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The coastal edge of the Northeast Water polynya in spring 1993

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Abstract

Multidisciplinary, marine ecological observations were conducted at the shallow water edge of the Northeast Water in June, 1993. Although variable in size and shape, a small polynya was constantly present at Eskimonaes, at the fast-ice edge of Ingolfsfjord. A shallow stratified layer developed at the water surface at negative water and air temperatures—an effect of sea ice melting in cold water early in the season. Nutrients were recorded in considerable quantities, although by mid July NO_3 had become depleted. The chlorophyll and phytoplankton maxima at 8–12 m depth had peak values of 2 mg chl a m^{-3}, typical for Arctic algal blooms. The phytoplankton included over 90 species and was dominated by the *Fragillariopsis* group. Zooplankton was poor in biomass and density, but over 23 taxa were found, with the copepods *Oithona similis* and *Pseudocalanus acuspes* being numerically dominant. Sedimentation was approximately 0.2 g dry weight m^{-2} d^{-1} and suspended matter concentrations ranged from 4 to 19 mg l^{-1}. The benthos was represented by hard bottom forms only, with a surprisingly dense cover of macrophytes. Juvenile sea urchins (*Strongylocentrotus droebachiensis*), brittle stars (*Ophiocten sericeum*) and amphipods were dominant. Higher trophic levels were represented by benthic feeders, such as eiders and walruses. The area observed was more similar to high Arctic fjord ecosystems than to the offshore central Northeast Water polynya.

Keywords: Arctic geology; coastal waters

1. Introduction

The Northeast Water polynya (NEW) has been studied intensively during the last years in the course of expeditions of the research vessels *Ymer*, *Polar Sea* and *Polarstern*. The main effort of these cruises focused on the central part of the polynya and its interactions with adjacent ice-covered waters. However, the coastal part of the polynya has not yet been investigated with regard to marine ecology. In general, Christian X Land, facing the NEW belongs to the least-known areas of Greenland. The geographically nearest region that has been studied is the Jorgen Bronlund Fjord (82°N), from where a number of hydrological and biological observations have been published (Just, 1970; Andersen, 1977; Schiotte, 1988; Bennike, 1991). A similar Greenland marine environment described in detail is the Franz Josef

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Fjord (74°N) (Hoel, 1935; Schellenberg, 1935; Kramp, 1943).

The aim of this coastal marine survey was to describe the shallow water edge of the Northeast Water polynya. Special emphasis was on plankton development for comparison with concurrent shipboard studies.

2. Material and methods

Work was conducted at the mouth of the Ingolfsfjord at Eskimonaes (80°26′N, 15°47′W) from 28 May to 17 June 1993 (Fig. 1). This area is adjacent to the coastal edge of the Northeast Water polynya. The deep entrance to the Ingolf Fjord is connected with the shelf slope through three valleys of 200 m depth (Kattner and Hirche, 1994). All measurements were conducted in a coastal polynya varying in area from 1 to 15 km^2; the size and shape of the polynya varied daily. The open-water area extended northeast

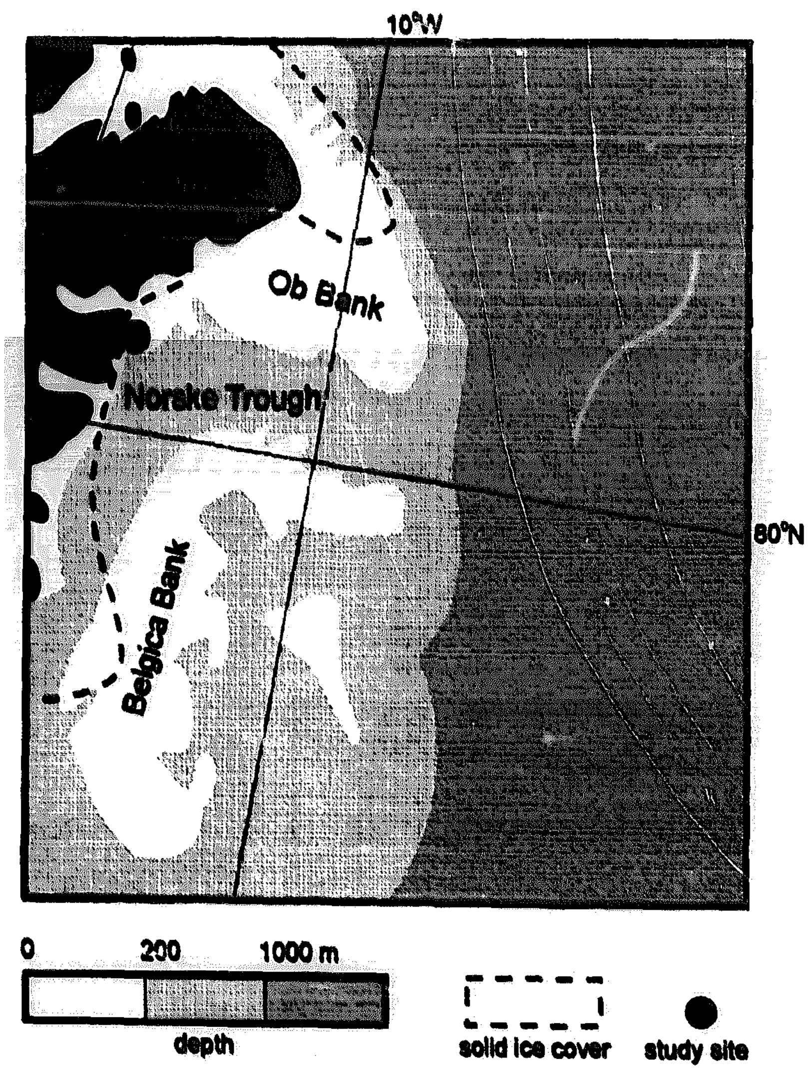

Fig. 1. Study area, land fast ice and isobaths, June 1993.

from the stony–gravel beach to a depth of 35 m. It was a shallow water bank, exposed to strong tidal currents, the bottom of which was covered by stones of different sizes (mainly ice-rafted, rough-edged dropstones) with a slight admixture of red mud at the deepest points.

The main sampling station was established 2 km offshore, on the edge of the fast ice, with a water depth of 30 m. It was visited every third day to sample the water column with a 5 l water cast. Surface to bottom profiles of salinity and temperature were measured using an SD 200 STD mini sonde. Chlorophyll a, nutrients, phytoplankton, and suspensions (POC, total suspended matter) were analysed. Water samples were collected from 6 levels: 100%, 50%, 30%, 15%, 5% and 1% of water transparency, established by Secchi disc readings (formula $LN(100) - LN(Z)/K$, where $K = 1.7$/Secchi disc depth). Samples of phytoplankton were preserved in acidified Lugol solution, chlorophyll a samples were filtered on GF/F Whatman filters. Filters were stored frozen until the end of the experiment and analysed using a Turner Designs fluorometer. Nutrient samples were fixed and analysed in two ways: 50 ml of seawater samples preserved with HgCl were analysed on board after approximately 3 weeks, while a second set of samples, stored frozen at −20°C, was analysed at Laval University. For POC and PON analyses 50–150 ml of water was filtered through precombusted GF/F Whatman filters; readings were taken at the Laval University after the expedition.

Sediment traps (cylinders of 100 × 10 cm) were placed approximately 3–4 m above the sea bed (25 m depth) and were changed every third day. The material from the traps was split for phytoplankton, chlorophyll a, POC and PON analyses, which were carried out using the same methods as for the pelagic samples.

Zooplankton samples were obtained with a WP-2 net (60 cm diameter, 200 μm mesh size), hauled vertically from bottom to surface, and preserved in 4% formalin. Owing to the hard bottom all over the ice-free area, grab samplers were useless. Thus zoobenthos was sampled with a light triangular dredge of 1 mm mesh. Thirty-two dredgings were done. Benthic samples of 5–10 l were sieved through a 0.5 mm screen and stored in 4% formalin. Biomass estimations and length/weight relations were taken from Mullin (1969); Mumm (1993) and our own unpublished data.

Tides were measured using a marked wooden tide-staff in the 'boat harbour'. In total, 126 tide observations were conducted during the 21 days of the study.

Meteorological data were provided by an automatic weather station, installed on Eskimonaes (P. Galbraith, unpubl. data). The weather conditions during our fieldwork were fairly stable, with high pressure (1022 mb), prevailing sunny weather (mean daily radiation 39 mW cm^{-2}), temperatures ranging from -8 to $+2$°C, and light west and east winds.

3. Results

3.1. Sea ice

During the whole period investigated the study area was covered by drifting ice ranging in thickness from 1.4 to 1.8 m. Drifting ice was a mixture of fresh ice (less than 1 m thick) and a variety of 1.5–2 m thick floes. The salinity of the older ice was approximately 0.4 ppt, while that of the 2–10 cm thick ice was 4–5 ppt (Table 1). The stable fjord fast-ice edge was situated northwest of Eskimonaes. Particulate matter showed a patchy distribution and ranged from 3 to 24 mg l^{-1} in old and fresh ice (Table 1). At least three times in June, the open channels between the ice floes froze overnight into 2–4 cm thick ice, which lasted well into the next day, until the wind moved it away. A few large icebergs were anchored in the area, their height above sea level not exceeding 15 m. A number of small melt ponds (in average 10 m in diameter) had been observed on the fast ice since the beginning of the study, most of them connected with cracks in the ice and stranded hummocks. STD profiles show that, despite the low air temperatures, brackish water was present in considerable amounts (Fig. 2; Table 2).

Table 1
Characteristics of sea ice at Eskimonaes

Thickness (cm)	Salinity (ppt)	Organic susp. (mg/l)	Mineral susp. (mg/l)	Organic matter in susp. (%)
2	5	6.2	2.2	74
2	5	2.4	1.4	63
2	5	10.8	3.2	77
10	4	4.4	4.4	50
10	4	9.2	6.8	58
10	5	2.8	8.8	24
10	4	1.2	8.4	13
10	5	1.2	8.4	13
150	0.4	7.6	5.2	59
150	0.4	18.6	5.6	77
150	0.4	5.2	7.6	41

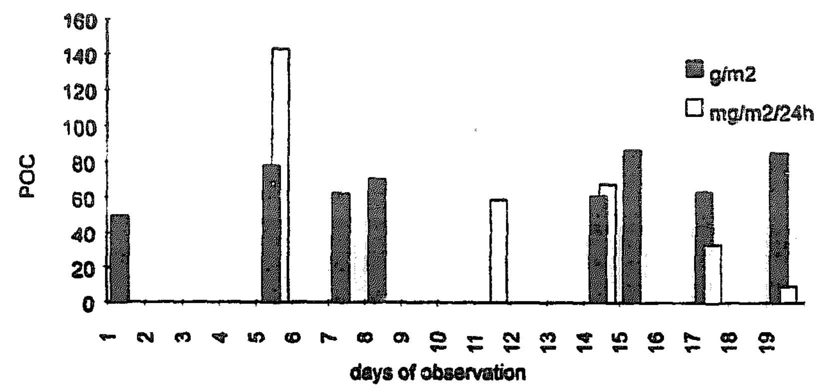

Fig. 2. Particulate organic carbon in sediment traps (light bars) and in suspended matter in the water column (dark bars), values integrated from 6 levels in 0–28 m depth.

3.2. Tides

Extrapolation of the tide observations shows that tides were regular, M2, with a 12.5 h period and 80 cm maximum amplitude. Occasional observations of the drift of ice floes and the zooplankton net indicated that the tidal currents in the study area were strong.

3.3. Hydrography

The water temperature at the main sampling point ranged from -1.6 to -1.15°C, the salinity from 33.0 to 31.8 ppt. A layer of less saline water was present at all times on the surface, regardless of the low air and water temperatures (Fig. 3). Two hydrological periods could be distinguished during the

Table 2
Characteristics of 6 melt ponds

Layer	Thickness (m)	Temperature (°C)	Salinity (ppt)
Upper	0.2–0.3	+1 to +1.5	25–28
Intermediate	0.3–1.8	−1.2 to +1	28–31
Lower	1.2–5	−1.5 to −1.2	31–32

field study. During the first one (31 May to 11 June) the water structure was nearly homogenous. There was no ice melting, or any atmospheric heating of surface waters. The track taken by the less saline water at the main station could have been due to the considerable influence of the stationary iceberg. During the second period (12 to 17 June) surface heating and desalting were observed. The salinity and temperature gradient was more pronounced at the fast-ice edge compared to that at the drifting ice and was probably due to the dynamic mixing at the edge of the pack ice.

3.4. Suspensions, sedimentation and light transmission

Suspended matter concentrations ranged from 0.6 to 5 mg POC dm^{-3}. Integrated over the water column from 0 to 28 m, POC averaged 60 g m^{-2} (Fig. 2). The highest concentrations were found between 4 and 12 m, midway through the observation period. The mineral particle concentrations ranged from 3 to 10 mg l^{-1} (30% of the mean suspended matter). Secchi disc depths ranged from 9 to 12 m, which corresponded to a light transmission of 50% at 3 m depth, 5% at 15–20 m and 1% at 25–30 m. The sedimentation rate at 25 m depth was estimated at ca. 0.2 g dry weight m^{-2} d^{-1} (60 mg POC m^{-2} d^{-1}), which is less than 1% of the suspended matter present in the water column above (Fig. 2).

3.5. Chlorophyll a and nutrients

Chlorophyll maxima (1.3 mg m^{-3} or 29 mg chl a m^{-2}) were found at 12–18 m depth during the

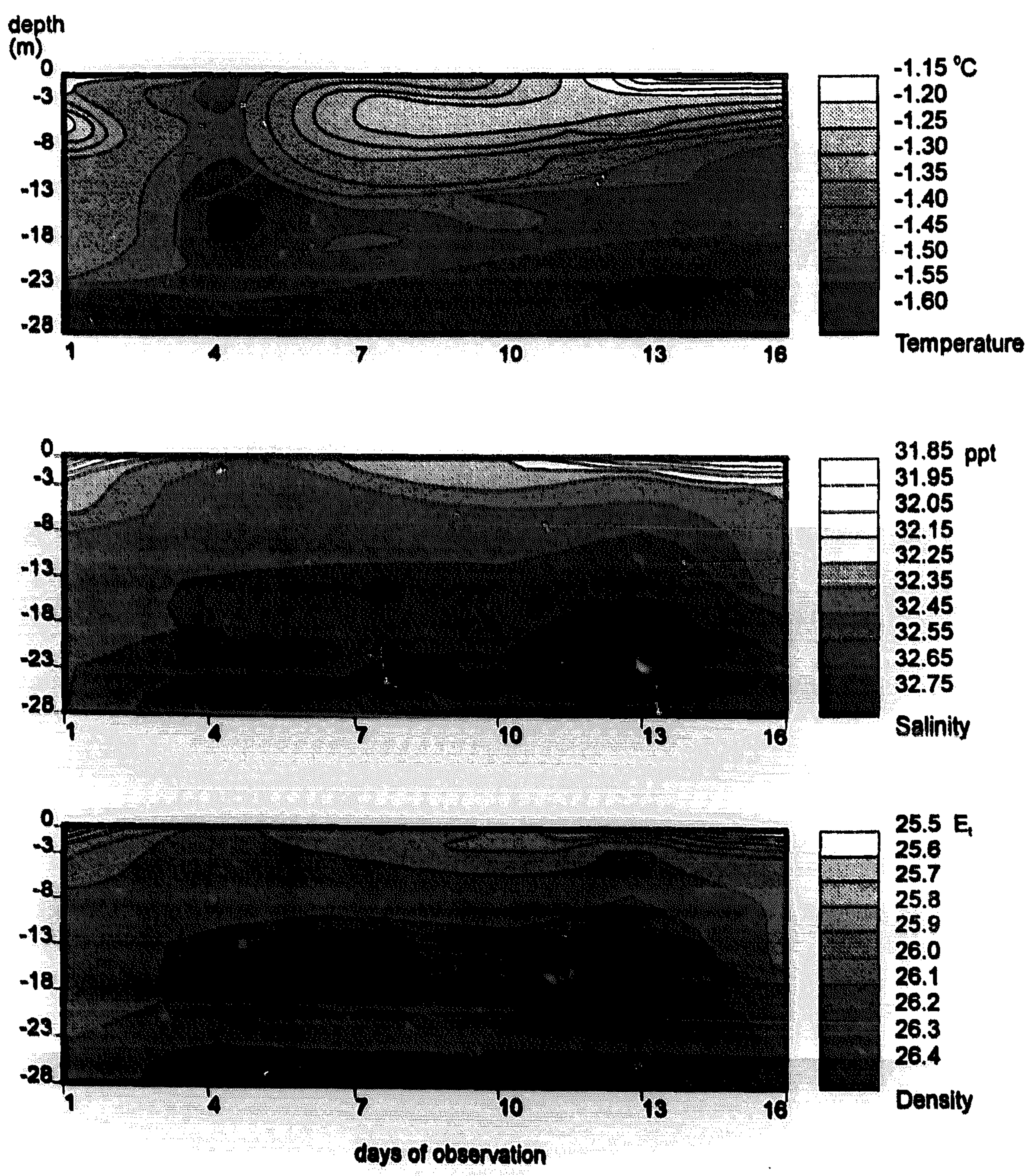

Fig. 3. Changes in temperature, salinity and density profile at main sampling point.

second part of our survey (Fig. 4). Towards the end of the study, chlorophyll concentrations were lowest both at the surface and in the near-bottom water layer (Fig. 4). NO_3–NO_2 and silicates displayed the inverse of the chlorophyll concentrations pattern. The near-bottom layers were richest in nutrients, while the 5–15 m water layer was characterised by a marked reduction in nutrients between 11 and 14 June (Fig. 4). NH_4 concentrations ranged from 0.2 to 0.7 μm dm^{-3} and PO_4 from 0.68 to 0.98 μm dm^{-3}, neither were depleted during the observation period.

3.6. Phytoplankton

At least 81 taxa of phytoplankton were found at the main sampling point (Table 3). The density of phytoplankton varied from 300×10^3 to 5000×10^6 cells m^{-3} (Table 3). Diatoms, mainly *Nitzschia grunovii* and members of the *Fragillariopsis* group, and unidentified flagellates were the dominant components of the phytoplankton, present mainly in the upper 10 m (Fig. 5; Table 3). Dinoflagellates were dominant only at the beginning of the observation

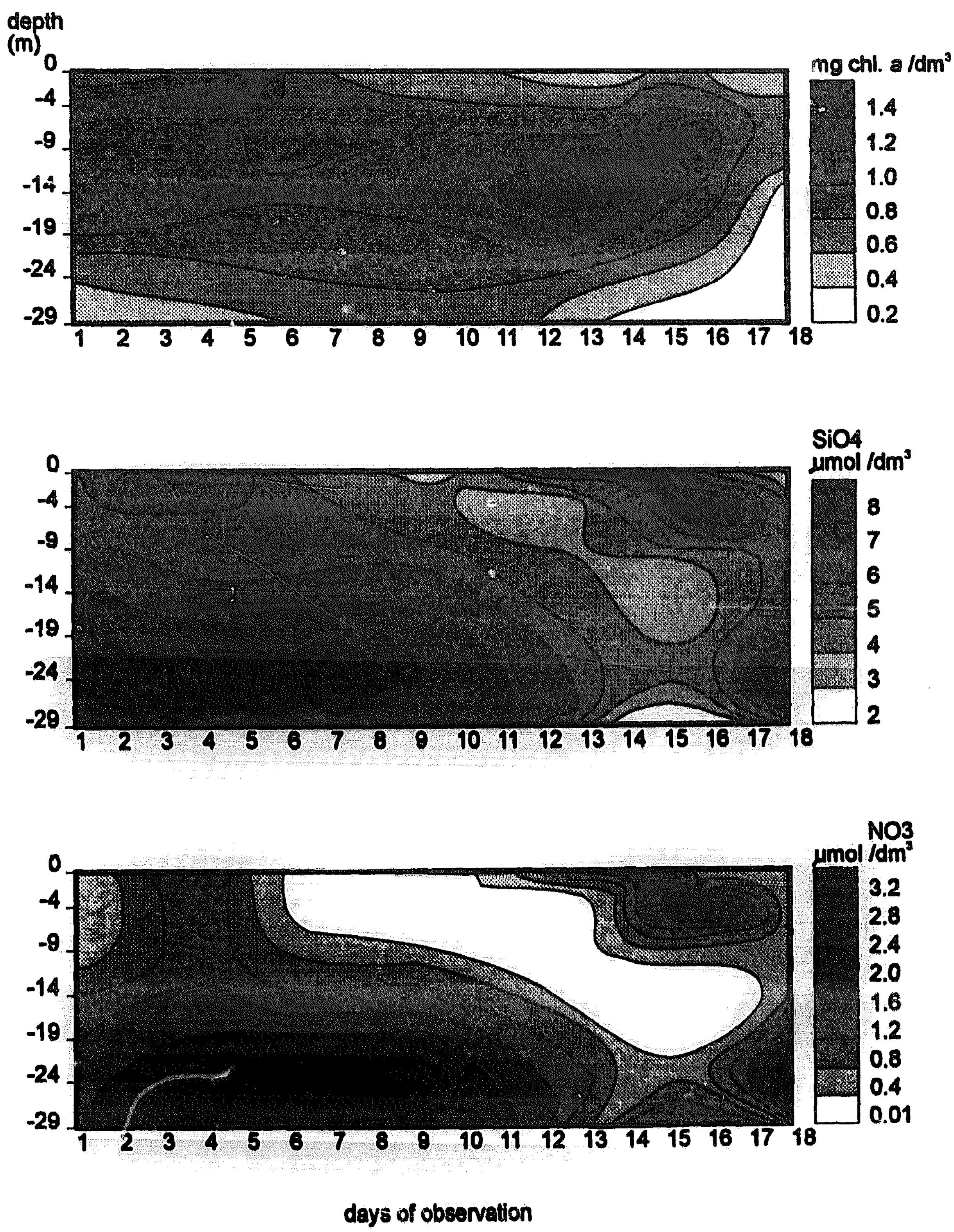

Fig. 4. Changes in chlorophyll, SiO_4 and NO_3 profile at main sampling point.

Table 3
Mean, maximum and minimum abundance (cells × 10^6 m^{-3}) and presence of phytoplankton species in water samples

No	Taxon	Mean	P (%)	Max	Min
1	*Nitzschia grunowii*	974439	100.0	3 189 375.00	17 307.69
2	*Flagellatae* n.d. 3	177703	77.8	1 398 387.10	16 802.33
3	*Thalassiosira* sp.	2930	77.8	15 300.00	340.91
4	*Chaetoceros socialis*	141354	75.0	812 812.50	2 295.92
5	*Nitzschia frigida*	6865	75.0	32 884.62	231.96
6	*Thalassiosira antarctica*	2839	75.0	15 707.55	261.63
7	*Pyramimonas* sp.	235768	63.9	928 928.57	1 384.62
8	*Fragillariopsis* group	33778	63.9	148 020.10	2 743.90
9	*Navicula* spp.	1169	55.6	11 250.00	252.81
10	*Amphiprora hyperborea*	1007	50.0	2 727.27	288.46
11	*Cryptomonas* sp.	309980	44.4	3 187 500.00	900.00
12	*Thalassiosira nordenskioeldii*	14752	44.4	134 418.60	267.86
13	*Chaetoceros* sp.	11410	44.4	68 809.52	304.05
14	*Nitzschia seriata* group	3901	44.4	36 125.00	304.05
15	*Nitzschia delicatissima*	1933	41.7	4 772.73	548.78
16	*Pleurosigma* sp.	634	36.1	1 607.14	261.63
17	*Gymnodinium simplex*	383678	33.3	2 786 785.71	2 195.12
18	*Protoperidinium* spp.	620	33.3	1 849.32	244.57
19	*Nitzschia longissima*	8093	27.8	61 928.57	312.50
20	*Gymnodinium* sp.	5272	27.8	36 396.08	244.57
21	*Gyrodinium* cf. *lachrima*	3269	27.8	29 489.80	271.08
22	*Flagellatae* n.d. 3–7	168728	25.0	438 660.71	12 656.25
23	*Amphidinium scolopax*	2033	25.0	14 744.90	244.57
24	*Leucocryptos marina*	72014	22.2	260 100.00	459.18
25	*Nitzschia promare*	8955	22.2	23 225.81	1 584.51
26	*Nitzschia* sp.	2637	19.4	14 450.00	424.53
27	*Gonioceros simplex*	225186	16.7	505 750.00	12 675.44
28	*Gymnodinium arcticum*	39573	16.7	180 625.00	304.05
29	*Nitzschia* cf. *cylindrus*	20636	16.7	92 628.21	576.92
30	Armoured dinoflagellates n.d.	13249	16.7	38 437.50	523.26
31	*Navicula vanhoffenii*	5344	13.9	10 613.21	1 153.85
32	*Nitzschia cylindrus*	10471	11.1	38 026.32	725.81
33	*Nitzschia cf. seriata* (thin)	3395	11.1	6 000.00	261.63
34	*Pennatae* < 50	509	11.1	692.31	401.79
35	*Dinobryon baltica*	224898	8.3	309 642.86	76 052.63
36	*Phaeocystis pouchetti*	109220	8.3	252 875.00	24 083.33
37	*Cylindrotheca closterium*	9930	8.3	28 900.00	340.91
38	*Nitzschia cf. promare*	7522	8.3	11 010.64	4 846.15
39	*Nitzschia* sp.	5372	8.3	10 800.00	2 343.75
40	*Thalassiosira bioculata*	2197	8.3	3 292.68	523.26
41	*Nitzschia* sp. > 50 μm	2142	8.3	3 068.18	1 264.04
42	*Thalassiosira* cf. *rotula*	940	8.3	1 273.58	681.82
43	*Coscinodiscus* sp.	477	8.3	505.62	424.53
44	*Nitzschia* sp., very small	33769	5.6	36 125.00	31 413.04
45	*Fragillaria* sp.	17419	5.6	19 471.15	15 365.85
46	*Chaetoceros* cf. *pseudocrinitus*	4599	5.6	5 250.00	3 947.37
47	*Peridiniella catenata*	4298	5.6	4 846.15	3 750.00
48	*Thalassiosira* sp., small	1842	5.6	2 500.00	1 184.21
49	*Gyrodinium* sp.	988	5.6	1 630.43	346.15
50	*Eutreptiella* sp.	401	5.6	432.69	368.85
51	*Chaetoceros furcellatus*	385	5.6	394.74	375.00

Table 3 (continued)

No	Taxon	Mean	P (%)	Max	Min
52	*Heterocapsa triquetra*	447262	2.8	447 261.90	447261.9
53	*Pennatae* small	40139	2.8	40 138.89	40 138.89
54	*Navicula* cf. *transitans*	15707	2.8	15 706.52	15 706.52
55	*Nitzschia* cf. *vanhoffenii*	9000	2.8	9 000.00	9 000.00
56	*Melosira* sp.	6223	2.8	6 223.40	6 223.40
57	*Leptocylindrus* sp.	5400	2.8	5 400.00	5 400.00
58	*Nitzschia vanhoffenii*	4375	2.8	4 375.00	4 375.00
59	*Achnanthes taeniata*	2951	2.8	2 950.82	2 950.82
60	*Nitzschia* cf. *vanhoffenii*	2344	2.8	2 343.75	2 343.75
61	*Nitzschia neofrigida*	2045	2.8	2 045.45	2 045.45
62	*Nitzschia seriata*	1705	2.8	1 704.55	1 704.55
63	*Eucampia groenlandica*	1698	2.8	1 698.11	1 698.11
64	*Navicula septentrionalis*	1534	2.8	1 534.09	1 534.09
65	*Gymnodinium*, small	1378	2.8	1 377.55	1 377.55
66	*Pennatae* spp.	1339	2.8	1 339.29	1 339.29
67	*Synedra* sp.	957	2.8	957.45	957.45
68	*Chaetoceros* cf. *holsaticus*	849	2.8	849.06	849.06
69	*Ceratium arcticum*	734	2.8	733.70	733.70
70	*Heterocapsa* cf. *minima*	703	2.8	703.13	703.13
71	*Nitzschia* sp., small	523	2.8	523.26	523.26
72	*Nitzschia longissima*	511	2.8	511.36	511.36
73	*Nitzschia* sp., large	464	2.8	463.92	463.92
74	*Thalassiosira fallax*	375	2.8	375.00	375.00
75	*Amphidinium sphaenoides*	346	2.8	346.15	346.15
76	*Melosira arctica*	346	2.8	346.15	346.15
77	Cysts of *Thalassiosira* sp.	326	2.8	326.09	326.09
78	*Nitzschia* cf. *pseudoseriata*	326	2.8	326.09	326.09
79	*Nitzschia pseudodelicatissima*	313	2.8	312.50	312.50
80	*Protoperidinium* cf. *pellucidum*	308	2.8	308.22	308.22
81	*Amphidinium* sp.	296	2.8	296.05	296.05

period in the intermediate layer (Fig. 5). The numbers of cells decreased during the second half of the observation period, along with a change in species composition. Dinoflagellates, common at the beginning of the observations, were replaced by flagellates. The proportion of the *Fragillariopsis* group decreased during the observations (Fig. 5).

3.7. Zooplankton

Over 23 taxa were identified (Table 4). Copepod nauplii (*Calanus* and *Pseudocalanus*) were predominant, next in abundance were postnaupliar stages of *Oithona similis*, *C. glacialis*, and *P. acuspes*. *Cirripedia* nauplii made up the major component of the non-copepod zooplankton. The larvae of benthic organisms and appendicularians were relatively abundant, but concentrations of zooplankton were low (117–700 ind m^{-3}), as was its biomass (0.07–0.23 g wet weight m^{-3} or 0.3–0.9 g dry weight m^{-2}). A number of *Bosmina corregoni* exoskeletons and the remains of two other freshwater cladocerans were found in half of the samples collected. These were classified as drifted, stray organisms and were not included in the analyses.

3.8. Benthos

Over 94 species of zoobenthos and 11 macrophytes were collected between 1 and 35 m depth (Table 5). Three ecological zones were distinguished for the benthos in the study area. The first is the barren tidal zone covered with large stones and inhabited only by the large amphipod, *Gammarus*

Table 4
Length, weight, mean abundance, biomass and presence of zooplankton species

Taxon	Length (mm)	Weight (mg)	Mean abundance (n/m^3)	Mean biomass (mg/m^3)	Presence (%)
Acartia spp.	1	0.26	3.06	0.79	22
Aeginopsis spp.	5	1.1	0.01	0.01	78
Bivalvia veliger	2	0.46	9.04	4.16	56
C. finmarchicus C3	2	1.00	0.10	0.10	56
C. finmarchicus C4	3	2.00	0.12	0.24	22
C. finmarchicus C5	4	2.54	0.07	0.17	22
C. finmarchicus C6 F	4	4.00	0.04	0.18	22
C. glacialis C2	2	1.00	0.08	0.08	100
C. glacialis C3	3	2.00	2.28	4.56	100
C. glacialis C4	3	2.00	2.76	5.51	44
C. glacialis C5	5	4.50	0.30	1.35	78
C. glacialis C6 F	6	7.80	0.32	2.51	67
C. hyperboreus C3	4	4.00	0.20	0.80	78
C. hyperboreus C4	5	4.00	0.33	1.33	89
C. hyperboreus C5	6	7.80	0.47	3.64	22
C. hyperboreus C6 F	8	12.28	0.04	0.55	22
Calanus glacialis C1	2	1.00	1.80	1.80	44
Cirripedia naupli	1	0.26	70.38	18.30	100
Calanus nauplii	1	0.26	146	37.96	100
Copepoda nauplii	1	0.26	321.00	84	100
Echinodermata lar.	2	0.46	2.86	1.31	67
Eupagurus sp. lar.	6	2.03	0.12	0.25	78
Fritillaria borealis	2	0.46	2.07	0.95	89
Harpacticoida spp.	1	0.26	1.04	0.27	33
Hyperinae spp. juv.	2	0.46	0.01	0.00	44
Isopoda spp.	1	0.26	0.03	0.00	11
Limacina helicina	2	0.46	1.03	0.48	11
Microcalanus spp.	1	0.26	4.83	1.26	100
Oikopleura spp.	2	0.46	1.56	0.72	100
Oithona similis	1	0.26	42.51	11.05	100
Oncea spp.	1	0.26	4.44	1.16	89
P. minutus C3	1	0.26	0.32	0.08	44
P. minutus C4 F	2	0.46	0.22	0.10	56
P. minutus C4 M	2	0.46	0.09	0.04	44
P. minutus C5 F	2	0.46	0.28	0.13	22
P. minutus C5 M	2	0.46	0.06	0.03	100
P. minutus C6 F	2	0.46	1.26	0.58	11
P. minutus C6 M	2	0.46	0.12	0.06	100
P. acuspes C3	1	0.26	0.29	0.08	78
P. acuspes C4 F	2	0.46	0.93	0.43	67
P. acuspes C4 M	2	0.46	0.27	0.12	78
P. acuspes C5 F	2	0.46	1.33	0.61	67
P. acuspes C5 M	2	0.46	0.14	0.07	89
P. acuspes C6 F	2	0.46	4.32	1.99	78
P. acuspes C6 M	2	0.26	3.01	0.78	56
Polychaeta lar.	3	1.98	0.89	1.76	33
Pseudocalanus spp. C1	1	0.26	0.18	0.05	44
Pseudocalanus spp. C2	1	0.26	0.06	0.01	44
Sabinea septemcarinata lar.	8	17.00	0.03	0.57	22
Sagitta elegans	5	1.00	0.72	0.72	78
Themisto libellula juv.	3	1.98	0.09	0.18	11
Abundance (n/m^3)			**634**		
Dry weight (mg/m^3)				**20.3**	
Dry weight (g/m^2)				**0.609**	

setosus. The second was the phytal zone (between 2 and 20 m depth) with a rich laminarian vegetation and a numerous and diverse fauna, dominated by sea urchins, *Strongylocentrotus droebachiensis*. The third zone, below 20 m, was a belt of red algae, *Phycodrys rubens*, on stones with a small admixture of red mud. *Ophiocten sericeum* was a leading species there. Among the dominant species, *S. droebachiensis* and *O. sericeum* were represented by a unimodal group of juvenile specimens (Fig. 6). The other two dominant species—the amphipod crustacean, *Anonyx nugax*, and the gastropod, *Margarites groenlandicus umbilicaris*—were represented by a full range of juvenile to adult specimens (Fig. 6). Traps baited with carrion attracted three other amphipod species not collected in the dredgings, *Anonyx lilljeborgi*, *Onisimus brevicaudatus* and *Tmetonyx cicada*.

The density of the macrophytobentos density was estimated from the boat, during calm weather on six profiles on 75 squares (10 × 10 m) over depths of

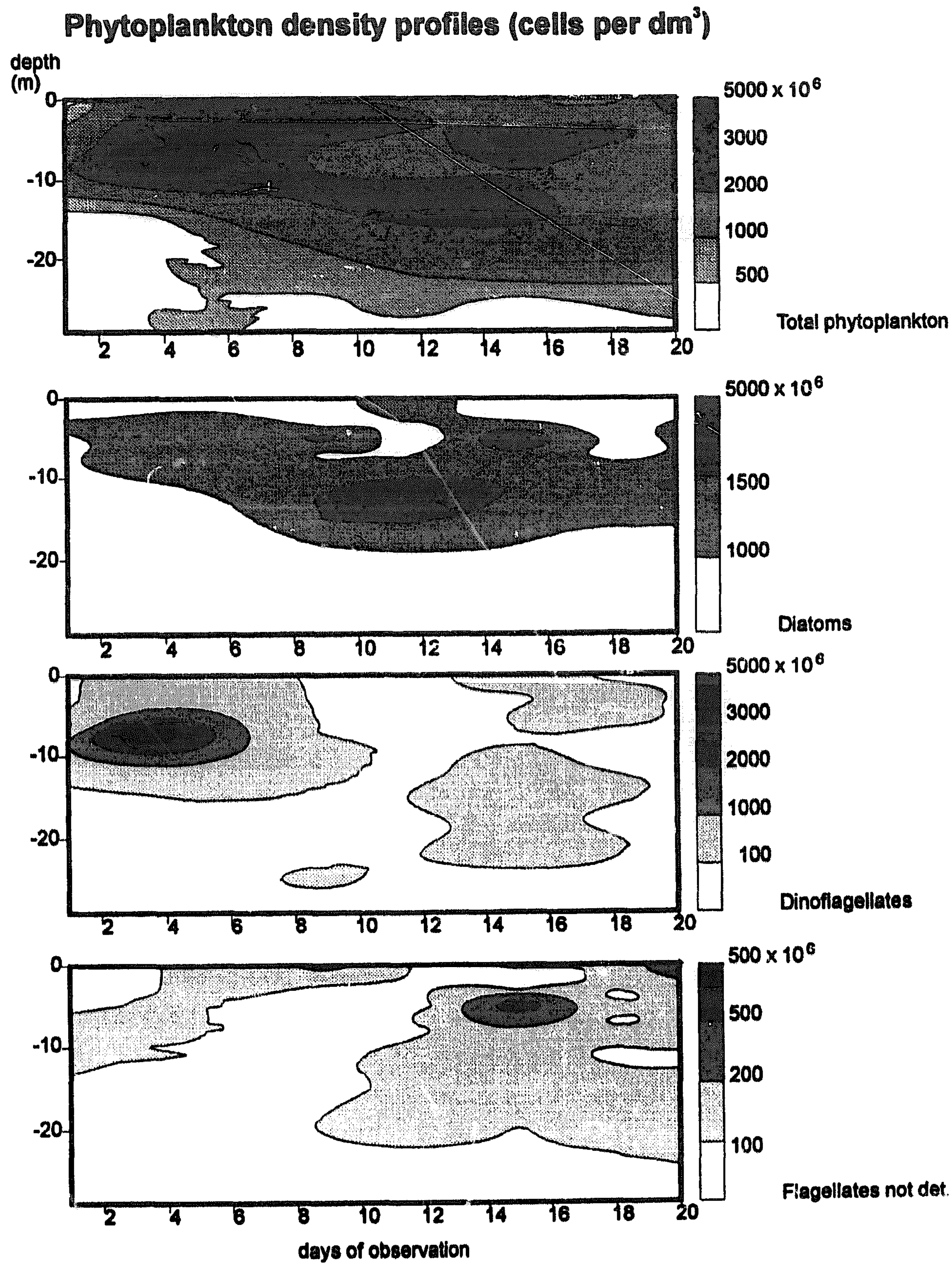

Fig. 5. Phytoplankton density profiles (cells dm^{-3}).

Table 5
Zoobenthos and phytobenthos from dredgings ($n = 32$) and baited traps

	n	P (%)	Occurrence per dredging (%)
Taxon Zoobenthos			
Amphitritinae n.d.	1	3.23	0.03
Anaitides groenlandica	1	3.23	0.03
Anonyx nugax	8	12.90	0.25
Anthozoa n.d.	2	6.45	0.06
Antinoella s. promamme	2	6.45	0.06
Antinoella sarsi sarsi	7	19.35	0.23
Apherusa glacialis	41	19.35	1.32
Apherusa sarsi	123	45.16	3.97
Arctinula groenlandica	41	16.13	1.32
Halocynthia sp.	4	9.68	0.13
Astarte borealis	28	25.81	0.90
Atylus carinatus	1	3.23	0.03
Balanus balanoides	30	22.58	0.97
Brada villosa	1	3.23	0.03
Bryozoa n.d.	0	0.00	0.00
Buccinuum hydrophanum	4	12.90	0.13
Capitella spp.	1	3.23	0.03
Chaetosone setosa	17	12.90	0.55
Ciona sp.	1	3.23	0.03
Cuspidaria subtorta	1	3.23	0.03
Cyclopteropsis macalpini	11	6.45	0.35
Cylichna sp.	1	3.23	0.03
Diastylis scorpionides	24	22.58	0.77
Eualus gaimardi	23	38.71	0.74
Euchone analis	2	6.45	0.06
Euone nodosa	1	3.23	0.03
Eusirus cuspidatus	1	3.23	0.03
Foraminifera n.d.	42	6.45	1.35
Gammarellus homari	1	3.23	0.03
Gammarus setosus	7	6.45	0.23
Gattyana cirrosa	35	25.81	1.13
Haliragesfulvocinctus	21	25.81	0.68
Harmothoe glabra	1	3.23	0.03
Harmothoe imbricata	127	51.61	4.10
Harmothoe impar	13	19.35	0.42
Harmothoe sp.	7	19.35	0.23
Hesionidae n.d.	1	3.23	0.03
Hiatella arctica	9	9.68	0.29
Hydrozoa n.d.	0	0.00	0.00
Laphania boecki	1	3.23	0.03
Lebbeus polaris	15	29.03	0.48
Lepeta caeca	6	19.35	0.19
Lumpenus lampraeteformis (?)	2	6.45	0.06
Macoma calcarea	1	3.23	0.03
Margarites groenlandicus	153	70.97	4.94
Melinna sp.	1	3.23	0.03
Monoculodes borealis	4	12.90	0.13
Munna fabricii	1	3.23	0.03
Mya truncata	2	6.45	0.06
Myriotrochus rinckii	4	6.45	0.13
Mysis oculata	39	25.81	1.26
Neptunea spp.	1	3.23	0.03
Nereimyra aphroditoides	16	22.58	0.52
Nudibranchia n.d.	1	3.23	0.03
Onisimus edwardsi	1	3.23	0.03
Ophelina cylindricaudata	2	6.45	0.06
Ophiocten sericeum	378	54.84	12.19
Ophiolepsis aculeata	15	19.35	0.48
Ophiura robusta	5	16.13	0.16
Ophiura sarsi	0	0.00	0.00
Philomedes brevida	51	22.58	1.65
Pardalisca cuspidata	2	6.45	0.06
Paroediceros lynceus	8	16.13	0.25
Pholoe minuta	1	3.23	0.03
Polynoidae n.d.	1	3.23	0.03
Portlandia arctica	31	9.68	1.00
Praxiella praetermissa	1	3.23	0.03
Rhachotropis aculeata	1	3.23	0.03
Rhachotropis oculata	24	29.03	0.77
Rhynchonella psittacea	2	3.23	0.06
Rozinante fragilis	8	9.68	0.25
Sabellides octocirrata	1	3.23	0.03
Sabinea septemcarinata	19	35.48	0.61
Sphaerodorum gracilis	1	3.23	0.03
Spio filicornis	1	3.23	0.03
Spirontocaris spinus	1	3.23	0.03
Spirontocaris turgida	1	3.23	0.03
Spirorbis granulatus	1	3.23	0.03
Spirorbis sp. 1	2	3.23	0.06
Spirorbis spiryllum	4	12.90	0.13
Stephanasterias albula	12	19.35	0.39
Strongylocentrotus droebachiensis	319	77.42	10.29
Syllis sp.	1	3.23	0.03
Syrrhoe crenulata	67	48.39	2.16
Tanaidacea n.d.	1	3.23	0.03
Terebellides stroemi	1	3.23	0.03
Triglops sp.	1	3.23	0.03
Weyprechtia pinguis	27	22.58	0.87
Total	**1878**		**60.58**
Taxon Phytobenthos			
Hildebrantia prototypus	6		
Laminaria agardhii	35		
Laminaria cucculata	6		
Laminaria intermedia	6		
Litothamnion cf. *compactus*	29		
Litothamnion sp. A	17		
Navicula sp. large colonies	17		
Phycodrys rubens	35		
Pseudolithoderma extensus	12		

Table 5 (continued)

	n	P (%)	Occurrence per dredging (%)
Sphacellaria arctica		12	
Sphacellaria plumosa		6	
Baited traps			
Anonyx lilljeborgi			
Anonyx nugax			
Lyssianassidae sp. A			
Onisimus brevicaudatus			
Onisimus edwardsi			
Tmetonyx cicada			

n = total number of specimens collected, P = presence.

2–10 m. A kelp coverage > 50% was observed on 37% of the squares.

3.9. Higher trophic levels

Minor fish species from the families Lumpenidae and Cottidae were represented by single, juvenile specimens. More common were small Cyclopteridae,

Table 6
Birds and mammals observed at Eskimonaes, June 1993

Taxon	Days	Remarks
Mammals		
Ursus maritimus	4	single animals
Odobaenus rosmarus	20	flocks of 2 to 12 young males, resting and feeding
Phoca hispida	5	single, on ice
Monodon monoceros	1	flock of five at the fast ice edge
Erignathus barbatus	2	single
birds		
Gavia stellata	4	single
Somateria mollissima	19	flocks of 4 to 24 birds
Somateria spectabilis	1	single
Clangula hyamalis	1	single
Branta bernicla	3	three birds
Stercorarius longicaudatus	2	six birds
Fulmarus glacialis	21	several birds each day
Rissa tridactyla	20	groups of 3 to 6 birds
Xema sabini	1	single
Larus hyperboreus	4	single
Pagophila eburnea	20	few birds each day
Uria lomvia	1	single
Sterna paradissea	6	six birds
Cepphus grylle	3	pair and single
Charadrius hiaticula	3	pairs
Plectrophenax nivalis	7	few birds

Days = number of days when animals were observed.

Cyclopterus macalpini (eleven specimens in two samples).

Sixteen bird species and five mammals were observed during our survey (Table 6). Only Common Eiders (*Somateria molissima*), Kittiwakes (*Rissa tridactyla*), Fulmars (*Fulmarus glacialis*) and Ivory Gulls (*Pagophila eburnea*) were sighted daily, al-

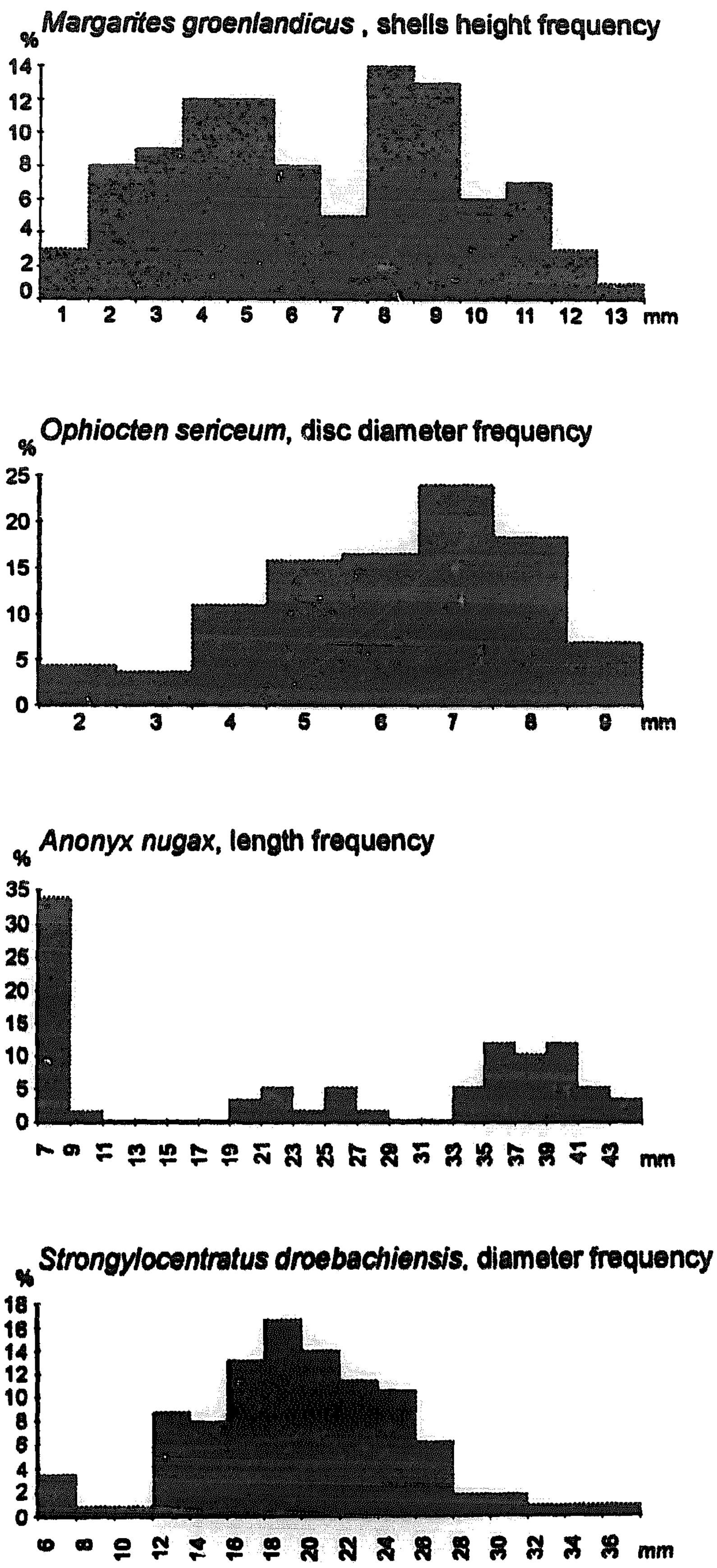

Fig. 6. Length frequency distribution of dominant zoobenthos taxa from Eskimonaes.

Table 7
Composition of excrements of eiders and walruses

	Number of items	Prey size class (mm)
Walruses (500 g excrements)		
Sabinea septemcarinata	16	40–60
Mya truncata	32	40
Anonyx nugax	14	30–35
Buccinuum spp	3	40–?
Ascidiae n.d.	2	45
Polychaeta n.d.	3	?
Gravel	300 g	
Common Eider (100 g excrements)		
Margarites groenlandicus	?	?
Hiatella arctica	?	?
Gammarellus homari	2	20–25
Polychaeta n.d.	1	?
Strongylocentrotus droebachiensis	?	?
Hydrozoa n.d.	?	?
Gravel	10 g	

though never in large numbers. A herd of several walruses (young males?) rested and fed close to the coast throughout June. Analyses of droppings left by Common Eiders and walruses (Table 7) showed gastropods, amphipods and decapods to be important in their diet. All these prey items were also represented in the dredging material.

4. Discussion

4.1. Sea ice

The area studied was situated in the middle of a large, dense, pack-ice aggregation, between two large coastal polynyas, which later fused in the Northeast Water polynya in July (Schneider and Budéus, 1997-this volume). According to satellite data from previous years the Eskimonaes area became ice-free early during the polynya opening (Schneider and Budéus, 1997-this volume). The salinity of fresh, 2–10 cm thin ice was rather low (Table 1), and should be 10–15 ppt (Weslawski et al., 1993). These low values suggest that this sea ice had been formed from the uppermost, desalted, thin water layer.

4.2. Hydrography

Schneider and Budéus (1994) classified the two-layered hydrographic structure of the NEW as formed by Polar Water at the surface (up to 150 m) and Arctic Intermediate Water below. Eskimonaes is situated in an area of low salinity and relatively high surface temperature, as can be seen from horizontal profiling in July (Schneider and Budéus, 1997-this volume). Surface water stratification is commonly regarded as the key factor starting the algal bloom in the Arctic (Rey and Loeng, 1985). Our samples show that the melting of sea ice in cold water was an important component of initial stratification, prior to intensive atmospheric melting. This later phenomenon has been described in detail (Huppert and Josberger, 1980). A desalted surface layer some 3 m thick was observed from the beginning of our observations (Fig. 3). A value of 32.5 ppt was taken as the background salinity in the area (Schneider and Budéus, 1994). The freshwater layer catches most of the atmospheric heat, as was observed in Arctic leads (Golovin et al., 1993). Further south in Franz Josef Fjord (74°N), summer sea surface temperatures may reach 6°C (Jakkhelln, 1936). Our study site was situated in an area where marine surface waters contained a high proportion of freshwater (Schneider and Budéus, 1994). Later, in June, when air temperatures increased, the stagnant water in the fast-ice melt ponds displays a relatively high temperature as a result of intense atmospheric heating. This did not occur in the open-water body at our main sampling point (Fig. 3). Our observations were conducted on relatively deep melt ponds, different from those observed on pack ice by Carstens (1994), who found only very shallow freshwater puddles of different sizes.

4.3. Suspended matter

Bauerfeind et al. (1997-this volume) recorded average sedimentation rates of 0.02 g dry weight m^{-2} d^{-1} at 130 m depth in the central part of the NEW. This is about 10% of the values we observed in coastal waters at 25 m depth. Considering the higher phytoplankton densities found in our samples and the shallower sampling depth, the percentage of sedimenting organic matter at Eskimonaes is similar to that of the central NEW. The amount of suspended matter found in the fast ice of Spitsbergen fjords was similar to the ice at Eskimonaes: the amount of sedimenting matter, however, was nearly 10 times higher in Spitsbergen fjord basins compared with the present data (Weslawski et al., 1993). We believe that resuspension was minimal, since the salinity–density–temperature profiles show a relatively stable near-bottom water layer, except on 13 June (Fig. 3).

4.4. Nutrients

Lara et al. (1994) found abundant silicates and phosphates in the NEW, although the low concentration of nitrates (below 4 μm/l in surface waters) suggested limitations to primary production. Our data show similarly low nutrient concentrations at the chlorophyll concentration peak. Other nutrients are apparently reduced but not depleted in the coastal area of the NEW in May–June. Silicate concentrations at Eskimonaes were at the level of the late July concentrations found in the NEW (Kattner and Budéus, 1997-this volume) or the early bloom situation in Spitsbergen fjords (Weslawski et al., 1988; Eilertsen et al., 1989).

4.5. Phytoplankton

Our results differ from the data obtained by Rey and Loeng (1985) from the ice-covered Barents Sea. There, the main phytoplankton component was *Phaeocystis pouchetti* and *Nitzschia grunovii*. In Spitsbergen fjords *P. pouchetti* and *Chaetoceros socialis* predominated (Eilertsen et al., 1989). In our coastal samples *P. pouchetti* was found only occasionally, despite the presence of this species in NEW open water (Hellum, 1997-this volume, and our own observations from RV *Polarstern*). *N. grunovii* was recorded in concentrations of 6×10^9 cells dm^{-3} in the central NEW and of 9×10^8 cells dm^{-3} in Eskimonaes. The observations from the marginal ice zone north of Svalbard in June (Socal and Wiktor; unpubl. data) showed low cell concentrations (2.7×10^6 cells dm^{-3}) with a high proportion of *Phaeocystis pouchetti*. The lack of *P. pouchetti* in the coastal zone of the NEW was probably due to the relatively high concentration of silicate, which favoured diatoms. The phytoplankton succession north of Svalbard (Socal and Wiktor; unpubl. data) shows the spring-bloom diatoms being replaced by Prymnesiophyceae, minor flagellates and dinoflagellates in the course of June–July. Hellum (1997-this volume) reports over 100 phytoplankton species from the entire NEW area (> 80 found in our samples).

The species composition and abundance of cells found in the NEW in June 1991 are similar to our data (Lara et al., 1994). The main components were *Fragillariopsis spp.* and flagellates, the abundances varying from 0.12×10^6 to 1.71×10^6 cells dm^{-3} (Lara et al., 1994). In July 1993, Legendre et al. (1994) found high concentrations (5×10^3 cells dm^{-3}) of large phytoplankton cells. Our coastal samples resembled the "High biomass" phytoplankton community as determined by Lara et al. (1994). In the central NEW, Gosselin et al. (1994) found an average of 5 mg chlorophyll a m^{-2} in June and 15 mg in July. Our data were close to the highest summer values, which are double the spring values.

4.6. Primary production

An approximate relation between chl a (chlorophyll a) concentrations and primary production could be estimated from the data of Platt et al. (1982) and Legendre et al. (1994), using the conversion PP = chl a/0.025. As a result, the coastal NEW primary production would range from 1000 to 1500 mg C m^{-2} d^{-1} in June 1993. Another indirect method of estimating the primary production is the relation between sedimenting POC and total primary production. Using the equations summarised in Wassman (1990), the primary production estimated from POC sedimented at Eskimonaes in June ranged from 50 to 1000 mg C m^{-2} d^{-1}. One should bear in mind the strong advection component which diminishes the sedimentation rates at our shallow water station, and underestimates the production derived from it. The estimated values place the coastal edge of the NEW among the highly productive Arctic areas; such as southwest Greenland, with 160 g C m^{-2} yr^{-1} or 70–100 g C m^{-2} yr^{-1} (Smidt, 1979; Andersen, 1981), or the Svalbard fjords with 80–120 g C m^{-2} yr^{-1} (Eilertsen et al., 1989). Much lower values were noted in a northern Greenland fjord with 187 mg C m^{-2} d^{-1} (Andersen, 1977). The influence of ice cover on light attenuation is not a factor limiting primary production, since the shade-adapted Arctic algae reported from Baffin Bay were more productive below the 1% light transparency depth, than in the 50% light transmission layer (Subba Rao and Platt, 1984).

4.7. Zooplankton

Hirche et al. (1994) reported a low zooplankton biomass (10 mg dry weight m^{-3}) and extremely low macrozooplankton densities in the NEW area in 1991. These findings were confirmed by data from 1993 (Hirche and Kwasniewski, 1997-this volume) and are within the ranges found in our samples. Typically, herbivore grazing was low and much of the production was advected downstream or sedimented (Hirche et al., 1994; Hirche and Kwasniewski, 1997-this volume). In spring, stray *Calanus finmarchicus*, and copepodite IV *C. glacialis* dominated the NEW zooplankton. Contrary to our own observations, other workers found *Pseudocalanus spp.* to be relatively low in density and species rank in the central part of the NEW (Fortier, 1994; Hirche and Kwasniewski, 1997-this volume).

The zooplankton species composition found at Eskimonaes is similar to the offshore polynya assemblages, with the exception of the minor calanoids and *Cirripedia nauplii* characteristic of Arctic fjord plankton (Koszteyn and Kwasniewski, 1989; Weslawski et al., 1992). A comparably low biomass and species composition is characteristic of the fast-ice, fjordic plankton assemblage observed on Spitsbergen (Weslawski et al., 1993). The most common calanoid in our samples, *Oithona similis* (Table 4), was also numerically dominant in the 0–100 m layer in the offshore polynya (Hirche and Kwasniewski, 1997-this volume).

The striking feature of the study area is the absence of ice-associated fauna reported from all high-Arctic localities (Barnard, 1959; Gulliksen, 1984; Gulliksen and Lonne, 1989; Melnikov, 1989). A possible explanation is the type of ice cover observed—namely the predominance of fjordic fast ice and one-year ice. Ice-associated fauna is not common in this type of ice (Weslawski et al., 1993); however, aggregations of this fauna are typical for the multi-year pack ice (Gulliksen, 1984). Ice fauna were not found in the offshore polynya zooplankton either (Hirche and Kwasniewski, 1997-this volume).

The unusual presence of freshwater cladocerans in our zooplankton samples could be due to land run-off transporting matter from lakes and ponds. Subfossil cladoceran findings have been reported in northeast Greenland by Roen (1988). However, recent populations of *Bosmina* have been found in the freshwaters of the area (Roen, 1962).

4.8. Benthos

Despite the small area sampled and the rather uniform type of sea bed, the species number is suggestive of rich and diversified benthic communities. If we include several unidentified species of bryozoa, hydrozoa and large foraminifera, the benthic fauna of this shallow, hard bottom area may be in excess of 150 species. This number is in the same range as in comparable localities in Svalbard (Weslawski et al., 1992). One of the principal taxonomic groups in the Arctic benthos are the amphipoda. Of these, over 86 species are known from northeast Greenland (Stephensen, 1944), whereas only 28 have been found in the Jorgen Bronlund Fjord at North Greenland (Just, 1970). Our 21 species show that amphipods are well represented in the limited area studied. The dominant benthic species, *S. droebachiensis*, is commonly reported from a number of Arctic localities, and it is an important grazer on macrophytes. The body sizes prevailing in our samples were similar to those of 1–2 year old Alaskan juveniles (Munk and MacIntosh, 1993). The trochid gastropod *Margarites groenlandicus*, one of the most common species in the area, is also a kelp grazer. Thorson (1934) reported different macrophytes from Franz Josef Fjord, dominated by *Desmarestia sp.* The high percentage cover of large macrophytes in relatively shallow water is an unusual phenomenon for the High Arctic. Observations from Franz Josef Land and eastern Svalbard show that large kelps are rare at depths shallower than 20 m, probably because of ice scouring (Weslawski and Zajaczkowski, 1992). The permanent presence of a small polynya in the study area may explain the wealth of macrophytes.

4.9. Higher trophic levels

Cyclopteropsis macalpini, a small benthic fish commonly found in our samples, is a rare species, known from a few localities in northernmost Greenland (Muus et al., 1981). The absence of pelagic feeding birds and seals in the NEW area, as well as the predominance of benthic feeders was noted by

Joiris et al. (1994). This is typical of Arctic ecosystems with a benthic-channelled energy transfer (Petersen, 1990).

5. Conclusions

The coastal edge of the NEW in spring was the site of a small stationary coastal polynya. Early water stratification was caused by the melting of sea ice in cold water; atmospheric heating was less important. Throughout June, recurrent freezing of a thin surface water layer was observed. It was an area where the algal bloom was early and intensive, comparable to the peak values found offshore later in summer. There was an evident lack of specialised ice-associated fauna, the zooplankton was poor in biomass and density and its species represented a neritic assemblage type. This leads to the conclusion that most of the production sinks ungrazed to the bottom: indeed, the relatively high sedimentation rates confirm this. However, strong tidal currents apparently remove much of the sedimenting matter from the coastal area. The benthos was represented mainly by smaller and juvenile forms, which may suggest the importance of the area as a nursery ground. The wealth of macrophyte cover found at Eskimonaes and the abundance of herbivores in the benthos is an unusual phenomenon in high Arctic ice-covered waters. This, as well as the absence of sympagic fauna, place the characteristics of the area studied close to those of other Arctic fjords. Higher trophic levels were represented mainly by benthic feeders (eiders, walruses and minor benthic fishes); seals and pelagic-feeding seabirds were uncommon.

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