-	-	+
Navicula	560	1 280	94 302	180 810	80	240	40
N. algida	-	-	-	2 870	-	-	-
N. ammophila	-	-	-	-	40	-	-
N. cancellata	-	-	-	-	-	+	-
N. cancellata var. apiculata	-	-	-	-	-	-	+
N. cancellata var. retusa	-	-	-	-	-	+	-
N. cincta	-	-	-	-	-	40	+
N. cincta var. heufleri	-	-	-	-	-	80	-
N. crassirostris	-	-	-	-	-	+	-
N. crucigeroides	-	-	-	-	-	+	-
N. cryptocephala	80	-	3 627	-	-	-	-
N. directa	80	120	18 135	51 660	-	80	-
N. distans	-	-	-	-	-	+	-
N. forcipata	-	-	-	8 610	+	+	-
N. gelida	-	-	10 881	5 740	-	-	-
N. gracilis	-	-	-	-	-	+	+
N. novadecipiens	-	-	-	-	-	40	-
N. oestrupi	-	-	3 627	2 870	-	-	-
N. placentula	-	-	-	-	40	+	-

Table 9. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-45	Middle 45-91	Bottom 91-137	Bottom 132-137	0	10	40
N. pseudoscutiformis	-	-	-	-	-	+	-
N. radiosa	-	-	-	-	-	+	-
N. salinarum	-	-	3 627	-	-	-	-
N. spicula	-	-	7 254	2 870	-	-	-
N. transitans	120	120	3 627	31 570	-	+	-
N. transitans var. *derasa*	-	-	-	-	-	+	-
N. transitans var. *incudiformis*	-	-	-	5 740	-	+	-
N. trigonocephala	-	-	7 254	14 350	-	-	-
N. ulvacea	-	-	-	-	-	+	-
N. valida	80	320	21 762	37 310	-	-	-
N. valida var. *minuta*	-	600	7 254	-	-	-	-
N. spp.	200	120	7 254	17 220	-	-	40
Nitzschia	2 280	13 320	892 242	1 081 990	40	40	40
N. acicularis	-	-	29 016	-	-	-	-
N. angularis	-	-	-	5 740	-	-	-
N. brebissonii var. *borealis*	-	-	18 135	8 610	-	-	-
N. cylindrus	280	1 120	18 135	83 230	40	+	40
N. frigida	280	7 760	261 144	393 190	-	-	-
N. frustulum var. *perpusilla*	-	-	-	-	+	-	+
N. grunowii	560	2 640	373 581	275 520	-	-	-
N. hybrida	-	200	-	11 480	-	+	-
N. laevissima	280	-	-	14 350	-	-	-
N. lecointei	-	320	3 627	-	-	-	-
N. linearis	600	960	152 334	218 120	-	-	-
N. longissima	-	120	25 389	43 050	-	-	-
N. spp.	280	200	10 881	28 700	+	40	-
Pinnularia	-	80	7 254	14 350	-	+	+
P. obscura	-	-	-	-	-	+	+
P. parva	-	-	-	-	-	-	+
P. quadratarea	-	-	3 627	-	-	-	+

Table 9. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-45	Middle 45-91	Bottom 91-137	Bottom 132-137	0	10	40
P. quadratarea var. *bicontracta*	-	-	-	8 610	-	+	-
P. quadratarea var. *capitata*	-	-	-	5 740	-	-	-
P. quadratarea var. *constricta*	-	80	3 627	-	-	-	-
Plagiogramma	-	-	-	-	-	+	+
P. staurophorum	-	-	-	-	-	+	+
Pleurosigma	120	40	7 254	28 700	-	-	-
P. antarcticum	-	40	3 627	11 480	-	-	-
P. clevei	-	-	3 627	14 350	-	-	-
P. elongatum var. *karianum*	120	-	-	2 870	-	-	-
Rhabdonema	-	-	-	-	-	+	80
R. arcuatum	-	-	-	-	-	+	40
R. minutum	-	-	-	-	-	-	40
Stauroneis	-	720	-	8 610	-	-	-
S. prominula	-	-	-	-	+	-	-
S. quadripedis	-	720	-	8 610	-	-	-
Synedra	200	80	21 762	37 310	-	200	80
S. pulchella	120	80	18 135	22 960	-	-	-
S. tabulata	80	-	3 627	2 870	-	120	80
S. tabulata var. *fasciculata*	-	-	-	-	-	80	-
S. spp.	-	-	-	11 480	-	-	-
Tabellaria	120	-	7 254	-	-	160	+
T. flocculosa	120	-	7 254	-	-	160	+
Unidentified	-	120	-	-	520	1 000	2 040
Chlorophyta	1 280	3 440	87 048	51 660	1 440	2 520	2 120
Carteria	-	-	-	-	1 440	2 080	2 120
C. spp.	-	-	-	-	1 440	2 080	2 120
Unidentified green filaments	120	-	-	-	-	440	-
Unidentified green flagellates	1 160	3 440	87 048	51 660	-	-	-

Table 9. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-45	Middle 45-91	Bottom 91-137	Bottom 132-137	0	10	40
Cyanophyta	20 514	5 924	3 627	-	5 240	-	-
Unidentified Cyanophyceae	20 514	5 924	3 627	-	5 240	-	-
Euglenophyta	640	40	10 881	5 740	-	-	-
Euglena	640	40	10 881	-	-	-	-
E. spp.	640	40	10 881	5 740	-	-	-
Pyrrophyta	-	-	14 508	2 870	-	-	-
Goniaulax	-	-	7 254	2 870	-	-	-
G. spp.	-	-	7 254	2 870	-	-	-
Unidentified	-	-	7 254	-	-	-	-

Table 10. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 6 May 1980.

Sea ice thickness (cm)	162						
Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-54	Middle 54-108	Bottom 108-162	Bottom 157-162	0	10	40
Total sea ice microalgae or phytoplankton (cells/litre)	40 560	42 120	1 055 457	14 038 038	29 160	9 600	10 360
Bacillariophyta	36 840	40 240	997 425	13 058 640	3 200	3 400	4 080
Centrales	1 600	2 200	14 508	108 822	2 520	1 360	2 480
Chaetoceros	1 160	520	3 627	-	40	+	40
C. furcellatus	720	520	-	-	-	-	-
C. karianus	440	-	-	-	-	-	-
C. spp.	-	-	-	-	40	+	40
Coscinodiscus	160	80	-	-	-	-	120
C. lacustris var. septentrionalis	160	80	-	-	-	-	120
Cyclotella	-	-	-	-	+	+	-
C. bodanica	-	-	-	-	+	+	-
Melosira	-	640	10 881	-	+	-	-
M. arctica	-	640	10 881	-	-	-	-
M. roeseana	-	-	-	-	+	-	-
Rhizosolenia	-	240	-	-	-	-	-
R. spp.	-	240	-	-	-	-	-
Stephanodiscus	-	-	-	-	-	-	+
S. astraea	-	-	-	-	-	-	+
Thalassiosira	200	440	-	72 548	+	+	+
T. bioculata var. exigua	-	-	-	-	-	-	+
T. eccentrica	-	-	-	-	-	+	-
T. gravida	-	-	-	36 274	-	-	-
T. kryophila	-	-	-	-	-	+	-
T. nordenskioldii	120	200	-	-	-	-	-
T. oestrupii	80	240	-	36 274	+	-	-

Table 10. (Continued)

Sample type	Ice core (cm) Top 0-54	Middle 54-108	Bottom 108-162	Bottom 157-162	Seawater depth (m) 0	10	40
Triceratium	-	-	-	-	-	+	-
T. arcticum	-	-	-	-	-	+	-
Unidentified	80	280	-	36 274	2 480	1 360	2 320
Pennales	35 240	38 040	982 917	12 949 818	680	2 040	1 600
Achnanthes	960	-	32 643	399 014	40	-	40
A. clevei	-	-	-	-	40	-	+
A. hauckiana	-	-	-	-	-	-	40
A. lemmermannii	-	-	-	-	-	-	+
A. marginulata	-	-	-	-	+	-	-
A. taeniata	960	-	32 643	399 014	-	-	-
Amphiprora	240	3 120	18 135	72 548	-	-	-
A. kjellmanii var. kariana	240	3 120	14 508	-	-	-	-
A. kjellmanii var. striolata	-	-	3 627	36 274	-	-	-
A. kryophila	-	-	-	36 274	-	-	-
Amphora	-	-	14 508	108 822	+	40	40
A. exigua	-	-	-	-	+	40	40
A. laevis var. laevissima	-	-	7 254	108 822	-	-	-
A. laevis var. minuta	-	-	7 254	-	-	-	-
A. terroris	-	-	-	-	-	+	+
Cocconeis	-	-	-	36 274	160	120	160
C. californica	-	-	-	-	+	+	+
C. costata	-	-	-	-	80	120	80
C. diminuta	-	-	-	-	+	-	+
C. interrupta	-	-	-	-	40	-	+
C. pellucida	-	-	-	-	40	-	-
C. scutellum var. stauroneiformis	-	-	-	36 274	-	-	80
C. thumensis	-	-	-	-	+	-	+
Cylindrotheca	480	320	43 524	1 124 494	80	-	40
C. closterium	480	320	43 524	1 124 494	80	-	40

Table 10. (Continued)

Sample type	Ice core (cm) Top 0-54	Middle 54-108	Bottom 108-162	Bottom 157-162	Seawater depth (m) 0	10	40
Diploneis	240	3 120	36 270	399 014	+	80	+
D. didyma	-	-	-	-	+	-	-
D. interrupta	-	-	-	-	-	40	-
D. lineata	-	-	7 254	-	-	-	-
D. litoralis var. arctica	80	1 920	29 016	399 014	-	-	-
D. litoralis var. clathrata	160	1 200	-	-	-	-	-
D. reichardtii var. tschuktschorum	-	-	-	-	-	-	+
D. spp.	-	-	-	-	-	40	-
Fragilaria	-	-	-	-	+	-	80
F. pinnata	-	-	-	-	+	-	80
F. virescens	-	-	-	-	-	-	+
Gomphonema	80	280	-	108 822	+	+	40
G. aestuarii	-	-	-	-	+	+	+
G. exiguum var. pachycladum	80	280	-	108 822	-	-	-
G. kamtschaticum	-	-	-	-	+	-	40
Grammatophora	-	-	-	-	-	-	+
G. arctica	-	-	-	-	-	-	+
Navicula	1 680	4 920	155 961	2 248 988	80	-	80
N. algida	-	-	-	72 548	-	-	40
N. crassirostris	-	-	-	36 274	-	-	-
N. crucigeroides	-	-	10 881	-	-	-	-
N. cryptocephala	-	40	7 254	-	-	-	-
N. digitoradiata	-	-	3 627	-	40	-	-
N. directa	200	1 480	21 762	616 658	-	-	-
N. forcipata	-	-	3 627	-	-	-	-
N. gelida	200	640	21 762	253 918	-	-	-
N. glacialis	-	-	3 627	-	-	-	-
N. novadecipiens	-	80	-	72 548	-	-	-
N. oestrupi	40	-	-	-	-	-	-
N. transitans	-	520	14 508	290 192	-	-	40

Table 10. (Continued)

Sample type	Ice core (cm) Top 0-54	Middle 54-108	Bottom 108-162	Bottom 157-162	Seawater depth (m) 0	10	40
N. transitans var. derasa	40	360	-	-	-	-	-
N. transitans var. incudiformis	-	-	14 508	181 370	-	-	-
N. trigonocephala	40	160	3 627	108 822	-	-	-
N. trigonocephala var. depressa	-	-	7 254	-	-	-	-
N. valida	760	920	10 881	399 014	-	-	-
N. valida var. minuta	-	360	10 881	108 822	-	-	-
N. spp.	400	360	21 762	108 822	40	-	-
Nitzschia	29 640	24 040	616 590	7 327 348	+	+	40
N. acicularis	640	1 080	-	-	-	-	-
N. brebissonii var. borealis	240	-	-	326 466	-	-	-
N. cyclindrus	1 240	1 040	-	-	+	+	40
N. distans var. erratica	-	-	-	108 822	-	-	-
N. frigida	15 160	4 080	188 604	943 124	-	-	-
N. frustulum var. perpusilla	-	-	-	-	+	-	-
N. grunowii	7 520	13 360	170 469	3 337 208	-	-	+
N. hybrida	-	120	3 627	-	-	-	-
N. laevissima	-	-	47 151	326 466	-	-	-
N. lecointei	-	120	7 254	-	-	-	-
N. linearis	3 040	1 880	39 897	725 480	-	-	-
N. longissima	1 000	1 560	-	-	-	-	-
N. polaris	520	520	-	36 274	-	-	-
N. tergestina	-	-	130 572	1 197 042	-	-	-
N. spp.	280	280	29 016	326 466	-	-	-
Pinnularia	120	880	18 135	253 918	-	120	-
P. ambigua	-	-	-	36 274	-	-	-
P. quadratarea	120	200	3 627	72 548	-	40	-
P. quadratarea var. bicontracta	-	680	10 881	108 822	-	40	-
P. quadratarea var. bicuneata	-	-	-	36 274	-	-	-
P. quadratarea var. capitata	-	-	3 627	-	-	-	-
P. quadratarea var. constricta	-	-	-	-	-	40	-

Table 10. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-54	Middle 54-108	Bottom 108-162	Bottom 157-162	0	10	40
Plagiogramma	-	-	-	-	+	-	+
P. staurophorum	-	-	-	-	+	-	+
Pleurosigma	280	120	25 389	652 932	-	-	-
P. antarcticum	200	80	7 254	181 370	-	-	-
P. clevei	80	40	10 881	435 288	-	-	-
P. stuxbergii var. minor	-	-	7 254	36 274	-	-	-
Rhabdonema	-	-	-	-	-	-	+
R. minutum	-	-	-	-	-	-	+
Stauroneis	1 160	840	-	217 644	-	-	-
S. quadripedis	1 160	840	-	217 644	-	-	-
Synedra	360	400	21 762	-	+	+	40
S. pulchella	-	200	3 627	-	-	-	+
S. tabulata	360	200	18 135	-	+	+	40
S. tabulata var. fasciculata	-	-	-	-	-	+	-
Tabellaria	-	-	-	-	+	-	40
T. flocculosa	-	-	-	-	+	-	40
Unidentified	-	-	-	-	320	1 680	1 000
Chlorophyta	2 880	1 760	58 032	906 850	5 560	5 280	6 280
Carteria	-	-	-	-	5 240	2 240	1 560
C. spp.	-	-	-	-	5 240	2 240	1 560
Unidentified green filaments	560	-	-	-	-	-	160
Unidentified green flagellates	2 320	1 760	58 032	906 850	320	3 040	4 560
Cyanophyta	320	-	-	-	19 560	920	-
Unidentified Cyanophyceae	320	-	-	-	19 560	920	-
Euglenophyta	480	120	-	36 274	80	-	-
Euglena	480	120	-	36 274	-	-	-
E. proxima	-	-	-	36 274	-	-	-

Table 10. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-54	Middle 54-108	Bottom 108-162	Bottom 157-162	0	10	40
E. spp.	480	120	-	-	80	-	-
Pyrrophyta	40	-	-	36 274	760	-	-
Peridinium	40	-	-	-	-	-	-
P. spp.	40	-	-	-	-	-	-
Unidentified	-	-	-	36 274	760	-	-

Table 11. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 6 June 1980.

Sea ice thickness (cm)	152					
	Ice core (cm)			Seawater depth (m)		
Sample type	Top 0-50	Middle 50-101	Bottom 101-152	0	10	40
Total sea ice microalgae or phytoplankton (cells/litre)	291 651	192 983	1 403 649	39 120	12 240	3 920
Bacillariophyta	281 494	181 375	1 294 839	17 360	5 560	2 240
Centrales	23 216	15 961	61 659	8 600	5 080	1 680
Chaetoceros	10 157	4 353	25 389	640	-	-
C. furcellatus	4 353	1 451	10 881	120	-	-
C. karianus	2 902	1 451	-	-	-	-
C. septentrionalis	2 902	1 451	14 508	520	-	-
Coscinodiscus	-	-	-	440	-	-
C. lacustris	-	-	-	440	-	-
Melosira	-	-	7 254	-	-	-
M. arctica	-	-	7 254	-	-	-
Rhizosolenia	2 902	-	-	-	-	-
R. spp.	2 902	-	-	-	-	-
Thalassiosira	5 804	10 157	29 016	+	-	-
T. gravida	-	-	3 627	-	-	-
T. nordenskioldii	5 804	2 902	18 135	+	-	-
T. oestrupii	-	7 255	7 254	-	-	-
Unidentified	4 353	1 451	-	7 520	5 080	1 680
Pennales	258 278	165 414	1 233 180	8 760	480	560
Achnanthes	31 922	23 216	68 913	240	-	-
A. clevei	-	-	-	+	-	-
A. flexella	-	-	-	+	-	-
A. groenlandica	-	-	-	40	-	-
A. hauckiana	-	-	-	160	-	-
A. lemmermannii	-	-	-	40	-	-
A. taeniata	31 922	23 216	68 913	-	-	-

Table 11. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-50	Middle 50-101	Bottom 101-152	0	10	40
Amphiprora	2 902	1 451	14 508	-	-	-
A. gigantea var. septentrionalis	-	1 451	7 254	-	-	-
A. kjellmanii var. kariana	2 902	-	3 627	-	-	-
A. kryophila	-	-	3 627	-	-	-
Amphora	-	-	-	480	-	+
A. costata	-	-	-	240	-	-
A. exigua	-	-	-	240	-	+
Caloneis	-	-	-	+	-	-
C. brevis	-	-	-	+	-	-
Cocconeis	-	-	-	1 320	40	40
C. californica	-	-	-	40	-	-
C. costata	-	-	-	600	40	40
C. diminuta	-	-	-	120	-	-
C. interrupta	-	-	-	80	-	-
C. pellucida	-	-	-	120	-	-
C. placentula var. euglypta	-	-	-	40	-	-
C. scutellum	-	-	-	200	-	+
C. thumensis	-	-	-	120	-	+
Cylindrotheca	37 726	20 314	58 032	80	80	-
C. closterium	37 726	20 314	58 032	80	80	-
Diploneis	-	2 902	18 135	120	-	+
D. incurvata	-	-	-	+	-	-
D. interrupta	-	-	-	80	-	-
D. litoralis	-	-	-	+	-	-
D. litoralis var. arctica	-	2 902	18 135	-	-	-
D. reichardtii var. tschuktschorum	-	-	-	40	-	+
Eunotia	-	-	-	80	-	-
E. bigibba	-	-	-	40	-	-
E. exigua	-	-	-	40	-	-

Table 11. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-50	Middle 50-101	Bottom 101-152	0	10	40
Fragilaria	-	-	-	240	-	+
F. pinnata	-	-	-	240	-	+
Gomphonema	1 451	-	3 627	200	-	+
G. aestuarii	-	-	-	40		-
G. exiguum var. pachycladum	-	-	3 627	-	-	+
G. groenlandicum	1 451	-	-	-	-	-
G. kamtschaticum	-	-	-	160	-	-
Grammatophora	-	-	-	160	-	-
G. arcuata	-	-	-	160	-	-
Navicula	15 961	7 255	54 405	520	40	40
N. ammophila	-	-	-	120	-	-
N. cancellata	-	-	-	40	-	-
N. crassirostris	-	-	10 881	-	-	-
N. directa	2 902	-	10 881	-	-	-
N. distans	-	-	-	80	-	+
N. forcipata	-	-	-	40	-	-
N. gelida	5 804	2 902	10 881	-	-	-
N. transitans	2 902	-	-	-	-	-
N. valida	-	-	7 254	+	-	-
N. valida var. minuta	-	1 451	3 627	-	-	-
N. spp.	4 353	2 902	10 881	240	40	40
Nitzschia	153 806	104 472	993 798	320	-	160
N. acuminata	-	-	-	+	-	-
N. brebissonii var. borealis	1 451	-	-	-	-	-
N. cylindrus	7 254	-	39 897	160	-	+
N. distans var. erratica	-	-	10 881	-	-	-
N. frigida	36 275	14 510	522 288	-	-	-
N. frustulum	-	-	-	80	-	-
N. frustulum var. perpusilla	-	-	-	+	-	-
N. grunowii	88 511	44 981	257 517	80	-	-
N. hybrida	-	-	3 627	-	-	-

Table 11. (Continued)

Sample type	Ice core (cm) Top 0-50	Middle 50-101	Bottom 101-152	Seawater depth (m) 0	10	40
N. laevissima	1 451	1 451	18 135	-	-	-
N. lecointei	-	14 510	29 016	-	-	-
N. linearis	2 902	11 608	58 032	-	-	-
N. longissima	-	-	3 627	-	-	-
N. peregrina var. *meniscus*	-	-	-	+	-	-
N. tergestina	11 608	14 510	36 270	-	-	-
N. spp.	4 353	2 902	14 508	-	-	160
Pinnularia	-	-	-	+	-	-
P. quadratarea var. *constricta*	-	-	-	+	-	-
Plagiogramma	-	-	-	40	-	+
P. staurophorum	-	-	-	40	-	+
Rhabdonema	-	-	-	+	-	-
R. arcuatum	-	-	-	+	-	-
Stauroneis	13 059	4 353	21 762	-	-	-
S. quadripedis	13 059	4 353	21 762	-	-	-
Synedra	1 451	1 451	-	280	-	40
S. camtschatica	-	-	-	-	+	-
S. pulchella	-	-	-	40	-	-
S. tabulata	1 451	-	-	240	+	40
S. tabulata var. *fasciculata*	-	1 451	-	-	-	-
Tabellaria	-	-	-	40	-	+
T. flocculosa	-	-	-	40	-	+
Trachyneis	-	-	-	-	-	+
T. aspera	-	-	-	-	-	+
Unidentified	-	-	-	4 640	320	280
Chrysophyta	-	-	10 881	-	-	-
Phaeocystis	-	-	10 881	-	-	-
P. pouchetii	-	-	10 881	-	-	-

Table 11. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-50	Middle 50-101	Bottom 101-152	0	10	40
Chlorophyta	8 706	10 157	87 048	21 040	6 680	1 680
Carteria	-	-	-	17 920	640	120
C. spp.	-	-	-	17 920	640	120
Unidentified green filaments	-	-	3 627	-	120	-
Unidentified green flagellates	8 706	10 157	83 421	3 120	5 920	1 560
Euglenophyta	-	1 451	7 254	-	-	-
Euglena	-	1 451	7 254	-	-	-
E. proxima	-	-	3 627	-	-	-
E. spp.	-	1 451	3 627	-	-	-
Pyrrophyta	1 451	-	3 627	720	-	-
Peridinium	-	-	-	640	-	-
P. spp.	-	-	-	640	-	-
Unidentified	1 451	-	3 627	80	-	-

Table 12. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 13 June 1980.

Sea ice thickness (cm)			158			
Sample type	Ice core (cm)			Seawater depth (m)		
	Top	Middle	Bottom			
	0-53	53-105	105-158	0	10	40
Total sea ice microalgae or phytoplankton (cells/litre)	484 634	362 750	2 415 582	75 880	11 920	15 240
Bacillariophyta	451 261	332 279	2 201 589	25 880	1 080	3 920
Centrales	31 922	17 412	90 675	3 960	640	1 520
Chaetoceros	21 765	4 353	61 659	120	-	+
C. furcellatus	7 255	2 902	14 508	80	-	+
C. karianus	2 902	-	-	-	-	-
C. septentrionalis	11 608	1 451	47 151	40	-	-
Coscinodiscus	-	1 451	-	120	-	-
C. lacustris	-	-	-	80	-	-
C. polyacanthus	-	1 451	-	40	-	-
Cyclotella	-	-	-	80	-	-
C. comta	-	-	-	40	-	-
C. comta var. oligactis	-	-	-	40	-	-
Melosira	-	2 902	-	-	-	-
M. binderana	-	2 902	-	-	-	-
Rhizosolenia	-	1 451	3 627	-	-	-
R. spp.	-	1 451	3 627	-	-	-
Stephanodiscus	-	-	-	+	-	-
S. astraea	-	-	-	+	-	-
Thalassiosira	7 255	5 804	18 135	+	-	240
T. eccentrica	-	-	-	-	-	120
T. nordenskioldii	7 255	2 902	7 254	-	-	-
T. oestrupii	-	2 902	10 881	+	-	-
T. spp.	-	-	-	-	-	120
Unidentified	2 902	1 451	7 254	3 640	640	1 280

Table 12. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-53	Middle 53-105	Bottom 105-158	0	10	40
Pennales	419 339	314 867	2 110 914	21 920	440	2 400
Achnanthes	18 863	7 255	43 524	320	-	-
A. clevei	-	-	-	+	-	-
A. flexella	-	-	-	160	-	-
A. groenlandica	-	-	-	+	-	-
A. kriegeri	-	-	-	+	-	-
A. marginulata	-	-	-	+	-	-
A. taeniata	18 863	7 255	43 524	160	-	-
Amphiprora	-	10 157	7 254	-	-	-
A. gigantea var. septentrionalis	-	7 255	3 627	-	-	-
A. kjellmanii var. kariana	-	2 902	-	-	-	-
A. kryophila	-	-	3 627	-	-	-
Amphora	2 902	2 902	32 643	80	-	80
A. exigua	-	-	-	-	-	80
A. exsecta	-	-	7 254	-	-	-
A. laevis	-	-	-	80	-	-
A. laevis var. laevissima	2 902	2 902	25 389	-	-	-
A. ovalis var. libyca	-	-	-	+	-	-
Caloneis	-	-	-	120	-	-
C. silicula	-	-	-	120	-	-
Cocconeis	1 451	-	-	480	40	440
C. californica	-	-	-	40	-	-
C. costata	-	-	-	80	40	320
C. diminuta	-	-	-	120	+	40
C. scutellum	1 451	-	-	80	-	+
C. scutellum var. stauroneiformis	-	-	-	80	-	+
C. thumensis	-	-	-	80	-	+
C. spp.	-	-	-	-	-	80
Cylindrotheca	68 197	39 177	130 572	40	360	240
C. closterium	68 197	39 177	130 572	40	360	240
Cymbella	-	-	-	320	-	-
C. angustata	-	-	-	160	+	-

Table 12. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-53	Middle 53-105	Bottom 105-158	0	10	40
C. naviculiformis	-	-	-	160	-	-
Diploneis	2 902	2 902	47 151	80	+	-
D. interrupta	-	-	-	+	-	-
D. lineata	-	-	3 627	-	-	-
D. litoralis	-	-	-	80	-	-
D. litoralis var. arctica	2 902	2 902	43 524	-	-	-
D. reichardtii var. tschuktschorum	-	-	-	-	+	-
D. smithii	-	-	-	-	-	+
Eunotia	-	-	-	40	-	40
E. bigibba	-	-	-	+	-	-
E. bigibba var. pumila	-	-	-	-	-	40
E. exigua	-	-	-	+	-	-
E. exigua var. compacta	-	-	-	+	-	-
E. monodon var. major	-	-	-	40	-	-
E. pectinalis var. minor	-	-	-	+	-	-
E. pectinalis var. ventralis	-	-	-	+	-	-
Fragilaria	-	-	-	160	+	40
F. construens	-	-	-	+	-	-
F. pinnata	-	-	-	160	+	40
F. vaucheriae	-	-	-	+	-	-
Frustulia	-	-	-	40	-	-
F. rhomboides var. saxonica	-	-	-	40	-	-
Gomphonema	-	-	3 627	40	+	+
G. aestuarii	-	-	-	+	+	+
G. exiguum var. pachycladum	-	-	3 627	-	-	-
G. kamtschaticum	-	-	-	40	-	+
Navicula	5 804	7 255	72 540	1 440	40	400
N. anglica var. subsalsa	-	-	-	+	-	-
N. avenacea	-	-	-	+	40	-
N. cancellata	-	-	-	40	-	40

Table 12. (Continued)

Sample type	Ice core (cm) Top 0-53	Middle 53-105	Bottom 105-158	Seawater depth (m) 0	10	40
N. cancellata var. apiculata	-	-	-	-	-	+
N. cincta	-	-	-	240	-	-
N. cincta var. heufleri	-	-	-	+	-	+
N. cluthensis var. pagophila	-	-	7 254	-	-	-
N. crucigeroides	-	1 451	-	-	-	-
N. cryptocephala	-	-	-	40	+	-
N. digitoradiata	-	1 451	-	-	-	-
N. directa	2 902	-	14 508	-	-	40
N. exigua	-	-	-	40	-	-
N. explanata	-	-	-	+	-	-
N. forcipata	-	-	-	-	-	80
N. fortis	-	-	-	-	-	40
N. gelida	-	1 451	3 627	-	-	-
N. halophila	-	-	-	-	+	-
N. minima	-	-	-	80	-	-
N. novadecipiens	-	-	3 627	-	-	-
N. pseudoscutiformis	-	-	-	+	-	-
N. pupula	-	-	-	40	-	-
N. radiosa	-	-	-	+	-	-
N. subinflata	-	-	-	+	-	-
N. transitans	-	-	7 254	-	-	-
N. transitans var. incudiformis	-	-	7 254	-	-	-
N. valida	-	-	7 254	+	-	-
N. valida var. minuta	-	-	7 254	-	-	-
N. vulpina	-	-	-	+	-	-
N. spp.	2 902	2 902	14 508	920	+	200
Nitzschia	296 004	237 964	1 730 079	480	+	120
N. angustata var. acuta	-	-	-	+	-	-
N. cylindrus	8 706	1 451	54 405	160	-	40
N. distans var. erratica	-	-	18 135	-	-	-
N. frigida	42 079	98 668	609 336	-	-	-

Table 12. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-53	Middle 53-105	Bottom 105-158	0	10	40
N. frustulum var. *perpusilla*	-	-	-	160	-	40
N. grunowii	197 336	92 864	808 821	-	-	-
N. hybrida	4 353	1 451	-	-	-	-
N. laevissima	-	8 706	32 643	-	-	-
N. lecointei	1 451	7 255	97 929	-	+	-
N. linearis	2 902	8 706	14 508	-	-	-
N. longissima	-	4 353	14 508	-	-	-
N. tergestina	33 373	13 059	47 151	-	-	-
N. spp	5 804	1 451	32 643	160	-	40
Pinnularia	-	-	3 627	240	-	40
P. divergens	-	-	-	+	-	-
P. gibba	-	-	-	+	-	-
P. mesolepta	-	-	-	+	-	-
P. obscura	-	-	-	40	-	-
P. quadratarea	-	-	3 627	160	-	40
P. viridis	-	-	-	40	-	-
Plagiogramma	-	-	-	-	-	+
P. staurophorum	-	-	-	-	-	+
Pleurosigma	-	-	3 627	40	-	-
P. antarcticum	-	-	-	40	-	-
P. clevei	-	-	3 627	-	-	-
Rhabdonema	-	-	-	-	-	+
R. arcuatum	-	-	-	-	-	+
Stauroneis	20 314	7 255	25 389	+	-	-
S. phoenicenteron	-	-	-	+	-	-
S. quadripedis	20 314	7 255	25 389	-	-	-
Stenoneis	-	-	3 627	-	-	-
S. inconspicus var. *baculus*	-	-	3 627	-	-	-
Synedra	2 902	-	7 254	240	-	80
S. pulchella	-	-	-	120	-	-

Table 12. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-53	Middle 53-105	Bottom 105-158	0	10	40
S. tabulata	-	-	-	120	-	80
S. tabulata var. *fasciculata*	2 902	-	7 254	+	-	-
Tabellaria	-	-	-	3 800	+	-
T. fenestrata	-	-	-	80	-	-
T. flocculosa	-	-	-	3 720	+	+
Unidentified	-	-	-	14 000	-	920
Chlorophyta	29 020	20 314	195 858	45 920	10 360	10 440
Carteria	-	-	-	29 600	7 640	440
C. spp.	-	-	-	29 600	7 640	440
Unidentified green filaments	-	-	-	80	800	-
Unidentified green flagellates	29 020	20 314	195 858	16 240	1 920	10 000
Cyanophyta	1 451	1 451	-	3 840	480	880
Spirulina	-	-	-	40	-	-
S. spp.	-	-	-	40	-	-
Unidentified Cyanophyceae	1 451	1 451	-	3 800	480	880
Euglenophyta	-	-	7 254	80	-	-
Euglena	-	-	7 254	-	-	-
E. spp.	-	-	7 254	80	-	-
Pyrrophyta	2 902	8 706	10 881	160	-	-
Gymnodinium	1 451	-	7 254	40	-	-
G. spp.	1 451	-	7 254	40	-	-
Prorocentrum	-	4 353	-	120	-	-
P. ovalis	-	4 353	-	120	-	-
Unidentified	1 451	4 353	3 627	-	-	-

Table 13. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 20 June 1980.

Sea ice thickness (cm)	100					
Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-33	Middle 33-66	Bottom 66-100	0	10	40
Total sea ice microalgae or phytoplankton (cells/litre)	634 087	597 812	3 053 934	69 760	32 080	29 000
Bacillariophyta	599 263	561 537	2 868 957	32 360	2 800	11 840
Centrales	43 530	30 471	72 540	9 840	840	2 680
Chaetoceros	26 118	20 314	43 524	1 640	40	120
C. fragilis	-	2 902	3 627	240	-	40
C. furcellatus	1 451	2 902	3 627	1 040	40	80
C. karianus	7 255	2 902	-	240	-	-
C. septentrionalis	17 412	11 608	36 270	120	-	-
Coscinodiscus	-	-	7 254	360	-	80
C. lacustris	-	-	-	280	-	80
C. lacustris var. *septentrionalis*	-	-	7 254	80	-	-
Cyclotella	-	-	-	120	-	-
C. comta var. *oligactis*	-	-	-	+	-	-
C. spp.	-	-	-	120	-	-
Melosira	2 902	-	-	-	-	-
M. arctica	2 902	-	-	-	-	-
Stephanodiscus	-	-	-	-	+	-
S. astraea	-	-	-	-	+	-
Thalassiosira	11 608	7 255	7 254	720	-	80
T. bioculata var. *exigua*	-	4 353	7 254	+	-	+
T. eccentrica	-	-	-	120	-	80
T. nordenskioldii	7 255	2 902	-	80	-	-
T. oestrupii	4 353	-	-	360	-	-
T. spp.	-	-	-	160	-	-
Unidentified	2 902	2 902	14 508	7 000	800	2 400

Table 13. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-33	Middle 33-66	Bottom 66-100	0	10	40
Pennales	555 733	531 066	2 796 417	22 520	1 960	9 160
Achnanthes	14 510	10 157	166 842	680	-	200
A. clevei	-	-	-	120	-	40
A. flexella	-	-	-	40	-	-
A. groenlandica	-	-	-	+	-	40
A. marginulata	-	-	-	+	-	+
A. taeniata	14 510	10 157	166 842	120	-	-
A. spp.	-	-	-	400	-	120
Amphiprora	7 255	1 451	3 627	+	-	-
A. concilians	-	-	-	+	-	-
A. gigantea var. septentrionalis	7 255	1 451	3 627	-	-	-
Amphora	-	1 451	21 762	240	+	200
A. exigua	-	-	-	120	-	120
A. exsecta	-	-	7 254	-	-	-
A. laevis	-	-	-	120	-	80
A. laevis var. laevissima	-	1 451	14 508	-	-	-
A. terroris	-	-	-	-	40	-
Cocconeis	-	-	-	520	+	800
C. californica	-	-	-	-	+	-
C. costata	-	-	-	240	160	400
C. diminuta	-	-	-	40	+	40
C. interrupta	-	-	-	-	-	40
C. placentula var. euglypta	-	-	-	160	-	40
C. scutellum	-	-	-	80	-	200
C. scutellum var. stauroneiformis	-	-	-	-	+	-
C. thumensis	-	-	-	-	+	-
C. spp.	-	-	-	-	-	80
Cylindrotheca	59 491	34 824	170 469	-	1 000	720
C. closterium	59 491	34 824	170 469	-	1 000	720

Table 13. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-33	Middle 33-66	Bottom 66-100	0	10	40
Cymbella	-	-	-	280	-	-
C. angustata	-	-	-	160	-	-
C. naviculiformis	-	-	-	120	-	-
Diploneis	2 902	1 451	18 135	240	+	80
D. lineata	1 451	-	-	-	-	-
D. litoralis	-	-	-	160	-	40
D. litoralis var. arctica	1 451	1 451	18 135	80	-	-
D. puella	-	-	-	+	-	-
D. reichardtii var. tschuktschorum	-	-	-	-	-	40
D. smithii	-	-	-	-	+	-
Eunotia	-	-	-	40	-	-
E. exigua	-	-	-	40	-	-
E. glacialis	-	-	-	+	-	-
Fragilaria	-	-	-	+	+	-
F. pinnata	-	-	-	+	+	-
F. virescens	-	-	-	+	-	-
Gomphonema	-	-	7 254	160	40	1 120
G. aestuarii	-	-	-	40	40	+
G. exiguum var. pachycladum	-	-	7 254	-	-	+
G. kamtschaticum	-	-	-	120	-	1 120
Gyrosigma	-	-	-	40	-	-
G. lineare	-	-	-	+	-	-
G. prolongatum	-	-	-	40	-	-
Licmophora	-	-	-	-	-	+
L. hyalina	-	-	-	-	-	+
Navicula	11 608	8 706	72 540	3 080	120	3 400
N. algida	-	-	7 254	+	-	+
N. cancellata	-	-	-	-	-	40
N. cancellata var. apiculata	-	-	-	40	-	+
N. cincta	-	-	-	480	-	-
N. cincta var. heufleri	-	-	-	-	-	120

Table 13. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-33	Middle 33-66	Bottom 66-100	0	10	40
N. cluthensis var. pagophila	-	-	7 254	+	-	40
N. crassirostris	-	-	-	-	-	120
N. crucigeroides	-	1 451	3 627	-	-	-
N. cryptocephala	-	-	-	40	-	-
N. digitoradiata	-	2 902	-	-	-	80
N. directa	2 902	-	3 627	200	-	120
N. distans	-	-	-	+	40	40
N. forcipata	-	-	-	-	-	40
N. gastrum	-	-	-	-	-	280
N. gracilis	-	-	-	40	-	-
N. kariana	-	-	-	+	-	+
N. kryokonites var. subprotracta	-	-	-	120	-	160
N. marina	-	-	-	+	-	-
N. minuscula	-	-	-	40	-	-
N. novadecipiens	-	-	-	+	-	80
N. peregrina var. meniscus	-	-	-	-	80	-
N. placentula	-	-	-	40	-	440
N. pupula	-	-	-	+	-	-
N. radiosa	-	-	-	80	-	-
N. rhynchocephala	-	-	-	40	-	40
N. rotaeana	-	-	-	120	-	-
N. ruttneri	-	-	-	40	-	-
N. superba	-	-	-	-	-	80
N. transitans	-	-	7 254	240	-	360
N. transitans var. derasa	-	-	-	-	-	160
N. transitans var. incudiformis	-	-	-	+	-	+
N. trigonocephala	-	-	-	-	-	40
N. trigonocephala var. contracta	-	-	-	-	-	40
N. valida	1 451	-	-	+	-	240
N. valida var. minuta	1 451	1 451	14 508	-	-	-

Table 13. (Continued)

Sample type	Ice core (cm)			Seawater depth (m)		
	Top 0-33	Middle 33-66	Bottom 66-100	0	10	40
N. viridula var. *slesvicensis*	-	-	-	+	-	-
N. spp.	5 804	2 902	29 016	1 560	-	880
Nitzschia	449 810	451 261	2 277 756	3 120	80	200
N. cryophila	-	-	-	80	-	-
N. cylindrus	7 255	17 412	47 151	480	80	-
N. distans var. *erratica*	2 902	2 902	14 508	-	-	-
N. frigida	149 453	153 806	852 345	-	-	-
N. frustulum var. *perpusilla*	-	-	-	+	-	-
N. grunowii	265 533	243 768	1 109 862	80	+	-
N. hybrida	1 451	-	-	200	-	-
N. laevissima	1 451	1 451	29 016	-	-	-
N. lecointei	4 353	8 706	126 945	+	-	-
N. longissima	1 451	1 451	-	-	-	-
N. tergestina	10 157	13 059	68 913	-	-	-
N. spp.	5 804	8 706	29 016	2 280	-	200
Pinnularia	-	-	14 508	160	-	560
P. ambigua	-	-	7 254	-	-	-
P. divergentissima	-	-	-	40	-	-
P. quadratarea	-	-	-	80	-	320
P. quadratarea var. *bicontracta*	-	-	3 627	40	-	40
P. quadratarea var. *capitata*	-	-	3 627	-	-	40
P. quadratarea var. *constricta*	-	-	-	-	-	120
P. spp.	-	-	-	-	-	40
Pleurosigma	-	-	7 254	-	-	-
P. antarcticum	-	-	3 627	-	-	-
P. clevei	-	-	3 627	-	-	-
Stauroneis	10 157	18 863	21 762	-	-	-
S. quadripedis	10 157	18 863	21 762	-	-	-
Stenoneis	-	-	-	-	-	80
S. inconspicua var. *baculus*	-	-	-	-	-	80

Table 13. (Continued)

Sample type	Ice core (cm) Top 0-33	Middle 33-66	Bottom 66-100	Seawater depth (m) 0	10	40
Synedra	-	2 902	14 508	200	+	120
S. acus var. radians	-	-	-	+	-	-
S. camtschatica	-	-	-	+	-	-
S. pulchella	-	-	-	80	-	-
S. tabulata	-	-	-	80	+	80
S. tabulata var. fasciculata	-	2 902	14 508	-	-	-
S. spp.	-	-	-	40	-	40
Tabellaria	-	-	-	120	+	-
T. fenestrata	-	-	-	40	-	-
T. flocculosa	-	-	-	80	+	-
Tropidoneis	-	-	-	120	-	-
T. vitrea	-	-	-	120	-	-
Unidentified	-	-	-	13 520	520	1 680
Chlorophyta	31 922	29 020	170 469	35 760	27 720	15 800
Carteria	-	-	-	20 200	2 640	1 680
C. spp.	-	-	-	20 200	2 640	-
Unidentified green filaments	-	-	-	-	560	-
Unidentified green flagellates	31 922	29 020	170 469	15 560	24 520	14 120
Cyanophyta	-	-	-	1 640	1 560	1 360
Unidentified Cyanophyceae	-	-	-	1 640	1 560	1 360
Euglenophyta	-	1 451	-	-	-	-
Euglena	-	1 451	-	-	-	-
E. proxima	-	1 451	-	-	-	-
Pyrrophyta	2 902	5 804	14 508	-	-	-
Gymnodinium	-	4 353	7 254	-	-	-
G. spp.	-	4 353	7 254	-	-	-
Unidentified	2 902	1 451	7 254	-	-	-

Table 14. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 14 February 1981.

Sea ice thickness (cm)	123						
Sample type	Ice core (cm)				Seawater depth (m)		
	Top	Middle	Bottom	Bottom			
	0-41	41-82	82-123	118-123	0	10	42
Total sea ice microalgae or phytoplankton (cells/litre)	41 520	21 240	194 500	2 868 957	10 560	10 560	12 680
Bacillariophyta	32 040	17 120	165 400	2 560 662	2 760	2 400	4 040
Centrales	13 680	4 920	7 700	145 080	1 160	1 160	760
Chaetoceros	8 360	1 600	2 900	+	960	920	520
C. fragilis	400	-	-	-	+	+	-
C. furcellatus	1 360	440	500	+	720	800	520
C. karianus	4 880	920	1 400	+	-	-	-
C. septentrionalis	1 520	120	1 000	+	160	-	-
C. spp.	200	120	-	-	80	120	-
Coscinodiscus	360	560	1 200	50 778	-	-	-
C. lacustris var. septentrionalis	360	560	1 200	50 778	-	-	40
Rhizosolenia	-	-	100	+	-	-	-
R. spp.	-	-	100	+	-	-	-
Thalassiosira	4 600	2 560	2 600	76 167	-	-	-
T. nordenskioldii	4 040	2 200	2 300	29 016	+	+	+
T. oestrupii	440	240	+	29 016	-	-	-
T. spp.	120	120	300	18 135	-	-	-
Unidentified	360	200	900	18 135	200	240	200
Pennales	18 360	12 200	157 700	2 415 582	1 600	1 240	3 280
Achnanthes	1 440	360	13 900	29 016	-	-	-
A. taeniata	1 440	360	13 900	29 016	-	-	-
Amphiprora	360	1 360	7 000	68 913	-	-	-
A. concilians	-	-	2 400	25 389	-	-	-
A. gigantea var. septentrionalis	120	480	3 600	36 270	-	-	-

Table 14. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-41	Middle 41-82	Bottom 82-123	Bottom 118-123	0	10	42
A. kjellmanii var. *kariana*	240	520	500	+	-	-	-
A. kryophila	-	360	500	7 254	-	-	-
Amphora	400	400	1 600	50 778	-	-	-
A. exsecta	240	80	1 600	25 389	-	-	-
A. laevis var. *laevissima*	160	320	+	25 389	-	-	-
Caloneis	-	-	200	3 627	-	-	-
C. kryophila	-	-	200	3 627	-	-	-
Cocconeis	880	120	100	7 254	440	440	440
C. costata	880	120	100	7 254	440	440	440
Cylindrotheca	200	240	9 900	3 627	120	-	-
C. closterium	200	240	9 900	3 627	120	-	-
Diploneis	720	320	5 400	10 881	200	-	-
D. litoralis var. *arctica*	600	240	3 300	3 627	200	-	-
D. litoralis var. *clathrata*	120	80	2 100	7 254	-	-	-
Gomphonema	240	80	1 600	29 016	-	120	120
G. exiguum	120	+	500	+	-	120	120
G. exiguum var. *pachycladum*	120	80	+	18 135	-	-	-
G. groenlandicum	-	-	1 100	10 881	-	-	-
Licmophora	280	-	-	-	-	-	-
L. gracilis var. *anglica*	280	-	-	-	-	-	-
Navicula	1 720	1 800	29 000	772 551	-	-	80
N. algida	-	80	800	14 508	-	-	-
N. cluthensis var. *pagophila*	-	-	+	3 627	-	-	-
N. crassirostris	-	-	+	3 627	-	-	-
N. crucigeroides	-	-	1 100	32 643	-	-	-
N. digitoradiata	-	40	400	21 762	-	-	-
N. directa	+	120	6 800	232 128	-	-	40
N. gelida	320	200	4 600	50 778	-	-	-
N. glacialis	-	-	+	7 254	-	-	-
N. novadecipiens	40	+	900	14 508	-	-	-

Table 14. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-41	Middle 41-82	Bottom 82-123	Bottom 118-123	0	10	42
N. recurvata	-	-	1 300	18 135	-	-	-
N. transitans	440	840	4 500	79 794	-	-	-
N. transitans var. *derasa*	-	-	900	7 254	-	-	-
N. transitans var. *incudiformis*	-	200	1 000	61 659	-	-	-
N. trigonocephala	-	-	600	3 627	-	-	-
N. trigonocephala var. *depressa*	-	-	2 500	29 016	-	-	-
N. valida	520	200	1 800	101 556	-	-	-
N. valida var. *minuta*	80	+	600	36 270	-	-	40
N. spp.	320	120	1 200	54 405	-	-	-
Nitzschia	11 320	7 120	78 700	1 160 640	640	240	2 000
N. acicularis	-	-	100	+	-	-	-
N. brebissonii var. *borealis*	200	160	2 900	29 016	-	-	-
N. cylindrus	-	-	900	29 016	-	-	-
N. distans var. *erratica*	-	40	3 200	39 897	-	-	-
N. frigida	960	1 960	17 200	246 636	-	-	200
N. gelida	-	120	-	-	-	-	-
N. grunowii	7 520	3 640	30 300	493 272	360	120	1 320
N. hybrida	40	-	-	-	-	-	-
N. laevissima	280	+	1 600	50 778	160	-	-
N. linearis	-	80	-	-	-	-	-
N. longissima	-	-	500	-	-	+	+
N. seriata	560	+	1 500	+	-	-	-
N. tergestina	1 120	1 000	17 800	235 755	-	-	-
N. spp.	640	120	2 700	36 270	120	120	480
Pinnularia	360	200	2 200	43 524	-	-	-
P. ambigua	-	-	+	3 627	-	-	-
P. quadratarea	120	120	200	10 881	-	-	-
P. quadratarea var. *bicontracta*	80	40	700	3 627	-	-	-
P. quadratarea var. *capitata*	-	-	+	10 881	-	-	-
P. quadratarea var. *constricta*	160	40	1 300	14 508	-	-	-

Table 14. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-41	Middle 41-82	Bottom 82-123	Bottom 118-123	0	10	42
Pleurosigma	280	200	3 900	159 588	-	-	-
P. antarcticum	40	200	1 100	87 048	-	-	-
P. clevei	200	+	1 700	21 762	-	-	-
P. elongatum var. kariana	40	-	1 100	50 778	-	-	-
Stauroneis	-	-	800	7 254	-	-	-
S. quadripedis	-	-	800	7 254	-	-	-
Stenoneis	-	-	1 900	25 389	-	-	-
S. inconspicua var. baculus	-	-	1 900	25 389	-	-	-
Synedra	-	-	1 200	21 762	-	80	320
S. pulchella	-	-	+	3 627	-	-	-
S. tabulata	-	-	900	18 135	-	80	200
S. tabulata var. fasciculata	-	-	-	-	-	-	120
Unidentified	160	-	300	21 762	200	360	320
Chlorophyta	8 480	3 680	26 300	261 144	7 080	7 160	8 280
Carteria	160	240	100	+	120	-	120
C. spp.	160	240	100	+	120	-	120
Unidentified green flagellates	8 320	3 440	26 200	261 144	6 960	7 160	8 160
Cyanophyta	120	-	-	-	-	-	-
Unidentified Cyanophyceae	120	-	-	-	-	-	-
Euglenophyta	360	120	500	7 254	280	720	360
Euglena	360	120	500	7 254	280	720	360
E. proxima	-	-	200	+	-	-	-
E. spp.	360	120	300	7 254	280	720	360
Pyrrophyta	520	320	2 300	39 897	440	280	-
Gymnodinium	80	160	1 400	21 762	120	-	-
G. spp.	80	160	1 400	21 762	120	-	-

Table 14. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-41	Middle 41-82	Bottom 82-123	Bottom 118-123	0	10	42
Peridinium	80	+	200	+	-	-	-
P. spp.	80	+	200	+	-	-	-
Prorocentrum	360	40	200	+	-	-	-
P. ovalis	360	40	200	+	-	-	-
Unidentified	-	120	500	18 135	320	280	-

Table 15. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 24 March 1981.

Sea ice thickness (cm)	142						
Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-47	Middle 47-94	Bottom 94-142	Bottom 137-142	0	10	40
Total sea ice microalgae or phytoplankton (cells/litre)	20 680	20 040	56 000	8 465 418	10 120	15 480	18 120
Bacillariophyta	14 880	18 080	46 800	7 943 130	6 440	8 480	12 000
Centrales	3 480	5 120	8 700	184 977	4 200	5 080	5 920
Chaetoceros	2 520	520	900	18 135	3 400	4 440	4 600
C. borealis	-	-	-	-	120	-	-
C. fragilis	-	-	500	-	-	-	-
C. furcellatus	440	-	-	-	2 040	2 720	2 840
C. karianus	960	-	-	-	-	680	800
C. septentrionalis	1 000	440	+	7 254	1 040	920	600
C. spp.	120	80	400	10 881	200	120	360
Coscinodiscus	-	480	400	47 151	-	-	-
C. lacustris var. septentrionalis	-	480	400	47 151	-	-	-
Melosira	-	840	800	14 508	-	-	-
M. arctica	-	840	800	14 508	-	-	-
Thalassiosira	600	2 240	4 500	68 913	400	320	840
T. nordenskioldii	440	1 000	4 500	50 778	400	320	760
T. oestrupii	160	720	+	18 135	-	-	80
T. spp.	-	520	-	-	-	-	-
Triceratium	-	-	-	-	40	-	-
T. arcticum	-	-	-	-	40	-	-
Unidentified	360	1 040	2 100	36 270	360	320	480
Pennales	11 400	12 960	38 100	7 758 153	2 240	3 400	6 080
Achnanthes	2 760	1 840	2 400	155 961	-	-	-
A. taeniata	2 760	1 840	2 400	155 961	-	-	-

Table 15. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-47	Middle 47-94	Bottom 94-142	Bottom 137-142	0	10	40
Amphiprora	-	3 520	3 900	192 231	-	-	-
A. concilians	-	-	+	79 794	-	-	-
A. gigantea var. septentrionalis	-	2 680	2 300	+	-	-	-
A. kjellmanii var. kariana	-	640	1 000	72 540	-	-	-
A. kryophila	-	200	600	39 897	-	-	-
Amphora	120	120	1 200	239 382	-	-	440
A. exsecta	120	120	700	199 485	-	-	240
A. laevis var. laevissima	-	-	500	39 897	-	-	200
Caloneis	-	-	+	3 627	-	-	-
C. kryophila	-	-	+	3 627	-	-	-
Cocconeis	120	-	-	-	360	760	1 040
C. costata	80	-	-	-	280	760	960
C. scutellum	40	-	-	-	80	+	80
Cylindrotheca	200	120	700	340 938	80	40	200
C. closterium	200	120	700	340 938	80	40	200
Diploneis	320	560	4 600	311 922	-	80	-
D. lineata	-	-	-	-		40	-
D. litoralis var. arctica	-	440	3 400	195 858	-	40	-
D. litoralis var. clathrata	320	120	1 200	116 064	-	-	-
Gomphonema	80	80	600	18 135	-	-	120
G. exiguum	80	-	300	+	-	-	120
G. exiguum var. pachycladum	-	80	300	18 135	-	-	-
Navicula	1 400	1 120	6 900	1 617 642	280	400	440
N. algida	-	-	+	10 881	-	-	-
N. cluthensis var. pagophila	40	-	-	-	-	-	-
N. crucigeroides	-	-	+	18 135	-	-	-
N. digitoradiata	-	-	+	61 659	-	-	-
N. directa	360	680	1 800	674 622	-	-	-
N. gelida	280	120	1 400	126 945	-	120	-
N. oestrupi	-	-	+	10 881	-	-	-

Table 15. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-47	Middle 47-94	Bottom 94-142	Bottom 137-142	0	10	40
N. recurvata	-	-	+	29 016	-	-	-
N. transitans	-	200	300	228 501	-	-	-
N. transitans var. *incudiformis*	200	-	300	145 080	-	-	-
N. trigonocephala	-	-	+	3 627	-	-	-
N. trigonocephala var. *depressa*	-	-	+	39 897	-	-	-
N. valida	-	-	1 100	152 334	80	-	120
N. valida var. *minuta*	-	-	900	47 151	-	80	-
N. spp.	520	120	1 100	68 913	200	200	320
Nitzschia	5 800	4 520	13 500	4 276 233	1 280	1 720	2 880
N. brebissonii var. *borealis*	-	80	300	43 524	-	-	-
N. distans var. *erratica*	-	120	300	94 302	-	-	-
N. frigida	720	-	1 100	1 701 063	360	-	280
N. grunowii	3 920	3 760	8 300	1 610 388	480	1 360	? 240
N. hybrida	-	-	+	94 302	-	-	-
N. laevissima	-	-	+	166 842	-	-	-
N. lecointei	-	200	+	18 135	-	-	-
N. polaris	280	-	-	-	-	-	-
N. sigma	-	-	+	58 032	-	-	-
N. tergestina	520	-	1 000	369 954	-	-	-
N. spp.	360	360	2 500	119 691	440	360	360
Pinnularia	160	120	1 200	145 080	-	-	80
P. quadratarea	160	120	900	65 286	-	-	80
P. quadratarea var. *bicontracta*	-	-	+	25 389	-	-	-
P. quadratarea var. *capitata*	-	-	+	43 524	-	-	-
P. quadratarea var. *constricta*	-	-	300	10 881	-	-	-
Pleurosigma	80	80	900	243 009	-	-	200
P. antarcticum	-	80	+	126 945	-	-	-
P. clevei	80	-	+	87 048	-	-	40
P. elongatum var. *kariana*	-	-	900	29 016	-	-	160

Table 15. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-47	Middle 47-94	Bottom 94-142	Bottom 137-142	0	10	40
Stauroneis	-	-	+	39 897	-	-	-
S. quadripedis	-	-	+	39 897	-	-	-
Stenoneis	-	-	400	47 151	-	-	-
S. inconspicua var. baculus	-	-	400	47 151	-	-	-
Synedra	-	80	1 100	94 302	-	120	240
S. pulchella	-	80	+	47 151	-	-	-
S. tabulata	-	-	600	36 270	-	120	120
S. tabulata var. fasciculata	-	-	500	10 881	-	-	120
Unidentified	360	800	700	32 643	240	280	440
Chlorophyta	4 120	1 520	8 200	449 748	2 960	6 480	5 320
Carteria	-	-	-	-	200	-	-
C. spp.	-	-	-	-	200	-	-
Unidentified green filaments	-	-	-	-	120	-	200
Unidentified green flagellates	4 120	1 520	8 200	449 748	2 640	6 480	5 120
Chrysophyta	40	-	-	-	-	-	-
Distephanus	40	-	-	-	-	-	-
D. speculum	40	-	-	-	-	-	-
Cyanophyta	-	-	-	-	-	-	120
Unidentified Cyanophyceae	-	-	-	-	-	-	120
Euglenophyta	320	200	200	39 897	280	280	240
Euglena	320	200	200	39 897	280	280	240
E. proxima	80	-	-	-	80	80	-
E. spp.	240	200	200	39 897	200	200	240

Table 15. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-47	Middle 47-94	Bottom 94-142	Bottom 137-142	0	10	40
Pyrrophyta	1 320	240	800	32 643	440	240	440
Gymnodinium	240	-	+	32 643	240	120	240
G. spp.	240	-	+	32 643	240	120	240
Prorocentrum	600	40	-	-	-	-	-
P. ovalis	600	40	-	-	-	-	-
Unidentified	480	200	800	+	200	120	200

Table 16. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 1 May 1981.

Sea ice thickness (cm)			145				
	Ice core (cm)				Seawater depth (m)		
Sample type	Top 0-48	Middle 48-96	Bottom 96-145	Bottom 140-145	0	10	40
Total sea ice microalgae or phytoplankton (cells/litre)	92 240	106 240	186 600	2 038 374	11 160	8 920	10 600
Bacillariophyta	84 560	99 200	153 300	1 864 278	4 160	3 160	3 800
Centrales	10 480	7 360	5 100	105 183	2 040	2 280	1 680
Chaetoceros	6 320	1 600	1 500	94 302	1 720	2 040	1 480
C. atlanticus	240	-	-	-	-	-	-
C. compressus	480	-	-	-	-	-	-
C. furcellatus	720	80	300	+	1 360	880	840
C. karianus	1 360	960	100	21 762	240	360	520
C. septentrionalis	2 880	480	800	47 151	120	600	120
C. spp.	640	80	300	25 389	-	200	-
Coscinodiscus	880	560	1 200	3 627	-	-	-
C. lacustris var. *septentrionalis*	720	560	1 200	3 627	-	-	-
C. spp.	160	-	-	-	-	-	-
Thalassiosira	2 080	2 800	900	+	40	-	-
T. nordenskioldii	1 840	1 920	900	+	40	-	-
T. oestrupii	240	640	-	-	-	-	-
T. spp.	-	240	-	-	-	-	-
Unidentified	1 200	2 400	1 500	7 254	280	240	200
Pennales	74 080	91 840	148 200	1 759 095	2 120	880	2 120
Achnanthes	5 120	4 560	9 400	+	-	-	-
A. taeniata	5 120	4 560	9 400	+	-	-	-
Amphiprora	640	7 280	12 100	83 421	-	-	-
A. concilians	400	80	900	10 881	-	-	-
A. gigantea var. *septentrionalis*	240	3 920	7 400	36 270	-	-	-

Table 16. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-48	Middle 48-96	Bottom 96-145	Bottom 140-145	0	10	40
A. kjellmanii var. kariana	-	2 640	2 700	14 508	-	-	-
A. kryophila	-	640	1 100	21 762	-	-	-
Amphora	1 440	800	2 300	43 524	-	-	-
A. exsecta	1 440	800	2 100	29 016	-	-	-
A. laevis var. laevissima	-	-	200	14 508	-	-	-
Caloneis	-	-	100	+	-	-	-
C. kryophila	-	-	100	+	-	-	-
Cocconeis	1 120	-	500	3 627	200	320	1 000
C. costata	1 040	-	500	3 627	200	320	960
C. scutellum	80	-	-	-	-	-	40
Cylindrotheca	2 640	1 920	9 700	79 794	120	-	-
C. closterium	2 640	1 920	9 700	79 794	120	-	-
Diploneis	4 880	7 600	6 300	43 524	-	40	-
D. lineata	-	160	-	-	-	-	-
D. litoralis var. arctica	2 960	3 520	3 900	14 508	-	40	-
D. litoralis var. clathrata	1 920	3 920	2 400	29 016	-	-	-
Gomphonema	-	320	-	-	80	-	-
G. exiguum	-	80	-	-	80	-	-
G. exiguum var. pachycladum	-	240	-	-	-	-	-
Licmophora	430	160	100	+	-	-	-
L. gracilis var. anglica	480	160	100	+	-	-	-
Navicula	4 560	3 120	17 500	275 652	200	-	120
N. algida	240	80	300	10 881	-	-	-
N. crucigeroides	-	-	500	+	-	-	-
N. digitoradiata	80	80	+	3 627	-	-	-
N. directa	480	640	4 800	126 945	-	-	-
N. gelida	320	320	2 900	32 643	-	-	40
N. oestrupi	-	-	200	+	-	-	-
N. recurvata	-	-	-	7 254	-	-	-
N. transitans	960	320	3 200	29 016	40	-	-

Table 16. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-48	Middle 48-96	Bottom 96-145	Bottom 140-145	0	10	40
N. transitans var. *incudiformis*	1 680	160	1 300	3 627	-	-	-
N. trigonocephala	80	-	100	+	-	-	-
N. trigonocephala var. *depressa*	-	-	+	14 508	-	-	-
N. valida	80	640	2 600	14 508	-	-	40
N. valida var. *minuta*	-	240	500	10 881	-	-	-
N. spp.	640	640	1 100	21 762	160	-	40
Nitzschia	47 520	63 520	81 300	1 164 267	1 040	520	840
N. acicularis	-	-	400	+	-	-	-
N. brebissonii var. *borealis*	160	-	600	18 135	-	-	-
N. cylindrus	800	560	-	-	-	-	-
N. diaphana	-	80	-	-	-	-	-
N. distans var. *erratica*	-	160	1 700	10 881	-	-	-
N. frigida	21 600	26 880	25 600	620 217	400	320	160
N. grunowii	21 280	32 640	37 200	268 398	640	-	560
N. hybrida	560	240	+	10 881	-	-	-
N. laevissima	-	-	1 500	32 643	-	-	-
N. longissima	-	-	100	+	-	-	-
N. polaris	-	-	+	3 627	-	-	-
N. tergestina	2 560	1 520	10 900	174 096	-	-	-
N. spp.	560	1 440	3 300	25 389	-	200	120
Pinnularia	1 200	880	1 100	3 627	120	-	-
P. quadratarea	800	560	300	+	-	-	-
P. quadratarea var. *bicontracta*	80	80	600	3 627	120	-	-
P. quadratarea var. *bicuneata*	-	80	-	-	-	-	-
P. quadratarea var. *constricta*	320	160	200	+	-	-	-
Pleurosigma	400	80	2 200	18 135	-	-	-
P. antarcticum	160	-	900	10 881	-	-	-
P. clevei	-	-	200	3 627	-	-	-
P. elongatum var. *kariana*	240	80	1 100	3 527	-	-	-

Table 16. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-48	Middle 48-96	Bottom 96-145	Bottom 140-145	0	10	40
Stauroneis	640	-	200	7 254	-	-	-
S. quadripedis	640	-	200	7 254	-	-	-
Stenoneis	400	80	500	+	-	-	-
S. inconspicua var. baculus	400	80	500	+	-	-	-
Synedra	400	400	1 400	18 135	-	-	-
S. pulchella	80	80	700	+	-	-	-
S. tabulata	320	320	700	14 508	-	-	-
S. tabulata var. fasciculata	-	-	+	3 627	-	-	-
Tabellaria	400	-	-	-	-	-	40
T. fenestrata	-	-	-	-	-	-	40
T. flocculosa	400	-	-	-	-	-	-
Unidentified	2 240	1 120	3 600	18 135	360	-	120
Chlorophyta	5 200	6 320	30 400	174 096	6 440	5 360	6 280
Unidentified green filaments	-	-	-	-	40	-	40
Unidentified green flagellates	5 200	6 320	30 400	174 096	6 400	5 360	6 240
Chrysophyta	-	-	300	+	120	120	80
Dinobryon	-	-	300	+	-	-	-
D. balticum	-	-	300	+	-	-	-
Unidentified	-	-	-	-	120	120	80
Cyanophyta	1 040	160	-	-	-	-	-
Unidentified Cyanophyceae	1 040	160	-	-	-	-	-
Euglenophyta	1 280	320	1 100	+	240	120	320
Euglena	1 280	320	1 100	+	240	120	320
E. proxima	240	80	-	+	-	-	-
E. spp.	1 040	240	1 100	+	240	120	320

Table 16. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-48	Middle 48-96	Bottom 96-145	Bottom 140-145	0	10	40
Pyrrophyta	160	240	1 400	+	200	160	120
Gymnodinium	-	-	1 400	+	-	-	120
G. spp.	-	-	1 400	+	-	-	120
Unidentified	160	240	-	-	200	160	-

Table 17. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 27 May 1981.

Sea ice thickness (cm)	148						
	Ice core (cm)				Seawater depth (m)		
Sample type	Top 0-49	Middle 49-98	Bottom 98-148	Bottom 143-148	0	10	40
Total sea ice microalgae or phytoplankton (cells/litre)	866 853	631 098	990 171	13 419 900	4 520	4 120	8 920
Bacillariophyta	841 464	602 082	982 917	13 419 900	4 520	4 120	8 920
Centrales	101 556	79 794	72 540	935 766	960	1 640	4 560
Biddulphia	+	-	-	-	-	+	-
B. aurita	+	-	-	-	-	+	-
Chaetoceros	3 627	3 627	-	14 508	+	80	120
C. furcellatus	-	-	-	-	-	-	40
C. spp.	3 627	3 627	-	14 508	+	80	80
Coscinodiscus	3 627	3 627	14 508	94 302	-	+	40
C. lacustris	-	3 627	7 254	90 675	-	-	+
C. spp.	3 627	+	7 254	3 627	-	+	40
Melosira	7 254	10 881	-	-	-	-	-
M. spp.	7 254	10 881	-	-	-	-	-
Thalassiosira	21 762	18 135	36 270	+	+	+	+
T. aestivalis	+	+	-	+	+	+	+
T. baltica	-	-	+	-	-	-	-
T. kryophila	-	-	-	-	-	+	+
T. nordenskioldii	+	+	7 254	-	-	-	+
T. oestrupii	10 881	18 135	29 016	+	+	+	+
T. spp.	10 881	+	-	-	-	-	-
Unidentified	65 286	43 524	21 762	826 956	960	1 560	4 400
Pennales	739 908	522 288	910 377	12 484 134	3 560	2 480	4 360
Achnanthes	-	+	-	+	240	-	+
A. curta	-	-	-	-	-	-	+
A. delicatula	-	-	-	-	120	-	-

Table 17. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-49	Middle 49-98	Bottom 98-148	Bottom 143-148	0	10	40
A. hauckiana	-	+	-	-	80	-	+
A. lemmermannii	-	-	-	+	40	-	+
A. marginulata	-	-	-	-	-	-	+
Amphiprora	14 508	25 389	29 016	221 247	+	-	-
A. concilians	-	-	7 254	177 723	-	-	-
A. gigantea var. *septentrionalis*	-	-	-	+	+	-	-
A. kjellmanii	14 508	+	18 135	-	-	-	-
A. kryophila	-	+	-	-	-	-	-
A. paludosa	-	-	3 627		-	-	-
A. spp.	-	25 389	-	43 524	-	-	-
Amphora	-	-	3 627	192 231	-	40	+
A. coffeaeformis	-	-	3 627	119 691	-	-	+
A. costata	-	-	-	-	-	+	-
A. exigua	-	-	-	-	-	-	+
A. laevis	-	-	-	-	-	40	-
A. laevis var. *laevissima*	-	-	-	58 032	-	-	-
A. terroris	-	-	-	-	-	+	-
A. spp.	-	-	-	14 508	-	-	-
Caloneis	-	+	-	3 627	-	-	-
C. kryophila	-	+	-	3 627	-	-	-
Cocconeis	10 881	3 627	+	10 881	320	320	520
C. californica	-	-	-	-	-	+	+
C. costata	10 881	3 627	-	7 254	280	280	440
C. finnmarchica	-	-	-	-	+	-	+
C. pellucida	-	-	-	-	-	-	+
C. placentula var. *euglypta*	-	-	-	-	+	-	40
C. scutellum	-	+	-	3 627	-	-	40
C. scutellum var. *stauroneiformis*	-	-	+	+	40	40	+
C. thumensis	-	-	+	-	+	+	+

Table 17. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-49	Middle 49-98	Bottom 98-148	Bottom 143-148	0	10	40
Cylindrotheca	50 778	25 389	47 151	997 425	-	-	-
C. closterium	50 778	25 389	47 151	997 425	-	-	-
Diploneis	39 897	3 627	+	14 508	80	-	40
D. contigua	-	-	-	7 254	-	-	-
D. didyma	3 627	-	+	7 254	-	-	-
D. litoralis	7 254	-	+	+	40	-	-
D. litoralis var. arctica	+	+	+	+	+	-	-
D. litoralis var. clathrata	-	3 627	-	+	-	-	-
D. reichardtii var. tschuktschorum	-	-	-	-	40	-	+
D. smithii	-	-	-	-	-	-	40
D. spp.	29 016	-	-	-	-	-	-
Fragilaria	+	-	-	+	+	+	+
F. brevistriata	-	-	-	+	-	-	-
F. construens	-	-	-	-	+	-	-
F. pinnata	+	-	-	+	+	+	+
Gomphonema	3 627	7 254	3 627	43 524	+	+	80
G. aestuarii	-	-	-	-	+	+	40
G. kamtschaticum	-	+	-	+	-	+	-
G. spp.	3 627	7 254	3 627	43 524	-	-	40
Grammatophora	-	-	-	-	-	+	+
G. arcuata	-	-	-	-	-	+	+
Gyrosigma	14 508	7 254	+	243 009	-	-	+
G. glaciale	+	+	+	148 707	-	-	-
G. lineare	-	+	+	94 302	-	-	+
G. spp.	14 508	7 254	-	-	-	-	-
Licmophora	21 762	3 627	3 627	-	-	-	-
L. gracilis var. anglica	21 762	+	-	-	-	-	-
L. spp.	-	3 627	3 627	-	-	-	-
Navicula	32 643	94 302	170 469	3 188 133	320	360	360
N. algida	-	-	3 627	7 254	+	-	-

Table 17. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-49	Middle 49-98	Bottom 98-148	Bottom 143-148	0	10	40
N. avenacea	-	-	-	-	-	-	+
N. brasiliensis	-	-	-	+	-	-	-
N. cancellata var. apiculata	-	-	-	-	40	-	40
N. cancellata var. retusa	-	-	-	+	-	-	-
N. cincta	-	-	-	-	40	-	+
N. cluthensis var. pagophila	-	+	-	-	-	-	-
N. corymbosa	-	-	+	+	-	-	-
N. crassirostris	-	3 627	3 627	174 096	40	-	-
N. creuzburgensis	-	-	-	+	-	-	-
N. crucigeroides	3 627	3 627	7 254	18 135	-	-	-
N. directa	7 254	25 389	54 405	591 201	-	-	+
N. directa var. cuneata	-	-	-	+	-	-	-
N. distans	-	-	-	-	-	+	-
N. forcipata	-	3 627	3 627	3 627	+	-	-
N. gelida	-	18 135	14 508	652 860	-	-	-
N. gelida var. curta	-	-	+	-	-	40	-
N. gracilis	-	-	3 627	25 389	-	40	+
N. imperfecta	-	-	3 627	14 508	-	-	-
N. insociabilis	-	-	-	-	+	-	-
N. kariana	7 254	7 254	14 508	268 398	-	+	-
N. kjellmanii	-	-	-	+	-	-	-
N. kryokonites var. subprotracta	-	3 627	7 254	94 302	-	-	-
N. marina	-	-	3 627	21 762	+	-	-
N. novadecipiens	-	-	-	+	-	-	-
N. peregrina	-	-	-	101 556	+	-	80
N. peregrina var. meniscus	+	3 627	-	87 048	-	-	-
N. placentula	-	+	10 881	221 247	40	80	40
N. pseudoscutiformis	-	-	-	-	+	-	-
N. pseudotenelloides	-	-	7 254	-	-	-	-
N. pygmaea	-	+	+	+	-	+	+
N. radiosa	-	3 627	-	-	-	-	-

Table 17. (Continued)

Sample type	Ice core (cm) Top 0-49	Middle 49-98	Bottom 98-148	Bottom 143-148	Seawater depth (m) 0	10	40
N. rhynchocephala	-	3 627	3 627	18 135	-	-	-
N. solitaria	-	-	-	+	+	-	80
N. superba	-	-	-	29 016	40	-	-
N. transfuga var. *septentrionalis*	-	-	-	3 627	-	-	-
N. transitans	-	7 254	14 508	301 041	40	-	-
N. transitans var. *asymmetrica*	-	+	-	-	-	-	-
N. transitans var. *derasa*	3 627	+	7 254	+	-	-	-
N. transitans var. *incudiformis*	-	+	-	+	-	-	-
N. trigonocephala	-	-	3 627	+	-	-	-
N. trigonocephala var. *contracta*	-	-	-	3 627	-	-	-
N. ulvacea	-	+	-	+	-	-	-
N. valida	-	3 627	-	47 151	-	-	-
N. vulpina	-	-	-	39 897	-	-	-
N. spp.	10 881	7 254	3 627	464 256	80	200	120
Nitzschia	29 016	50 778	130 572	511 407	40	80	80
N. acuminata	-	-	-	-	-	+	-
N. cryophila	-	-	+	-	-	-	-
N. cylindrus	18 135	21 762	43 524	101 556	+	+	40
N. distans	-	-	-	+	-	80	-
N. frustulum var. *perpusilla*	-	-	-	-	-	-	+
N. grunowii	-	-	-	-	-	-	+
N. hybrida	-	3 627	7 254	+	-	-	-
N. lecointei	-	+	3 627	+	-	-	-
N. linearis	-	+	-	+	-	-	-
N. longissima	-	-	-	7 254	-	-	-
N. obtusa	-	-	-	+	-	-	-
N. socialis	-	-	3 627	+	-	-	-
N. spp.	10 881	25 389	72 540	402 597	40	+	40
Pinnularia	14 508	25 389	7 254	351 819	+	40	+

Table 17. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-49	Middle 49-98	Bottom 98-148	Bottom 143-148	0	10	40
P. ambigua	-	-	-	7 254	-	-	-
P. parva	-	-	-	3 627	-	-	-
P. quadratarea	10 881	10 881	3 627	43 524	+	+	-
P. quadratarea var. *bicontracta*	3 627	3 627	3 627	239 382	+	40	+
P. quadratarea var. *capitata*	-	3 627	+	18 135	-	-	-
P. quadratarea var. *constricta*	-	7 254	+	32 643	-	-	+
P. quadratarea var. *cuneata*	-	-	-	7 254	-	-	-
Plagiogramma	-	-	-	+	-	-	+
P. staurophorum	-	-	-	+	-	-	+
Pleurosigma	-	3 627	7 254	210 366	-	-	-
P. antarcticum	-	-	-	+	-	-	-
P. clevei	-	-	+	21 762	-	-	-
P. cuspidatum	-	-	+	-	-	-	-
P. stuxbergii var. *rhomboides*	-	3 627	7 254	188 604	-	-	-
Rhabdonema	-	-	-	-	-	+	-
R. arcuatum	-	-	-	-	-	+	-
Stenoneis	-	-	-	25 389	+	-	-
S. inconspicua	-	-	-	25 389	-	-	-
S. inconspicua var. *baculus*	-	-	-	+	+	-	-
Synedra	3 627	+	3 627	+	+	+	40
S. affinis var. *rostrata*	-	-	-	-	-	-	+
S. pulchella	-	-	-	+	+	-	-
S. tabulata	3 627	+	3 627	-	+	+	40
S. spp.	-	-	+	-	-	-	-
Tabellaria	-	+	-	+	+	+	-
T. fenestrata	-	-	-	-	-	+	-
T. flocculosa	-	+	-	+	+	+	-
Tropidoneis	+	-	+	+	-	-	-
T. vitrea	+	-	+	+	-	-	-
Unidentified	504 153	272 025	504 153	6 470 568	2 560	1 640	3 240

Table 17. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-49	Middle 49-98	Bottom 98-148	Bottom 143-148	0	10	40
Cyanophyta	25 389	29 016	-	-	-	-	-
Unidentified Cyanophyceae	25 389	29 016	-	-	-	-	-
Pyrrophyta	-	-	7 254	-	-	-	-
Gymnodinium	-	-	7 254	-	-	-	-
G. spp.	-	-	7 254	-	-	-	-

Table 18. Quantitative composition and vertical distribution of sea ice microalgae and phytoplankton in the underlying water in Frobisher Bay at Station 1, 19 June 1981.

Sea ice thickness (cm) 137

Sample type	Ice core (cm) Top 0-46	Middle 46-92	Bottom 92-137	Bottom 132-137	Seawater depth (m) 0	10	40
Total sea ice microalgae or phytoplankton (cells/litre)	837 837	863 226	2 488 122	6 488 703	1 958 654	26 880	20 820
Bacillariophyta	837 837	863 226	2 484 495	6 488 703	776 244	17 000	19 540
Centrales	58 032	68 913	250 263	464 256	40 623	3 480	3 840
Chaetoceros	3 627	3 627	155 961	137 826	2 902	360	520
C. furcellatus	3 627	3 627	+	3 627	1 451	+	+
C. spp.	+	+	155 961	134 199	1 451	360	520
Coscinodiscus	-	-	10 881	18 135	1 451	560	600
C. lacustris	-	+	10 881	18 135	1 451	560	480
C. polyacanthus	-	-	+	+	-	-	+
C. spp.	-	+	+	+	-	-	120
Cyclotella	-	-	+	-	+	-	-
C. comta var. oligactis	-	-	+	-	+	-	-
Thalassiosira	14 508	18 135	7 254	+	1 451	520	720
T. aestivalis	+	+	+	+	+	-	+
T. baltica	-	-	+	+	+	-	-
T. bioculatus	+	-	-	-	+	-	-
T. eccentrica	-	-	-	-	-	+	+
T. hyalina	-	-	+	-	-	-	-
T. kryophila	-	+	-	-	-	-	+
T. nordenskioldii	3 627	-	-	+	1 451	120	40
T. oestrupii	10 881	18 135	7 254	+	+	+	+
T. spp.	-	-	-	-	-	520	680
Unidentified	39 897	47 151	76 167	308 295	34 819	1 920	2 000
Pennales	779 805	794 313	2 234 232	6 024 447	735 621	13 520	15 700

Table 18. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-46	Middle 46-92	Bottom 92-137	Bottom 132-137	0	10	40
Achnanthes	+	-	+	+	33 368	120	840
A. clevei	-	-	+	-	13 057	40	120
A. curta	+	-	+	-	+	-	-
A. delicatula	+	-	-	+	13 057	80	-
A. exilis	-	-	-	-	+	-	-
A. groenlandica	-	-	-	-	+	-	-
A. hauckiana	-	-	+	+	7 254	+	200
A. hauckiana var. rostrata	-	-	-	-	+	-	-
A. lemmermannii	-	-	-	-	-	-	40
A. marginulata	-	-	+	-	+	-	-
A. taeniata	-	-	-	+	-	-	480
Amphipleura	-	-	-	-	2 902	-	-
A. rutilans	-	-	-	-	2 902	-	-
Amphiprora	10 881	50 778	36 270	112 437	1 451	-	1 040
A. concilians	+	+	+	18 135	+	-	-
A. gigantea var. septentrionalis	-	-	+	+	1 451	-	-
A. kjellmanii	+	+	+	-	-	-	-
A. kryophila	-	-	+	-	-	-	-
A. spp.	10 881	50 778	36 270	94 302	-	-	1 040
Amphora	+	3 627	21 762	54 405	1 451	120	520
A. coffeaeformis	+	+	10 881	10 881	+	-	40
A. costata	-	-	-	-	-	-	+
A. exigua	-	-	+	-	1 451	80	80
A. holsatica	-	-	-	-	+	-	-
A. laevis	+	3 627	3 627	25 389	-	+	40
A. laevis var. laevissima	-	-	+	-	-	-	-
A. laevissima var. minuta	-	-	-	14 508	-	-	-
A. terroris	-	-	-	-	-	40	40
A. spp.	-	-	7 254	3 627	-	-	320
Caloneis	-	-	-	-	1 451	-	-

Table 18. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-46	Middle 46-92	Bottom 92-137	Bottom 132-137	0	10	40
C. silicula	-	-	-	-	1 451	-	-
Cocconeis	7 254	-	+	3 627	1 451	1 000	1 280
C. californica	-	-	+	-	-	40	40
C. costata	7 254	-	+	3 627	1 451	520	520
C. diminuta	-	-	+	-	-	-	+
C. distans	-	-	-	-	-	-	+
C. interrupta	-	-	-	-	-	+	+
C. pellucida	-	-	-	-	-	+	+
C. placentula var. *euglypta*	-	-	-	-	-	-	+
C. placentula var. *lineata*	-	-	-	-	+	-	-
C. pseudomarginata	-	-	-	-	-	+	+
C. scutellum	+	-	+	+	+	120	80
C. scutellum var. *stauroneiformis*	+	-	+	-	-	+	+
C. thumensis	-	-	-	+	+	320	400
C. spp.	-	-	-	-	-	-	240
Cylindrotheca	32 643	14 508	39 897	32 643	2 902	1 520	880
C. closterium	32 643	14 508	39 897	32 643	2 902	1 520	880
Cymbella	-	-	-	-	1 451	-	-
C. cesatii	-	-	-	-	+	-	-
C. cymbiformis	-	-	-	-	+	-	-
C. parva	-	-	-	-	+	-	-
C. tumida var. *fossilis*	-	-	-	-	+	-	-
C. ventricosa	-	-	-	-	+	-	-
C. spp.	-	-	-	-	1 451	-	-
Diatoma	-	-	-	+	1 451	-	-
D. elongatum	-	-	-	+	1 451	-	-
D. hiemale	-	-	-	-	+	-	-
Diploneis	7 254	58 032	+	101 556	5 803	200	240
D. contigua	-	-	+	-	-	-	-
D. didyma	-	-	+	+	-	-	-

Table 18. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-46	Middle 46-92	Bottom 92-137	Bottom 132-137	0	10	40
D. incurvata	-	-	-	-	+	+	+
D. litoralis	7 254	-	+	+	4 352	+	40
D. litoralis var. *arctica*	+	+	+	+	+	40	40
D. litoralis var. *clathrata*	-	-	-	+	-	+	40
D. marginestriata	-	-	-	-	-	-	+
D. oculata	-	-	-	-	-	-	+
D. parca	-	-	-	-	-	-	+
D. reichardtii var. *tschuktschorum*	-	-	-	-	-	40	-
D. smithii	-	-	-	+	1 451	40	40
D. spp.	-	58 032	-	101 556	-	80	80
Eunotia	-	-	-	-	1 451	-	+
E. arcus	-	-	-	-	+	-	-
E. cristagallii	-	-	-	-	1 451	-	+
E. lunaris	-	-	-	-	+	-	-
E. praerupta	-	-	-	-	+	-	-
Fragilaria	-	-	+	3 627	+	40	200
F. brevistriata	-	-	-	+	+	+	+
F. capucina	-	-	-	-	+	-	-
F. crotonensis	-	-	+	-	-	-	-
F. lapponica	-	-	-	-	-	+	
F. pinnata	-	-	-	-	+	40	200
F. virescens	-	-	+	3 627	+	-	-
F. virescens var. *elliptica*	-	-	-	-	-	+	-
F. virescens var. *subsalina*	-	-	+	-	-	-	-
Fragilariopsis	+	-	-	+	-	-	40
F. nana	+	-	-	+	-	-	40
Frustrulia	-	-	-	-	+	-	+
F. rhomboides var. *saxonica*	-	-	-	-	+	-	+
F. rhomboides var. *saxonica* f. *capitata*	-	-	-	-	+	-	-

Table 18. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-46	Middle 46-92	Bottom 92-137	Bottom 132-137	0	10	40
Gomphonema	+	+	+	10 881	+	880	40
G. aestuarii	-	-	-	-	+	880	40
G. kamtschaticum	+	+	+	10 881	+	-	-
Gyrosigma	3 627	7 254	10 881	29 016	-	40	80
G. acuminatum	-	-	-	-	-	-	+
G. glaciale	+	+	+	+	-	-	-
G. lineare	+	3 627	+	10 881	-	40	80
G. spp.	3 627	3 627	10 881	18 135	-	-	-
Navicula	97 929	195 858	311 922	1 225 926	8 706	1 680	4 160
N. algida	-	+	3 627	+	+	+	200
N. ammophila f. minuta	+	-	3 627	+	-	-	-
N. areschougiana	-	-	+	+	-	-	-
N. aucklandica	-	-	-	3 627	-	-	-
N. avenacea	-	-	+	-	1 451	-	-
N. cancellata	-	-	-	-	+	-	-
N. cancellata var. apiculata	-	-	-	-	-	+	+
N. cancellata var. retusa	-	-	-	-	-	-	+
N. cancellata var. subapiculata	-	-	-	-	+	-	-
N. cari	-	-	-	-	-	40	-
N. cincta	-	-	+	-	+	+	-
N. cincta var. heufleri	+	-	-	-	-	-	-
N. cincta var. leptocephala	-	-	-	-	-	120	-
N. cluthensis var. pagophila	-	-	+	-	+	-	-
N. comoides	+	7 254	-	-	-	-	240
N. crassirostris	-	+	+	54 405	+	120	40
N. creuzburgensis	-	-	-	21 762	-	120	-
N. crucigeroides	+	+	10 881	7 254	-	-	+
N. cryptocephala	-	-	-	+	+	-	-
N. digitoradiata	+	-	-	+	-	-	-
N. directa	7 254	18 135	32 643	152 334	2 902	160	280

Table 18. (Continued)

Sample type	Ice core (cm) Top 0-46	Middle 46-92	Bottom 92-137	Bottom 132-137	Seawater depth (m) 0	10	40
N. distans	-	-	-	-	+	-	+
N. explanata	-	-	-	-	+	-	-
N. forcipata	+	7 254	+	174 096	+	+	40
N. gelida	+	29 016	32 643	+	+	-	280
N. gelida var. curta	-	-	-	10 881	+	-	80
N. glacialis	-	-	-	-	-	+	-
N. gracilis	-	+	3 627	3 627	+	-	80
N. granulata	-	-	+	+	-	-	-
N. gregaria	-	-	-	-	+	-	-
N. hyalosira	-	-	-	50 778	+	-	640
N. imperfecta	-	-	+	+	-	-	+
N. insociabilis	-	-	-	-	+	+	-
N. jamalinensis	-	-	-	-	-	-	+
N. kariana	+	+	7 254	130 572	+	-	120
N. kariana var. detersa	-	-	+	-	-	-	-
N. kjellmanii	-	-	-	+	-	-	320
N. kryokonites	-	3 627	+	-	-	-	-
N. kryokonites var. subprotracta	-	-	18 135	18 135	1 451	-	800
N. longa	-	-	-	-	-	-	+
N. marina	-	-	+	+	+	-	40
N. monilifera	-	-	-	-	+	+	-
N. novadecipiens	-	3 627	+	+	-	40	+
N. obtusa	-	-	+	-	-	-	-
N. palpebralis	-	-	-	-	-	-	+
N. pellucida	-	-	-	+	-	-	-
N. peregrina	3 627	-	+	10 881	-	-	-
N. peregrina var. meniscus	-	+	10 881	76 167	+	+	+
N. placentula	+	3 627	14 508	87 048	+	+	160
N. placentula var. jenisseyensis	-	-	-	-	+	-	-
N. placentula f. lanceolata	-	-	+	10 881	-	-	+
N. pseudotenelloides	-	-	10 881	-	-	-	+

Table 18. (Continued)

Sample type	Ice core (cm) Top 0-46	Middle 46-92	Bottom 92-137	Bottom 132-137	Seawater depth (m) 0	10	40
N. pupula	-	-	-	-	+	-	-
N. pygmaea	+	7 254	+	39 897	+	-	-
N. radiosa	-	-	-	-	+	-	40
N. rhynchocephala	-	-	+	3 627	+	+	-
N. rotaeana	-	-	-	-	+	-	+
N. ruttneri	-	-	-	-	+	+	-
N. salinarum	-	-	-	-	+	-	-
N. solitaria	-	21 762	3 627	3 627	+	-	80
N. subinflata	+	+	3 627	-	+	-	-
N. superba	-	-	+	+	+	+	+
N. transfuga var. *septentrionalis*	-	-	-	+	-	-	-
N. transitans	18 135	36 270	10 881	61 659	+	+	80
N. transitans var. *derasa*	-	+	7 254	+	+	-	+
N. transitans var. *erosa*	-	-	-	+	-	-	-
N. transitans var. *incudiformis*	-	+	+	+	-	-	-
N. trigonocephala	-	+	10 881	7 254	-	-	-
N. trigonocephala var. *depressa*	-	-	-	3 627	-	-	-
N. trigonocephala f. *minor*	-	-	+	-	-	-	-
N. ulvacea	-	-	+	14 508	+	+	-
N. valida	-	-	+	18 135	-	-	+
N. spp.	68 913	58 032	126 945	261 144	2 902	1 080	640
Nedium	+	-	-	+	-	-	-
N. binodis	-	-	-	+	-	-	-
N. iridis var. *ampliatum*	+	-	-	-	-	-	-
Nitzschia	119 691	105 183	496 899	1 276 704	63 837	1 480	1 920
N. angularis	-	-	7 254	+	-	-	-
N. commutata var. *pamirensis*	-	-	-	-	+	-	-
N. cryophila	-	+	+	+	-	-	-
N. cylindrus	32 643	29 016	54 405	90 675	10 156	1 200	1 240
N. denticula	-	-	-	-	-	-	+
N. distans	-	-	+	+	-	-	-
N. frustulum	-	-	+	-	+	-	+
N. frustulum var. *perpusilla*	-	-	-	-	-	-	40

Table 18. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-46	Middle 46-92	Bottom 92-137	Bottom 132-137	0	10	40
N. gelida	-	-	+	+	-	-	-
N. grunowii	-	-	-	-	+	+	120
N. hybrida	3 627	+	3 627	7 254	+	40	+
N. lecointei	-	+	14 508	+	+	40	80
N. linearis	-	-	+	-	-	-	-
N. longissima	47 151	7 254	54 405	47 151	1 451	-	-
N. obtusa	-	+	+	-	+	+	-
N. socialis	+	-	+	+	1 451	-	80
N. socialis var. *kariana*	-	-	-	+	+	-	+
N. vitrea	-	-	-	+	+	-	-
N. spp.	36 270	68 913	362 700	1 131 624	50 779	1 200	360
Pinnularia	7 254	3 627	10 881	58 032	37 721	80	180
P. ambigua	-	-	+	+	-	-	+
P. appendiculata	-	-	-	-	+	-	-
P. divergentissima	-	-	-	-	+	-	-
P. divergentissima var. *subrostrata*	-	-	-	-	+	-	-
P. interrupta	-	-	-	-	+	-	-
P. quadratarea	7 254	+	3 627	29 016	+	-	80
P. quadratarea var. *bicontracta*	+	+	3 627	14 508	+	40	80
P. quadratarea var. *capitata*	-	+	+	3 627	-	-	-
P. quadratarea var. *constricta*	-	+	3 627	10 881	-	40	40
P. quadratarea var. *cuneata*	+	3 627	+	+	+	-	+
P. spp.	-	-	-	-	37 721	-	-
Plagiogramma	-	-	-	-	-	+	-
P. staurophorum	-	-	-	-	-	+	-
Pleurosigma	+	+	3 627	14 508	-	+	-
P. antarcticum	+	-	-	+	-	-	-
P. clevei	-	+	+	+	-	-	-
P. elongatum	-	-	+	-	-	-	-
P. stuxbergii var. *rhomboides*	-	-	3 627	14 508	-	+	-

Table 18. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-46	Middle 46-92	Bottom 92-137	Bottom 132-137	0	10	40
Rhabdonema	-	-	+	-	-	-	+
R. arcuatum	-	-	+	-	-	-	+
Stauroneis	-	-	-	-	2 902	-	-
S. anceps	-	-	-	-	+	-	-
S. gracilis	-	-	-	-	+	-	-
S. prominula	-	-	-	-	2 902	-	-
Stenoneis	-	-	3 627	+	+	40	40
S. inconspicua var. baculus	-	-	3 627	+	+	40	40
Surirella	-	-	+	-	+	-	-
S. ovata	-	-	+	-	+	-	-
Synedra	3 627	-	+	7 254	1 451	80	120
S. acus var. radians	+	-	-	-	-	-	-
S. affinis var. rostrata	-	-	+	-	-	-	-
S. camtschatica	-	-	+	-	-	-	+
S. cyclopum	-	-	-	-	+	-	-
S. hyperborea var. rostellata	-	-	+	-	-	-	-
S. pulchella	3 627	-	+	7 254	+	+	+
S. pulchella var. lanceolata	-	-	-	-	+	-	-
S. tabulata	-	-	+	-	1 451	80	120
S. tabulata var. fasciculata	-	-	-	-	+	-	-
Tabellaria	3 627	-	+	+	15 959	40	+
T. fenestrata	-	-	-	-	-	40	-
T. flocculosa	3 627	-	+	+	15 959	+	+
Tropidoneis	-	+	+	+	+	-	40
T. vitrea	-	+	+	+	+	-	40
Unidentified	486 018	355 446	1 298 466	3 093 831	549 913	5 200	4 080
Chlorophyta	-	-	-	-	1 121 468	9 880	1 280
Carteria	-	-	-	-	1 121 468	9 880	1 280
C. spp.	-	-	-	-	1 121 468	9 880	1 280

Table 18. (Continued)

Sample type	Ice core (cm)				Seawater depth (m)		
	Top 0-46	Middle 46-92	Bottom 92-137	Bottom 132-137	0	10	40
Cyanophyta	-	-	-	-	60 942	-	-
Unidentified Cyanophyceae	-	-	-	-	60 942	-	-
Pyrrophyta	-	-	3 627	-	-	-	-
Gymnodinium	-	-	3 627	-	-	-	-
G. spp.	-	-	3 627	-	-	-	-

THE FAUNA OF THE SEA ICE

E. H. Grainger

INTRODUCTION

From at least the time of publication of Ehrenberg's (1841) and Hooker's (1847) early botanical reports, diatoms have been known to exist in the sea ice, both in the arctic and antarctic. Strong interest in ice plants continued through the rest of the nineteenth century, but it was not until the appearance of Nansen's (1906) observations on ciliates occurring in pools on the surface of the ice of the Arctic Ocean that animals also were recognized as sea ice inhabitants. Nansen concluded that the protozoans were of marine origin, having been frozen into the ice in autumn.

In his 1906 work, Nansen made an interesting reference to an earlier observation of his made in 1882 in East Greenland waters. There he noticed that ice of 30-60 cm in thickness was frequently coloured reddish brown on the under side. This was called "seal-ice" by the sealers because of an apparent preference by the seals for ice of this kind. Nansen recognized the coloured material as diatoms, and suggested the existence of a trophic link between the under-ice diatoms, crustaceans which he stated would be expected to be attracted by the diatoms, and seals, which would feed on the crustaceans. This may have been the first "scientific" statement on the ice-based food chain which, almost exactly 100 years later, we are still far from understanding in a clear and measured way.

It was a long time before the appearance of Usachev's (1949) account of protozoans of the ice floes of the Kara Sea. He listed several ciliates, including Euplotes candata Meunier, E. truncata Meunier, Proboscidium armatum Meunier, Cephalotrichium tonsuratum Meunier, Amphorella vitrea (Brandt) and Difflugia sp.

Several observations followed on the larger and more readily visible ice-associated amphipods of the arctic. MacGinitie (1955) observed large numbers of Apherusa glacialis on the undersides of ice floes on the north coast of Alaska. Barnard (1959) reported Gammaracanthus loricatus as being possibly associated with the lower surface of the sea ice, and Onisimus (given as Pseudalibrotus) nanseni and Gammarus wilkitzki as being positively associated with the ice of the central Arctic Ocean. Also in the Arctic Ocean, unidentified amphipods were observed apparently grazing on the film of organic material which occurs on the bottom and sides of ice floes (English 1961). Small, probably newly produced unidentified amphipods were found by Appolonio (1965) attached in large numbers to the lower surface of the ice of Jones Sound. Appolonio concluded that they were feeding on algae in the ice.

The most diversified list of ice animals up to date was contributed by Horner and Alexander (1972) from the north Alaska coast. It included ciliated, mainly hypotrichs of the genera Euplotes and Stylonchia, and

unidentified heliozoans, nematodes, polychaete larvae, turbellarians and a single small, unnamed copepod. The worms and copepods were described as feeding on ice organisms, as shown by partly digested ice diatoms in their digestive tracts and fecal pellets. Horner (1972) referred to the organisms listed above and mentioned as well Onisimus (as Pseudalibrotus) littoralis, Gammaracanthus loricatus and Gammarus wilkitzki, all amphipods found apparently feeding on the undersurface of the ice on the north Alaska coast. Alexander, Horner and Clasby (1974) repeated the records given above.

Two amphipods, one a new record from the undersurface of the ice, were listed by Green and Steele (1975) from Resolute Bay. The species were Gammarus setosus and Gammaracanthus loricatus. From the same bay, Welch and Kalff (1975) described unidentified amphipods in association with the lower surface of the ice.

Some very detailed information was supplied by Buchanan et al. (1977) on under-ice amphipods from Bridport Inlet, Melville Island. Three species of Onisimus (O. littoralis, O. glacialis and O. nanseni) along with Gammarus setosus and Gammaracanthus loricatus were discussed in relation to the ice surface. Two other amphipods were mentioned, both having doubtful affinity with the ice. They were Gammarus wilkitzki and Apherusa glacialis.

In the antarctic, Hoshiai and Kato (1961) mentioned ciliates in an account of diatoms in sea ice. Records of multi-cellular animals in and associated with the sea ice of the antarctic began with Andriashev's (1968) important account of young polychaetes (Harmothoe and Pionosyllis), unidentified calanoid copepods, cyclopoid and harpacticoid copepods of the genera Oithona, Tisbe, Harpacticus and Dactylopodia, and amphipods Orchomenopsis and Bovallia walkeri.

Fenchel and Lee (1972) found five genera of ciliates in the ice, three of them at least known to be planktonic. Rakusa-Suszezewski (1972) and Whitaker (1977) mentioned amphipods (Pontogeneia, Cheirimedon, Paramoera). Bradford (1978) reviewed Andriashev's findings and referred to unidentified ciliates as well. He also suggested a possible ice association for two species of the euphausiid genus Euphausia.

Considerable knowledge of the ice flora has already been assembled (Horner 1977; Hsiao 1980), and indications given of the potential importance of the ice plants as food source for plankton and fishes. Our knowledge of the animals however has remained rudimentary, regarding their identity and numbers, their possible mobility and interrelationships with the fauna in the water beneath the ice, their food and predators, their origin and their fate when the ice melts in spring. Among the questions which we must try to answer are: what is the importance of

the ice animals in the economy of the sea in winter; what is their dependence upon the ice; and what would be the significance of temporary removal of their ice habitat?

It was against this background that the present study was begun on the ice fauna of Frobisher Bay, in the eastern Canadian arctic, in March of 1979. See Fig. 1.

METHODS

Collections of ice animals were made from above the ice by digging holes 60-90 cm in diameter from the surface down to about 15 cm from the bottom of the ice. Then the remaining ice discs were carefully extracted from the bottom of the holes and retrieved with as little disturbance to their lower surface as possible. The available undisturbed areas of lower ice surface were measured, then the useable parts of the discs were melted, after all ice more than 3 cm from the bottom of the discs had been removed. Only the lower 3 cm of the ice cover was retained for ice animal collection throughout the course of the study. The melted ice and its total content were filtered through nylon mesh (of 73 mμ at the start of the study, later of 10 mμ). Organisms were identified and counted, and reported numerically per m^2 of the ice surface.

At the time the ice was sampled, zooplankton samples were collected from the total water column beneath the ice hole, using 73-mμ mesh nets hauled vertically. Additionally, water was pumped from a few centimetres below the ice and the contained zooplankton retained on a 73-mμ mesh, and use was made as well of a new ice undersurface sampler.

The ice undersurface sampler (Fig. 2) was developed and constructed at the Arctic Biological Station. Lowered through an ice hole, it is subsequently expanded from above into an inverted T-shape, then rotated from the top of the ice to scrape a circular 15-cm path as much as 3.6 m in diameter. The diameter of the circle is adjustable, allowing a series of concentric rings to be scraped. During collecting, the sampler is moved horizontally against the lower surface of the ice and the catch is retained by a 73-mμ mesh.

An approximately 7.6-cm diameter SIPRE ice corer was used to collect ice samples for salinity, nutrient and chlorophyll *a* determinations. Water samples collected for similar measurements were taken with plastic closing samplers. Temperature was measured using calibrated immersion thermometers placed in water samples immediately after they were brought to the surface. Salinity was calculated using a Bissett Berman model 6230 laboratory salinometer or occasionally a Goldberg T/C model 10419 refractometer. Nutrients were analysed following Strickland and Parsons (1968) except for ammonia-nitrogen which was determined following G. Dal Pont *et al*. (1974). For chlorophyll *a* determination, the Jeffrey-Humphrey equations were used (Jeffrey and Humphrey 1975).

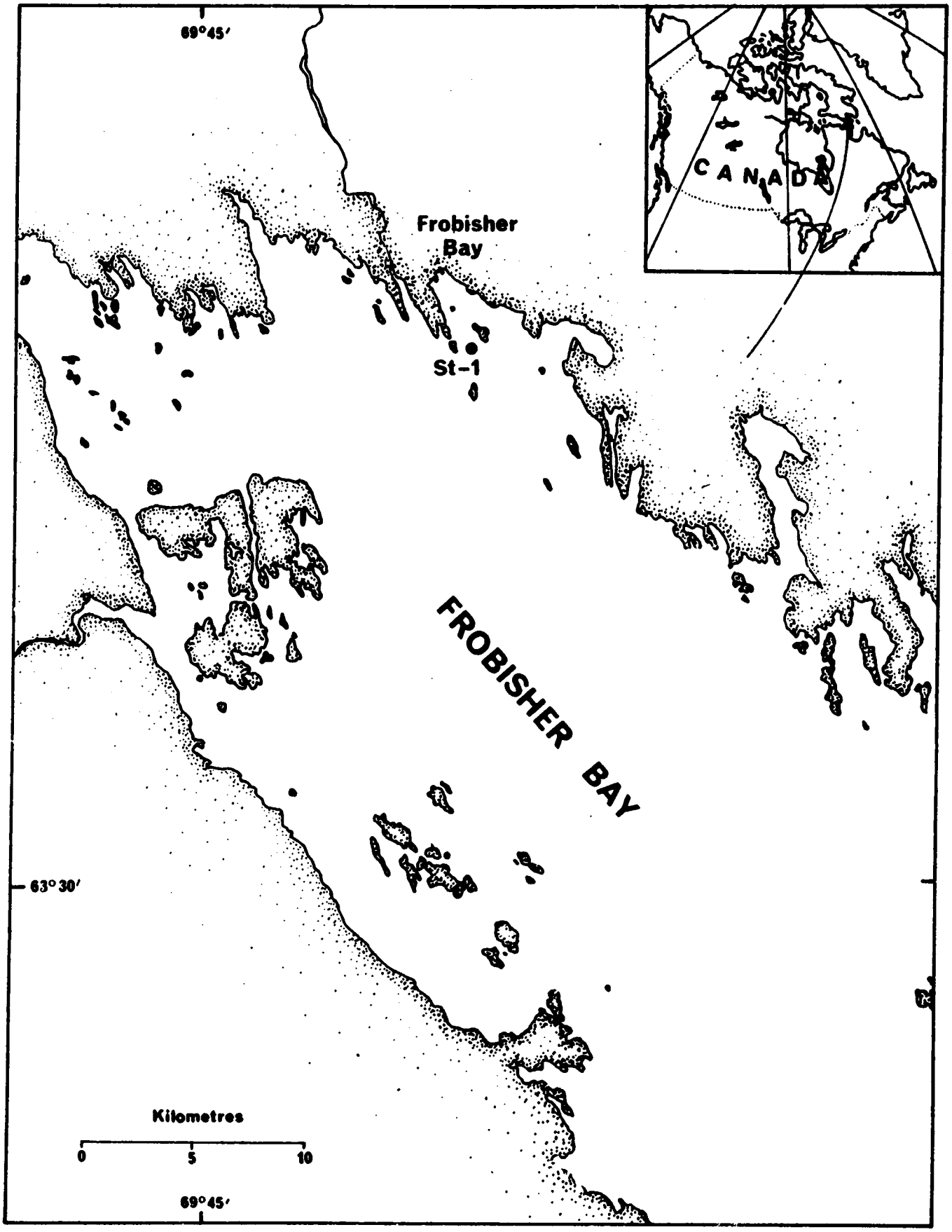

Fig. 1. Map of upper Frobisher Bay.

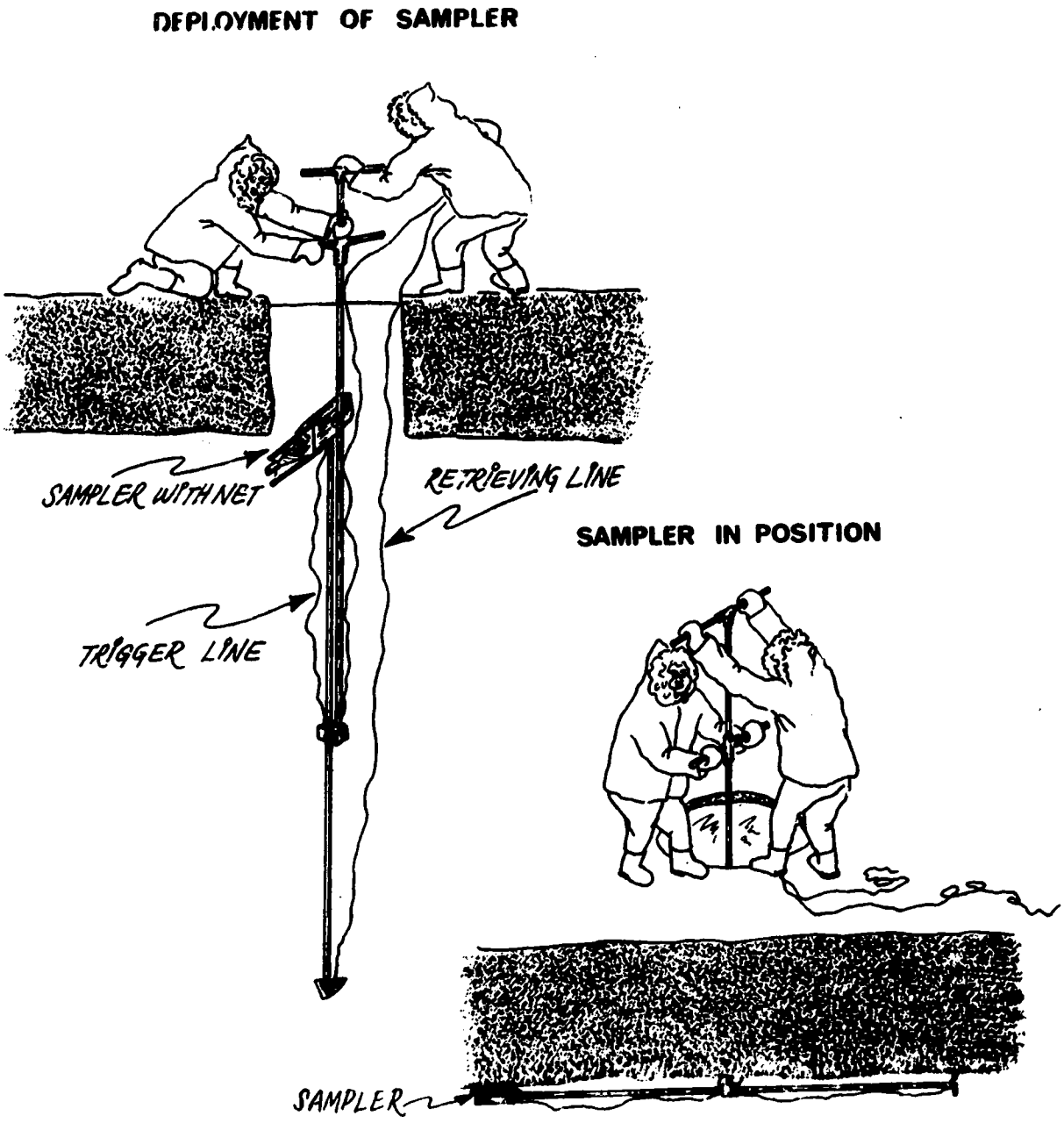

Fig. 2. Ice undersurface sampler.

RESULTS

Physical and chemical data assembled to support the in-ice and under-ice biota collections are given in Tables 1 and 2. Table 1 includes data collected mainly for the assessment of the environment of sea ice plants (see Hsiao, this volume). Of particular relevance to the ice fauna collection here is information on ice and snow thickness, salinity and chlorophyll a. In Table 2, data from three depths in the water column beneath the ice measure some features of the environment occupied by under-ice plankton.

Salinity values at the bottom of the ice were all low in comparison with sea water levels. These low values may be misleading however because they do not necessarily take into account the probable salinity variations within small spatial limits in and between brine channels in the ice. These could not be demonstrated by the "average" values obtained from the relatively large ice samples collected and melted for salinity determinations.

Under-ice water data show the effects of sea ice melting starting in June of each year reported. They also indicate the sometimes great differences in nutrient and chlorophyll content between the water and the sea ice immediately above.

There were representatives of at least 20 animal species collected within the ice at Frobisher Bay (Tables 3 and 4). Ciliates and other protozoans, small nematodes, and larvae of polychaetes, pelecypods, gastropods and tunicates were not identified further. Copepod copepodites were separated to stage within each species, but nauplii were not identified beyond subclass.

Nematodes were the most numerous animals in the ice, with 293250 individuals having been calculated to occupy a square metre of ice surface in the lower 3 cm of ice (which may be expressed as the equivalent of nearly 10^7 nematodes per m^3). Next were copepod nauplii (maximally 90920 per m^2). Other dominant forms included eggs (mainly copepod), polychaete larvae, pelecypod larvae, and the copepods Tisbe furcata and Cyclopina schneideri.

Table 4 also shows numbers of the same forms caught in the water under the ice (expressed as numbers per total column beneath 1 m^2). These do not necessarily include the most abundant water forms, but only those which occurred in the ice as well as in the water. Most numerous were the copepod Pseudocalanus, found as 54530 per m^2 in the water (or as 1330 per m^3, averaged over the whole water column) at a time when none was taken in the ice.

Table 1, Sea ice data, Frobisher Bay, 1979-1981.

Date	Ice (cm)	Snow	Ice sample (cm from top of ice)	Salinity (°/oo)	NO_2-N	NO_3-N	PO_4-P	SiO_3-Si	NH_3-N	Chlor. a (mg m^{-3})
					(ug-at.L^{-1})					
10 Mar 79	154	18	0-5	9.0	0.03	1.54	0.47	4.85	-	0.20
			75-80	2.0	0.10	1.24	0.28	3.71	-	0.20
			149-154		0.18	1.35	0.66	7.60	-	25.08
7 May 79	171	0	0-5	4.12	0.06	0.29	0.19	7.39	-	0.81
			83-88	<2.8	0.00	0.15	0.09	5.11	-	0.59
			166-171	4.17	0.08	1.19	1.45	0.76	-	4.76
16 Jun 79	142	0	0-137	-	0.02	0.75	0.37	2.11	2.64	0.52
			137-142	-	0.04	0.43	0.70	5.07	5.12	1.67
12 Dec 79	62	0	0-20	4.0	0.04	0.77	0.71	10.82	2.87	1.05
			20-41	6.0	0.05	0.77	0.19	2.50	3.57	0.91
			41-62	6.0	0.06	1.64	0.41	3.24	5.55	1.94
12 Mar 80	137	15	0-45	4.77	0.08	0.69	0.27	2.50	4.07	1.06
			45-91	3.71	0.00	0.42	0.15	4.94	1.55	0.21
			91-137	6.33	0.02	1.13	0.49	1.60	2.84	7.06
6 May 80	162	28	0-54	4.89	0.09	0.33	0.08	4.98	3.16	0.38
			54-108	5.09	0.07	0.46	0.05	3.18	3.29	1.04
			108-162	4.02	0.04	0.95	0.20	6.30	2.82	21.97
6 Jun 80	152	5	0-50	<2.8	0.06	0.58	0.07	0.00	1.38	1.23
			50-101	<2.8	0.04	0.36	0.05	0.00	2.14	0.84
			101-152	<2.8	0.05	0.48	0.24	0.00	3.37	1.57
13 Jun 80	158	2	0-53	<2.8	0.03	0.09	0.05	0.00	1.25	0.63
			53-105	<2.8	0.02	0.10	0.07	0.75	2.35	0.83
			105-158	<2.8	0.03	0.07	0.12	0.00	1.35	1.73
20 Jun 80	100	5	0-33	<2.8	0.02	0.21	0.12	0.00	1.98	0.76
			33-66	<2.8	0.01	0.20	0.00	0.00	1.47	0.94
			66-100	<2.8	0.00	0.18	0.12	0.84	1.76	1.63
14 Feb 81	123	8-50	0-41	7.66	0.15	1.17	0.06	5.08	4.00	0.33
			41-82	6.98	0.12	0.49	0.11	3.20	4.63	0.23
			82-123	7.34	0.10	0.53	0.70	4.19	4.91	5.43

Table 1, continued

Date	Ice (cm)	Snow	Ice sample (cm from top of ice)	Salinity (°/₀₀)	NO_2-N	NO_3-N	PO_4-P	SiO_3-Si	NH_3-N	Chlor. a (mg m^{-3})
					(ug-at. L^{-1})					
24 Mar 81	142	12-18	0-47	-	0.03	0.40	0.06	3.06	3.05	0.48
			47-94	-	0.03	0.10	0.11	3.16	2.93	0.42
			94-142	-	0.01	0.28	0.15	0.55	4.12	3.88
1 May 81	145	25-44	0-48	-	0.04	0.31	0.41	0.70	2.25	0.51
			48-96	5.07	0.06	0.31	0.12	0.00	1.27	0.73
			96-145	3.97	0.08	0.76	0.19	0.25	1.95	2.94
27 May 81	148	39	0-49	5.91	0.10	0.30	0.08	0.57	3.13	1.30
			49-98	4.72	0.09	0.00	0.08	0.00	2.50	2.09
			98-148	4.54	0.07	0.19	0.11	0.28	2.42	4.80
19 Jun 81	137	7	0-46	<2.8	0.03	0.33	0.15	1.95	5.12	0.51
			46-92	<2.8	0.05	0.29	0.07	0.00	1.68	1.14
			92-137	<2.8	0.05	0.06	0.19	0.00	1.32	1.94

Table 2, Under-ice, water column data, Frobisher Bay, 1979-1981.

Date	Depth (m)	Temp. (°C)	Salinity (°/₀₀)	NO_2-N	NO_3-N	PO_4-P (ug-at. L^{-1})	SiO_3-Si	NH_3-N	Chlor. a (mg m^{-3})
10 Mar 79	0	-1.4	32.0	0.06	2.81	0.80	15.63	-	0.29
	10	-1.4	33.8	0.06	2.90	1.32	11.92	-	0.20
	40	-	33.0	0.04	2.85	0.71	6.41	-	0.31
4 May 79	0	-1.8	32.52	0.08	1.73	0.75	13.59	-	0.31
	10	-1.8	33.53	0.06	1.51	0.52	6.85	-	0.20
	35	-1.8	33.52	0.06	0.91	0.66	6.74	-	0.29
16 Jun 79	0	-0.1	4.80	0.00	1.54	0.17	15.43	1.40	0.44
	10	-1.6	33.01	0.16	3.57	0.74	6.24	0.33	0.87
	33	-1.6	33.27	0.09	4.20	0.79	16.38	0.91	0.42
11 Dec 79	0	>-1	30.03	0.14	5.30	0.83	11.23	1.52	0.26
	10	>-1	32.64	0.17	6.03	0.88	8.87	3.51	0.95
	24	>-1	33.78	0.15	5.16	0.98	9.76	1.65	1.13
13 Mar 80	0	-1.8	32.56	0.06	6.74	1.03	8.22	0.43	0.12
	10	-1.8	33.34	0.08	6.66	1.11	9.88	0.43	0.09
	40	-1.8	33.70	0.09	6.83	1.11	12.25	0.99	0.28
7 May 80	0	-1.8	31.75	0.09	10.12	1.02	18.53	0.11	0.13
	10	-1.8	33.47	0.18	8.49	1.09	17.77	0.00	0.15
	40	-1.7	33.50	0.09	7.61	0.44	18.34	0.05	0.22
6 Jun 80	0	0.0	17.72	0.08	4.74	0.43	12.54	0.43	0.95
	10	-1.8	33.35	0.10	6.84	0.64	5.24	0.38	1.65
	40	-1.5	33.43	0.14	5.77	0.64	8.76	0.46	-
13 Jun 80	0	-0.5	10.35	0.07	2.64	0.26	10.49	1.11	0.42
	10	-1.5	33.06	0.10	7.19	0.88	9.56	1.13	1.63
	40	-1.5	33.31	0.09	7.40	0.88	8.51	1.30	1.25

Table 2, continued.

Date	Depth (m)	Temp. (°C)	Salinity (°/₀₀)	NO_2-N	NO_3-N	PO_4-P (ug-at. L^{-1})	SiO_3-Si	NH_3-N	Chlor. a (mg m^{-3})
20 Jun 80	0	0.5	<2.8	0.00	0.38	0.02	0.84	0.49	0.36
	10	-1.2	32.98	0.07	6.12	0.83	14.31	0.31	0.58
	40	-1.5	33.19	0.08	7.13	0.95	12.70	0.74	0.75
1 Jul 80	0	5.3	<2.8	0.08	0.33	0.02	10.40	0.24	0.49
	10	-1.1	32.43	0.02	5.88	0.74	12.01	0.13	2.90
	40	-1.3	32.95	0.23	5.93	0.79	13.56	0.56	0.81
14 Feb 81	0	-1.8	-	0.09	4.07	0.77	11.54	2.50	0.19
	10	-1.8	32.28	0.11	4.07	0.87	13.05	1.94	0.17
	42	-1.8	33.39	0.10	4.15	0.94	16.78	2.26	0.19
24 Mar 81	0	-1.8	-	0.05	5.24	0.82	13.05	1.62	0.13
	10	-1.8	-	0.05	5.06	0.86	11.77	1.27	0.16
	40	-1.8	-	0.07	4.65	0.80	9.21	1.62	0.13
1 May 81	0	-1.7	32.88	0.10	7.15	1.03	14.64	0.26	0.20
	10	-1.7	33.34	0.07	6.63	1.03	12.90	0.60	0.28
	40	-1.7	33.37	0.09	7.08	1.03	11.26	0.79	0.12
27 May 81	0	-1.7	32.29	0.09	6.90	1.00	13.77	0.32	0.48
	10	-1.7	33.29	0.09	7.42	1.00	11.66	0.55	0.24
	40	-1.7	33.34	0.10	7.48	1.05	11.96	0.28	0.50
17 Jun 81	0	-0.1	7.52	0.03	1.53	0.31	3.87	1.10	5.43
	10	-0.5	33.15	0.10	7.60	1.04	13.66	0.14	0.09
	40	-0.4	33.29	0.11	7.69	1.11	12.56	2.38	0.29

Table 3. Sea ice fauna, Frobisher Bay, 1979-1980. Numbers per m^2.

	7 May 79	12 Mar 80	6 May 80	21 Jun 80
Ciliates				4
other protozoans				34
Nematodes		168	293250	1032
Polychaete larvae			150	
Rotifers		18	14755	2838
Gastropod Larvae				4
Cyclopina schneideri	54		1257	
VIM			7	
VIF			20	
V			401	
IV			537	
III			238	
II			54	
Cyclopina sp.	15	174	204	
VIF		90	197	
V		12	7	
IV		18		
III		36		
II		18		
Ectinosoma sp. V	15		20	
Harpacticus superflexus		6	137	
VIM			41	
VIF		6	27	
V			41	
IV			7	
III			14	
II			7	
Harpacticus uniremis VIF	46		7	
Monstrilla sp. VIF		6		
Pseudocalanus sp. VIM	8			
Tisbe furcata	62	192	489	
VIM		60	143	
VIF		102	88	
V		6	41	
IV			68	
III		6	122	
II		18	27	
Copepodites (casts)			136[1]	5745[2]
Copepod nauplii (entire)		1032	10941	13175
(casts)				18335
Eggs (mainly copepod)	77	30[3]	2564	71999
Onisimus glacialis	54	108	7	43
Pollen grains				2442

[1] *H. superflexus* (75), *Tisbe* (54), *Ectinosoma* (7)
[2] all *Ectinosoma*
[3] mainly *Cyclopina*

Table 4. Sea ice fauna, Frobisher Bay, 1981. Numbers per m^2.

	14 Feb 81		24 Mar 81		1 May 81		27 May 81		19 Jun 81	
	Ice	Water	Ice	Water	Ice	Water	Ice	Water	Ice	Water
Ciliates	0	0	0	713	720	158	14	0	40	0
other protozoans	520	0	0	0	0	0	0	42	0	0
Nematodes	10560	185	30320	57	20700	70	108800	168	16000	1080
Polychaete larvae	460	1927	110	2542	8040	1584	28	504	0	16800
Rotifers	40	0	240	0	400	114	14	13	460	320
Pelecypod larvae	0	0	0	0	1680	6248	400	12726	20	39760
Gastropod larvae	0	115	0	1148	0	339	14	0	0	1160
Balanus larvae	0	0	0	0	0	154	0	421	20	19440
Acartia longiremis	5	4633	0	4633	IUS[1]	4444	IUS[1]	840	0	0
Cyclopina schneideri	2150	0	1730	57	120	0	56	26	0	300
VIM	0	0	0	0	0	0	0	0	0	16
VIF	0	0	0	0	0	0	0	0	0	16
V	0	0	0	0	0	0	14	13	0	56
IV	5	0	10	0	0	0	0	0	0	28
III	70	0	150	57	120	0	28	0	0	84
II	1790	0	720	0	0	0	14	0	0	100
I	285	0	850	0	0	0	0	13	0	0
Cyclopina sp.	25	0	40	57	680	114	42	13	0	32
VIM	5	0	0	0	0	0	0	0	0	16
VIF	15	0	40	57	680	0	28	0	0	0
V	5	0	0	0	0	0	0	0	0	16
IV	0	0	0	0	0	0	14	0	0	0
III	0	0	0	0	0	114	0	13	0	0
Ectinosoma sp.	0	29	10	0	0	13	0	0	0	76
Harpacticus superflexus	20	12	50	0	IUS[1]	0	84	13	20	76
VIM	0	0	0	0	0	0	14	0	0	16
VIF	20	12	10	0	0	0	14	13	0	44
V	0	0	0	0	0	0	42	0	0	16
IV	0	0	0	0	0	0	0	0	0	0
III	0	0	0	0	0	0	0	0	0	0
II	0	0	40	0	0	0	14	0	0	0
I	0	0	0	0	0	0	0	0	20	0

[1]Ice undersurface sampler

Table 4, continued.

	14 Feb 81		24 Mar 81		1 May 81		27 May 81		19 Jun 81	
	Ice	Water	Ice	Water	Ice	Water	Ice	Water	Ice	Water
Monstrilla sp. VIF	5	0	0	0	0	0	0	0	0	0
Pseudocalanus sp.	0	54530	IUS	43091	0	24200	IUS	6846	0	17360
Tisbe furcata	255	2108	310	1746	120	537	70	68	0	260
VIM	100	312	80	0	0	128	14	42	0	72
VIF	70	312	50	57	0	57	0	0	0	144
V	25	451	70	1066	0	313	56	13	0	16
IV	20	451	81	451	0	0	0	0	0	0
III	10	283	30	115	0	26	0	0	0	0
II	30	242	0	57	120	13	0	13	0	28
I	0	57	0	0	0	0	0	0	0	0
Copepodites (casts)	120[1]	185[1]	70[1]	283[1]	380[1]	2992	2002[2]	391	20[3]	232[4]
Copepod nauplii (entire)	90920	697	26080	1025	4200	1936	800	1302	800	8440
(casts)	2440	0	0	57	0	229	98	0	1600	0
Eggs (mainly copepods)	7040	4305	2720	1886	7880	792	+	3696	60	15080
Onisimus glacialis	60	0	110	0	120	0	IUS	0	0	0
Tunicate larvae	0	451	40	0	0	0	14	25	0	0
Pollen grains	0	0	640	282	120	0	14	0	40	0

[1]mainly *Tisbe*
[2]*H. superflexus* (1862), *Tisbe* (98), *Cyclopina* sp. (42)
[3]all *H. superflexus*
[4]mainly *Harpacticus*

Most ice inhabitants appeared to be generally more concentrated in the ice than in the water (nematodes, polychaete larvae, rotifers, pelecypod larvae (before June), Cyclopina schneideri (until late May), Harpacticus superflexus, Tisbe Furcata (before June), copepod nauplii, Onisimus, pollen grains). A few however were apparently less concentrated in the ice than in the water below, and they include gastropod larvae, Balanus larvae, Acartia longiremis and Pseudocalanus, all quite rare in the ice.

The maximum concentration of animals in the ice was the equivalent of more than 10^7 per m^3. In the water, it was calculated at around 3×10^3 per m^3, assuming equal dispersal throughout the 40-m water column. It is in fact probably less than that, according to available data on vertical distribution of zooplankton at Frobisher under the ice (Grainger 1971).

While all ice forms occurred also in the plankton, evidently not all water inhabitants occupied the ice. The two most abundant species found in the water (Pseudocalanus and Acartia) were especially rare in the ice, as were the less abundant gastropod and Balanus larvae. Table 5 shows several zooplankton species which were not found at all in the ice, including Oncaea borealis, Oithona similis, Metridia longa, Oncaea minuta, Fritillaria borealis, Microsetella, Danielssenia, Parathemisto and others.

DISCUSSION

The ice species are widely distributed zooplankton species generally well known in arctic seas. They represent considerable taxonomic diversity. Some are found in the ice as young animals only, others as adults only and still others in all stages of development. Adaptation to the ice is perhaps shown best by some of the copepods which occur there in all stages from eggs to adult copepodites. The most abundant and possibly successful ice inhabitants reach vastly greater numerical concentrations in the ice than they appear to do at any time in the sea. Others give the appearance of being of accidental occurrence in the ice, being found rarely and often as isolated individuals at times when far greater numbers of the same species swarm in the water below the ice.

There appear to be grounds for dividing ice-associated invertebrates into at least two groups. One comprises those animals which live within the ice where, it seems, they feed and grow, some possibly passing through much or all of their life cycle in the ice. The other group, comprising only a relatively few species, live beneath the ice but in close proximity to it, and they appear to feed on ice inhabitants.

Table 5. Major planktonic forms taken under the ice in Frobisher Bay, 1981

Species	14 Feb 81	24 Mar 81	1 May 81	27 May 81	17 Jun 81
Pseudocalanus sp. (*)	54530	43091	24200	6846	17360
Acartia longiremis (*)	4633	4633	4444	840	0
Copepod eggs *	4305	1886	792	3696	15080
Tisbe furcata *	2120	1746	537	68	260
polychaete larvae *	1927	2542	1584	504	16800
Oncaea borealis	902	779	924	84	228
copepod nauplii *	697	1025	1936	1302	8440
Oithona similis	697	0	114	25	0
tunicate larvae *	451	0	0	25	0
nematodes *	185	57	70	168	1080
Metridia longa	115	0	0	42	0
gastropod larvae *	115	1148	339	0	1160
Oncaea minuta	115	0	0	13	0
Fritillaria borealis	12	282	0	0	0
Ectinosoma neglectum *	12	0	0	0	76
Microsetella norvegica	29	0	0	0	32
Danielssenia typica	24	0	140	0	0
Parathemisto libellula	12	0	26	0	0
Harpacticus superflexus *	12	0	0	13	76
ciliates *	0	656	158	0	0
Cyclopina schneideri *	0	57	0	26	300
Mertensia ovum	0	29	0	13	0
pelecypod larvae *	0	0	6248	12726	39760
Balanus nauplii *	0	0	154	407	19440
rotifers *	0	0	114	13	320
Zaus abbreviatus	0	0	13	13	16
Sarsia tubulosa	0	0	0	13	44
Dactylopodia signata	0	0	0	13	28

* found in the sea ice as well; (*) very few in the ice

Those of the first group are small as individuals, of the second larger. Some species may spend their earliest days as in-ice animals then, as they grow, become under-ice animals. The amphipod Onisimus glacialis seems to be one of these.

The ice offers a surface, a complex "inverted bottom" kind of surface which may provide a source of food (ice diatoms) and of shelter from predators for animals able to use it. It is impermanent, however, in most localities forming in late autumn, growing in thickness until spring, then disappearing for the summer and early autumn periods. All the ice animals seem to survive well in open northern waters in the total absence of sea ice. Then, during its annual over-winter development in the arctic, certain animals colonize the ice, some with great success and others with less. Other animals adjust their positions in the water in response to the presence of an ice cover, and still others continue as planktonic animals making no apparent response at all to the ice cover and the growing ice community above them.

One almost certain attraction of the ice is the rich diatom growth which developes there. We have only rudimentary knowledge yet of the feeding habits of most of the ice inhabitants. From the literature however we can put together some pertinent information on food and predators of the ice fauna (Table 6).

All of the animal groups in the ice, about which there is available information on feeding habits, are known to feed primarily or exclusively on plant cells. Tunicate larvae and eggs of copepods are non-feeders, and we lack information on the feeding of a few of the rarer ice inhabiting copepods. It may be useful to consider under this heading the species found in the plankton under the ice which are small enough to inhabit the ice but which seem to do so either only rarely or not at all. From Table 5, Oncaea borealis is one of these, and it is a mixed feeder, depending to a large degree, although by no means entirely, on animal food. It does not seem that it can be excluded from the ice solely on the grounds of food. Oithona similis is another. Gauld (1966) suggested that Oithona feeds herbivorously only on large plant cells, and Petipa et al. (1970) that it is a predator on small animals at least during its late copepodite stages. Feeding may be a factor in its apparent exclusion from the ice. Pseudocalanus is a very rare occupant of the ice, but its diet would appear to be suited to ice feeding. Acartia longiremis, also rare in the ice, is a plant feeder in its young stages, but a mixed feeder when older (Petipa et al. 1970).

Depth of water occupied in winter is another condition of possible importance in explaining whether or not a species even comes into contact with the ice. We have only a little information on this, but what we have suggests that most of the species we are concerned with occur at least within the upper 10 m of the water column in Frobisher Bay during the winter. Pseudocalanus was taken at the very bottom of the

Table 6. Arctic ice species, their food and predators

Species	Food	Predators
In-ice species		
Ciliates	as a group:	various
Cephalotrichium tonsuratum	bacteria,	zooplankton,
Euplotes candata	detritus,	including
E. truncata	diatoms, small	copepods,
Proboscidium armatum	flagellates	cladocerans, etc.
Stylonchia		
Amphorella vitrea		
Difflugia		
Heliozoans	bacteria, diatoms, protozoans, rotifers, nematodes	
Nematodes	bacteria, diatoms,	larger nematodes
Theristus sp.	small metazoans, detritus	
Turbellarians	small metazoans	
Annelids		
polychaete larvae	diatoms	copepods, medusae
Mollusca		
pelecypod larvae	diatoms	ctenophores, medusae
gastropod larvae	diatoms	decapods, medusae
Rotifers	tiny organic	
Encentrum	particles,	
Notholca	protozoans, plant cells, rotifers	
Cirripedes		
Balanus larvae	plant cells	copepods, medusae, amphipods, centophores, chaetognaths, fishes
Copepods		
Acartia longiremis (Lilljeborg)	plants copepods	copepods, medusae, ctenophores, fishes
Cyclopina gracilis Claus		
C. schneideri Scott		
Ectinosoma		
Harpacticus superflexus Willey	diatoms, bacteria	fishes
H. uniremis Krøyer	ditto	ditto
Monstrilla		
Tisbe furcata (Baird)	plants, fish larvae	fishes
nauplii	plants	copepods, mysids, medusae, fishes, chaetognaths

Table 6, continued.

Species	Food	Predators
Amphipods		
Onisimus glacialis	plants	fishes, seals, birds
Copelata larvae	usually non-feeding	barnacles
Under-ice species		
Amphipods		
Apherusa glacialis	plants	fishes, seals, birds
Gammaracanthus loricatus	amphipods	ditto
Gammarus setosus	plants	fishes, birds
G. wilkitzki	plants	fishes, seals, birds
Onisimus glacialis	plants	ditto
O. litoralis	plants, scavanger	ditto
O. nanseni	plants	seals

ice as well as below it in the water at times when it did not appear within the ice. In May and June of 1981, the copepods Pseudocalanus, Acartia longiremis, Zaus abbreviatus and Dactylopodia signata were collected just beneath the ice by pumping but none of them was found in the ice at the same time. Perhaps significantly, neither Oncaea nor Oithona (species not found at all in the ice in these collections) was taken just beneath the ice, although they were quite plentiful in deeper water.

Some taxonomic groups of animals are commonly considered to be benthic, others planktonic, even though individual representatives of the groups may differ from the majority. Calanoid copepods, for instance, are holoplanktonic as a group, and it may be significant that there are almost no calanoids (except for rare finds of single Pseudocalanus and Acartia) found in the ice. On the other hand, the harpacticoid and cyclopoid copepods are predominantly benthic, and they are also the most successful ice-inhabiting copepods. The larvae of polychaetes, tunicates, gastropods, pelecypods and Balanus all metamorphose into benthic forms at the conclusion of their planktonic stage, hence are naturally surface seeking. In contrast, in addition to the calanoid copepods, the larvaceans and medusae are holoplanktonic animals, and not found under normal circumstances in association with solid surfaces. Members of this group were not found in any significant numbers in the ice.

Size is probably also an important factor in affecting occupation of the sea ice by planktonic animals. Some, including most stages of Metridia and Calanus, all but the smallest Parathemisto libellula, and virtually all Mertensia and Sarsia, for example, are too large for ice occupancy. Fritillaria, with its large and highly fragile "house", is another form not expected to be found as an ice dweller.

The apparent absence of some species from the ice may be accounted for any still other features. All of them, and especially those associated with feeding, vertical distribution and possible solid surface affinities, require additional study.

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CONCLUSION

The arctic sea ice supports a remarkably rich and diversified flora and fauna. In Frobisher Bay alone we have knowledge of 227 species of plants and 18 of animals which occur within the ice. The plants have been found in the ice at a density as great as 4×10^9 cells per m^2, the animals up to 3×10^5 per m^2.

The sea ice is a highly complex environment in which radiant energy and chemical nutrients during part of the year promote vigorous plant growth, and the plants support in turn a sizeable animal production. The relevance of this to the overall biological activity of the upper layers of northern seas is potentially of great importance; we may expect to see it, in practical terms, in the ice-based food chain affecting such indirectly ice-related species as the arctic cod and the ringed seal.

We have by now a good knowledge of the identity and numbers of plants occupying the ice, along with some information on rates of productivity. The sea ice however is a temporary environment, appearing and disappearing annually in most northern seas. We still have only limited knowledge of the fate of plants occupying the ice when it melts in early summer, and we know even less of the origin of the ice flora in early winter. The ice flora is a source of food for ice-inhabiting animals, but we still lack knowledge of specific prey-predator relationships and of nearly all quantitative features of this interaction.

The identity of plant-dwelling animals has been far less closely studied than that of the ice plants, and our knowledge of them is far less extensive. Numbers are less well known and we have no information at all on production rates. So far all the ice-inhabiting animals appear to be planktonic as well, when the ice is present or absent. It appears clear that they occupy the ice directly from the water below and that they return to a planktonic life in the water after ice melts in late spring or early summer. Like the plants, the ice animals tend to develop far denser concentrations in the ice than in the water below it (and, for many, in the water at any time, whether ice is present or not). A large gap in our knowledge concerns the relations between water-inhabiting and ice-inhabiting animals. Some, plentiful in the ice, are few in the water below the ice. Others show different relative distributions. The extent to which different species may move within the ice and between the ice and the water below it is a subject which requires study, as part of an attempt to understand the degree of dependence which different species may have at different times on the ice. Varying degrees of dependence on the ice also are expected in the different animal groups concerned with ice, including those characteristically in the ice, those which appear to exist planktonically but often in close association with the lower surface of the ice, and those occupying a wider range of depth under the ice.

The answers to the problems raised above will have to be sought if we are to make significant progress in understanding the real importance of the ice biota to the northern marine ecosystem as a whole, and particularly if we are to be able to predict the consequences of disruption of normal biological cycles in the ice.