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Phytoplankton and suspensions in relation to the freshwater in Arctic coastal marine ecosystems

ABSTRACT: Suspended matter, phytoplankton and light attenuation were investigated in various North East Greenland, Svalbard, and Siberian river mouths in 1992–1994. The amount of mineral suspensions well correlated with freshwater discharge in the case of tidal glacier bays, while such correlation in Siberian rivers and pack ice meltwater was not found. Freshwater phytoplankton species were found in Siberian estuaries only, and in two other ecosystems marine and ice phytoplankton species prevailed. The light attenuation connected with freshwater discharge seems to be a key factor limiting primary production in coastal Arctic waters in the summer. The amount of glacial suspensions well correlated with the salinity drop in the case of Svalbard, while Siberian river estuaries produced very turbid waters with the suspension loads not correlated to freshwater or depth.

Key words: Arctic, brackish waters, phytoplankton.

Introduction

The freshwater balance in the Arctic is one of the key factors regulating the climatic and hydrographic regime of the area. It is an especially vulnerable element of climate fluctuations (Skreslet 1986, Aagard and Carmack 1989). The Siberian rivers are regarded as the main source of freshwater on the scale of the entire Arctic Basin (Aagard and Carmack 1989, Schlosser *et al.* 1994), however

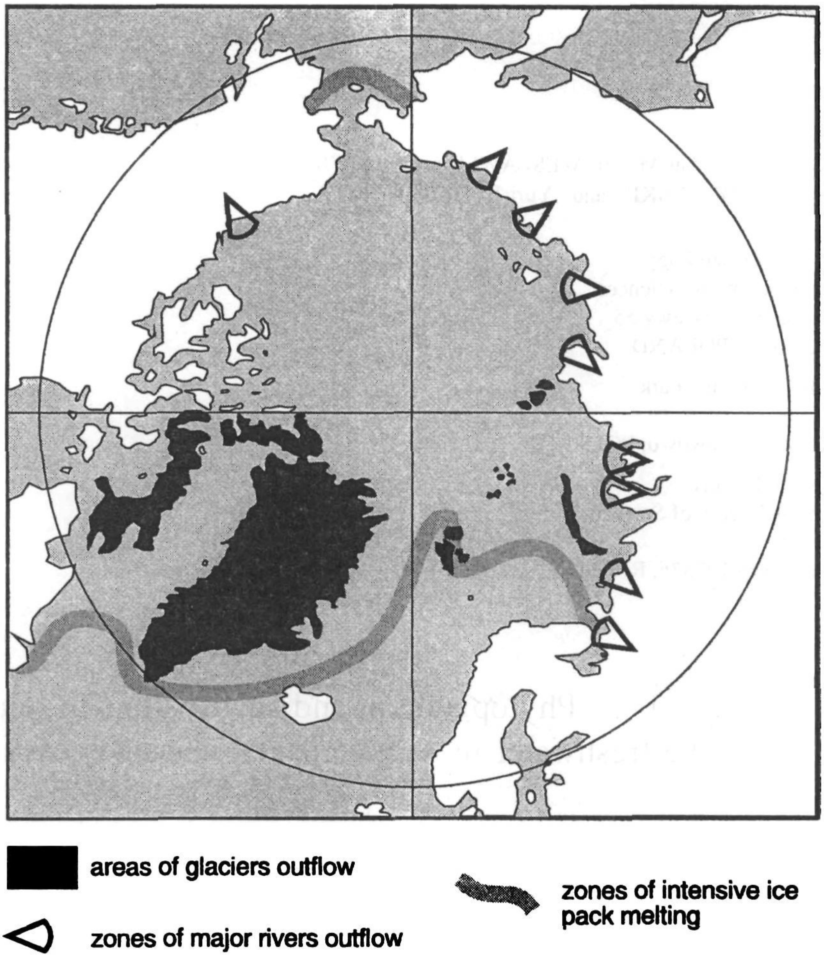


Fig. 1. Major sources of freshwater in the Arctic.

ice pack melt and glacial discharge may contribute significantly to the local freshwater budget (Węsławski *et al.* 1995, AOSB 1996; Fig. 1). Riverine discharge in the Russian Arctic is in the focus of several recent research programmes (SPASIBA, Laptev Sea Project, APARD, ISIRA). We have collected data from the three different regimes of Arctic, brackish and coastal waters. The region is influenced by pack ice (North East Greenland Polynya), by glacial discharge (Svalbard fjords–Kongsfjorden) and by riverine outflow (Barents-Kara Sea, mouth of Pechora and Ob–Yenisey). The problem of freshwater budget in Arctic fjord and its consequences have been presented previously in Węsławski *et al.* (1991a), Węsławski *et al.* (1995) and Beszczyńska-Moller *et al.* (1997). A more general reveiw of the biological consequences of freshwater discharge to the sea is given in Smetaček (1986).

The aim of the present paper is to discuss two hypotheses in light of new material. The working hypotheses for the present study were:

1) Because of its land origin, freshwater volume is positively correlated with the amount of mineral suspensions in Arctic coastal waters. Less saline, sediment-laden brackish waters are limited to surface layers of the sea.

2) Freshwater input decreases biodiversity and productivity of phytoplankton in Arctic ecosystems.

Materials and method

Original material used in the present study was collected during research cruises of the r/v *Oceania* to Svalbard in 1992 (partly presented in Beszczyńska-Moller *et al.* 1997), to NE Greenland on board the r/v *Polarstern* in 1993 (partly presented in Węsławski *et al.* 1997), and to the Barents and Kara seas on board the r/v *Jakov Smirnitsky* in August 1994 (not yet presented). Data are included from 38 stations of suspended matter measurements, and 54 stations with light attenuation measurements, collected in the Pechora, Ob and Yenisey river mouths. The following methods were used during the field work:

1. STD profiling (SD-200 Bergen Sensor Minisonde)
2. Water samples for suspension analysis on 0.45 μm Millipore Filters, data presented in mineral matter weight, after combusting filters in 450 deg C
3. Transmitometer profiling on 660 nm wave length (light attenuation coefficient "c"/m^{-1})
4. Phytoplankton analysis, under an inverted microscope (Utermöhl method). 31 samples were analysed from NE Greenland, 60 samples from Kongsfjorden and Hornsund (Spitsbergen) and 28 samples from Siberian river mouths. The last collection was supplied with materials provided by Botanical Institute of Russian Academy of Sciences in St. Petersburg.

Results

Suspensions and salinity

Three examples of suspended matter and salinity profiles for typical summer situations are shown in Fig. 2. The profile from Svalbard (Kongsfjorden) shows a high concentration of mineral suspensions in the surface water layer – freshened by glaciers' outflow. The amount of suspensions drop from over 40 in the surface water to less than 20 mg/dm^3 below 10 m depth. The profile from East Greenland shows much smaller suspension loads (5–15 mg/dm^3), concentrated below the ice pack, which suggest sedimentation from the ice cover. There is a separation of salinity minimum caused by meltwater in the uppermost 5 m and

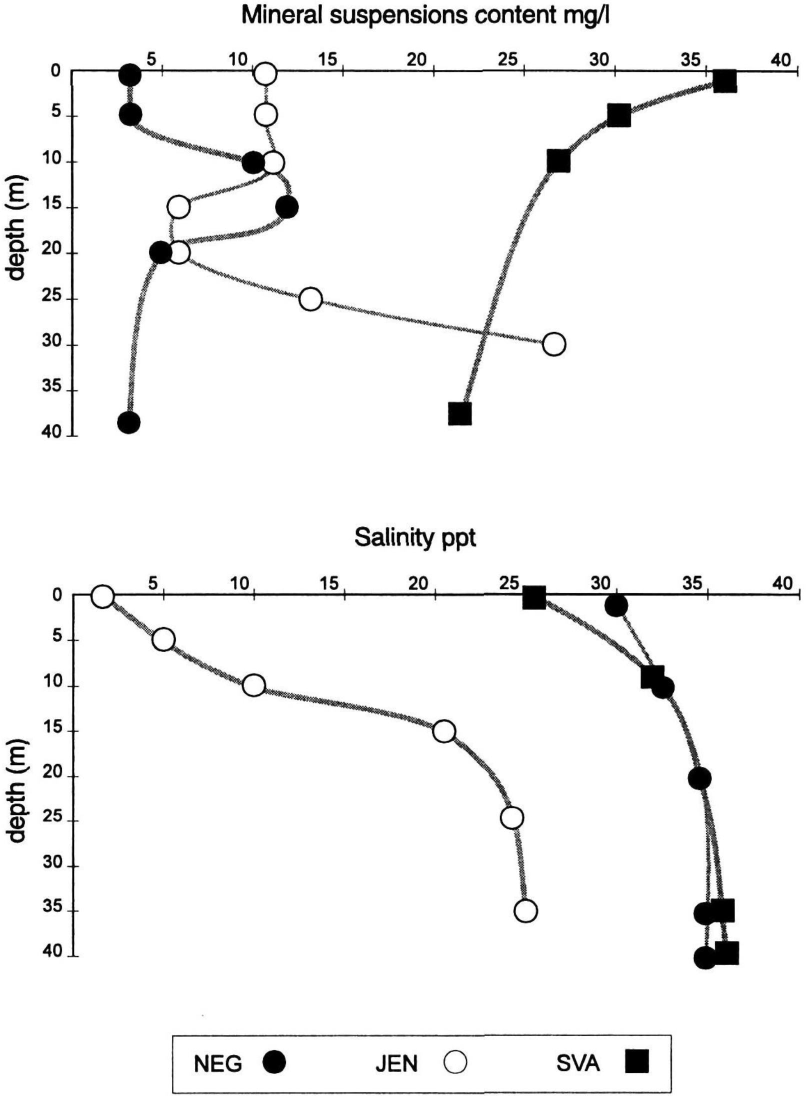


Fig. 2. Selected profiles of suspensions and salinity in examined water types. NEG – North East Greenland, ice pack, JEN – Yenisey river mouth, SVA – Spitsbergen tidal glacier fjord.

maximum suspension at 15 m depth (Fig. 2). The profile from the Ob and Yenisey rivers mouths show that the suspensions peak (30 mg/dm^3) occurred in the near bottom water at 25–30 m, while salinity minimum was observed in the upper 15 m (Fig. 3). Daily variability of suspension distribution is presented for station 81 in the Ob mouth (Fig. 3a). The maximal values of suspension loads range from 15 to 35 mg/dm^3, but the general layout of the profile remains constant, with maximum concentrations close to the bottom of the river. More

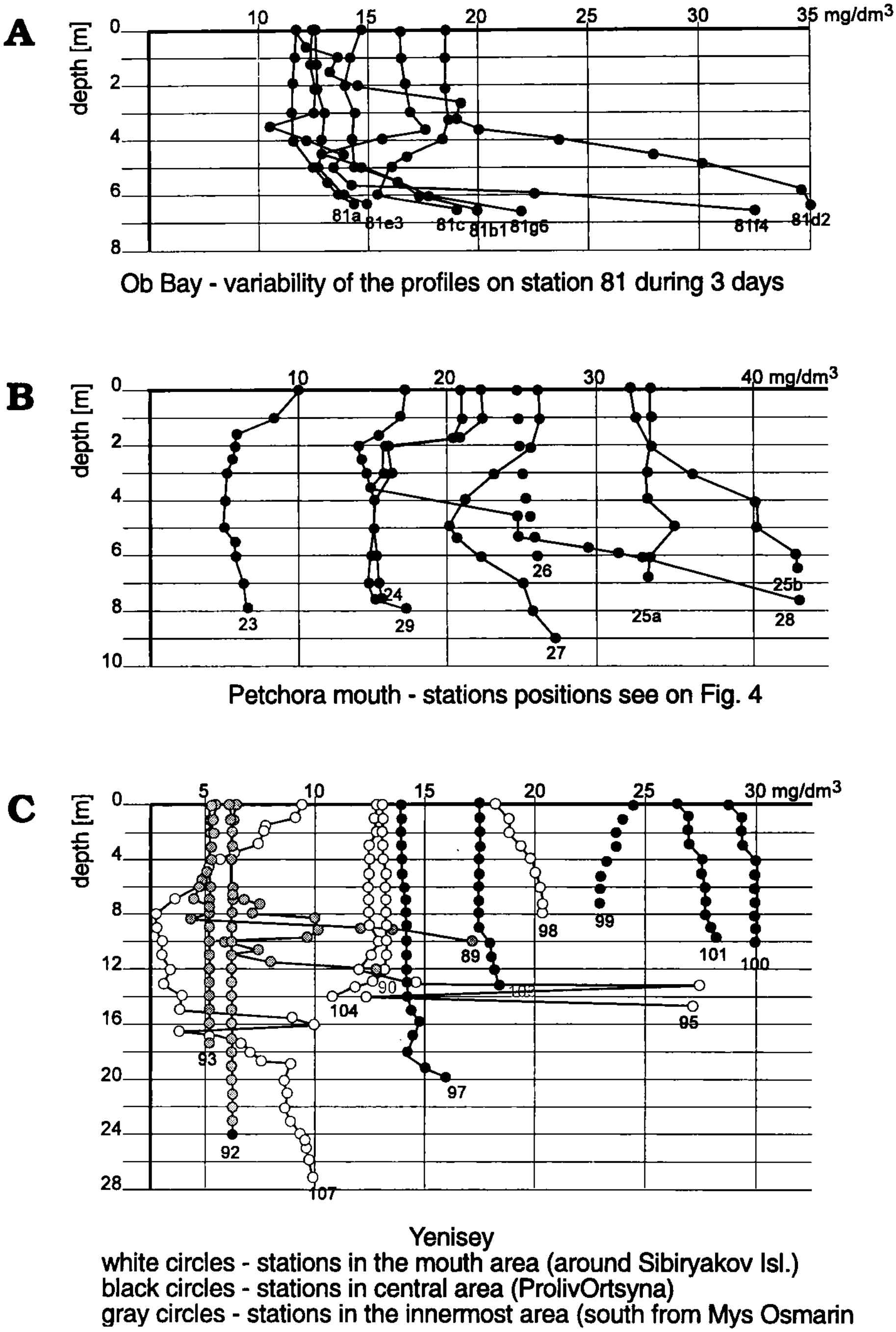
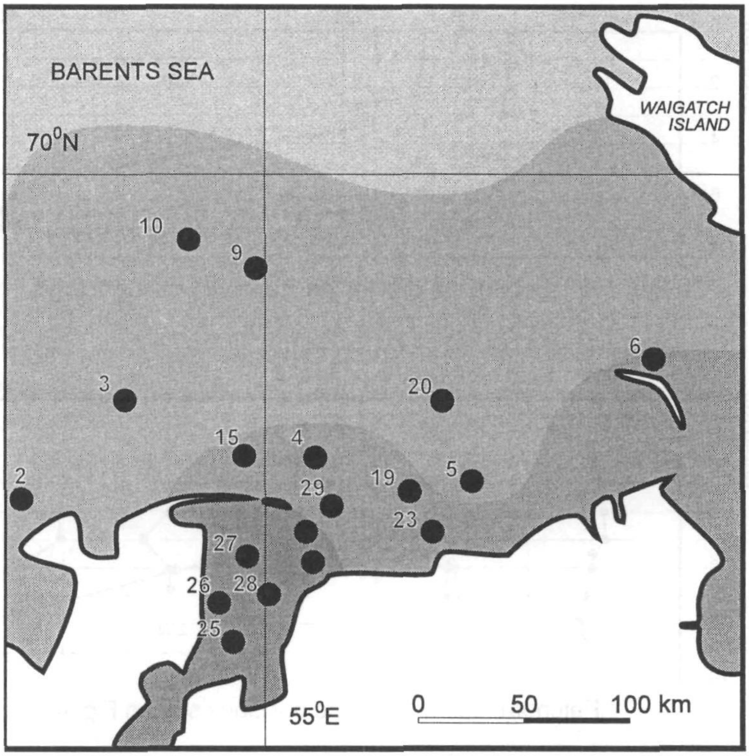


Fig. 3. Vertical profiles of mineral suspensions amount in water column of the Siberian rivers, August 1994. A – Ob – Bay the variability of suspensions profiles on station nr 81. B – Pechora river mouth, stations positions as on Fig. 4. C – Ob and Yenisey river mouths, August 1994.



	mg/dm3 suspensions	light attenuation coeff. [c]	Sechchi depth [m]
	<5	<1	>7
	5-15	1-5	3-7
	>15	>5	<3

Fig. 4. Horizontal distribution of sediment ladden surface waters in the mouth of Pechora river, August 1994. Stations numbers reffer to Fig. 3.

equal distribution of suspensions was observed in the Pechora river mouth, with concentrations decreasing there from innermost stations (25 and 28) to the outermost station 23 (Fig. 3b and Fig. 4). The horizontal range of suspension laden surface waters in not very large and does not exceed the outer border of the Pechora river estuary (Fig. 4). The profiles from Yenisey estuary show high suspension concentrations evenly distributed in the whole water column on stations situated in central area of Yenisey estuary, Fig. 3c. In contrast to observations from the Pechora (Fig. 4), the highest amount of suspended matter is observed in the central, not the inner, part of the Yenisey estuary (Fig 3c). The relationship between the amount of mineral suspensions and light attenuation in

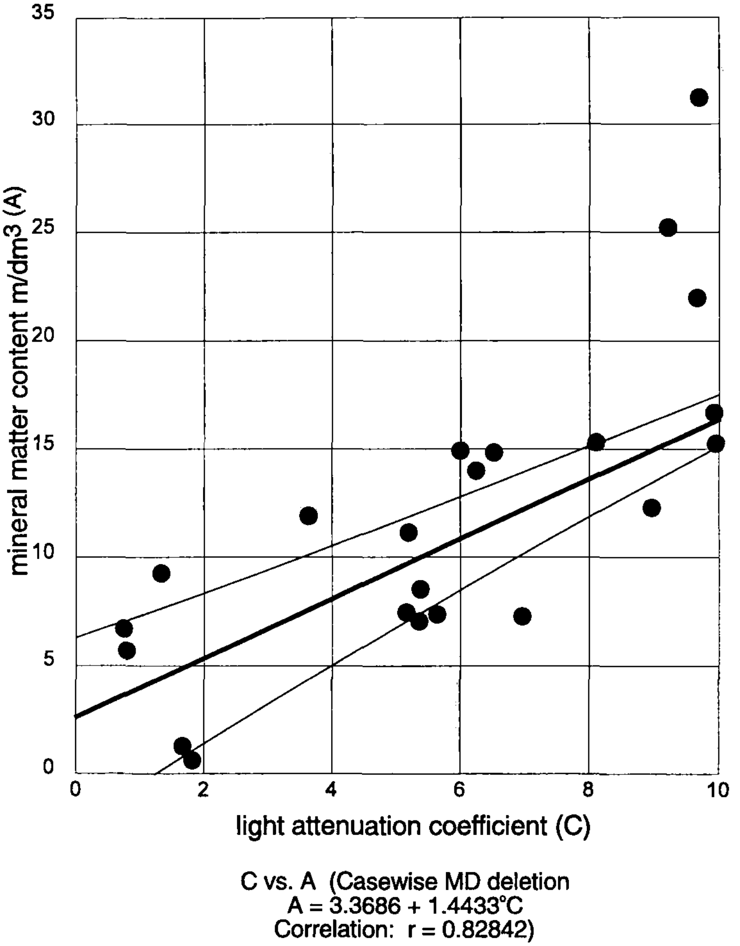


Fig. 5. Relation between suspensions amount and light attenuation coefficent, data from stations in Sibirian river mouths, August 1994.

samples from Siberia was found to be almost linear for all considered localities (Fig. 5). The relationship between salinity and suspension amounts was statistically not important for Siberian and NE Greenland material. Such a relationship was found for the Svalbard material, and published separately (Beszczyńska-Moller *et al.* 1997).

Phytoplankton

177 phytoplankton taxa, classified as marine, brackish and freshwater forms (Table 1) were found in the analysed samples. The least diverse were the Kara Sea samples (47 taxa), followed by NE Greenland (64 taxa) and Spitsbergen fjords (111 taxa). The freshwater species were found in the Kara Sea samples

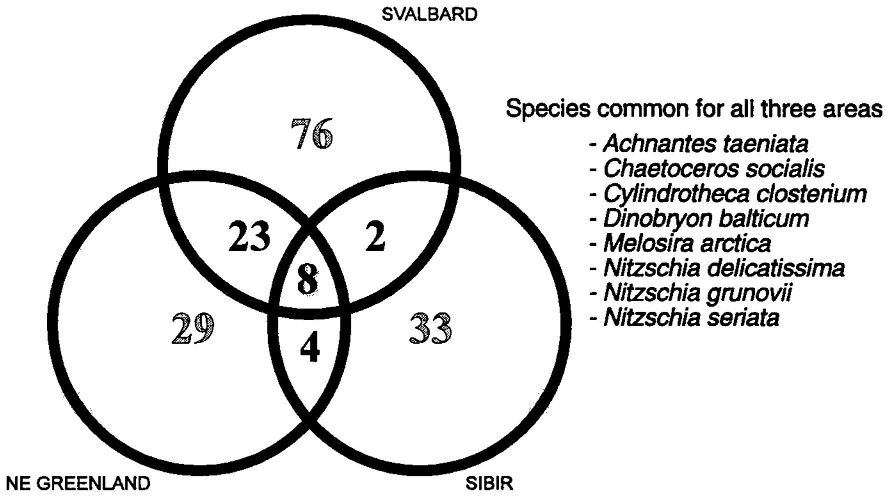


Fig. 6. Number of phytoplankton species observed in three analysed water masses.

only, while Svalbard and NE Greenland samples revealed 55 to 60% of brackish water forms (Table 1). From this list only eight species were found in all three localities. The most similar were the East Greenland and Svalbard samples, revealing 23 species in common, while only two species were common to the Svalbard and Kara Sea samples (Fig. 6). In the list of species from Table 1, only a few species are representatives of ice-associated flora, a phytoplankton group which was almost absent in our water column samples.

Table 1

Check list of phytoplankton taxa found in examined areas, summer seasons (b – brackish, m – marine, f – freshwater).

Taxa; total number 168	Kara Sea	NE Greenl.	W Spitsb.	
Achnanthes taeniata Grunow	+	+	+	b
Chaetoceros socialis Lauder	+	+	+	b
Cylindrotheca closterium (Ehrenberg) Lewin *et* Reiman	+	+	+	b
Dinobryon balticum (Shütt) Lemmermann	+	+	+	b
Melosira arctica (Ehrenberg) Dickie	+	+	+	m
Pseudo-nitzschia delicatissima (Cleve) Heiden	+	+	+	m
Fragilariopsis oceanica (Cleve) Hasle	+	+	+	m
Heterocapsa triquetra (Ehrenberg) Stein	+	+		b
Navicula vanhoffenii Gran	+	+		b
Fragilariopsis cylindrus (Grunow) Krieger	+	+		m
Peridiniella catenata (Levander) Balech	+	+		b
Chaetoceros wighamii Brightwell	+		+	b
Thalassiosira baltica (Grunow) Ostenfeld	+		+	b
Ceratium arcticum (Ehrenberg) Cleve		+	+	m
Phaeocystis pouchetii (Hariot) Lagerheim		+	+	m

Table 1 – *continued.*

Gyrodinium lachryma (Meunier) Kofoid *et* Swezy		+	+	m
Chaetoceros sp.		+	+	?
Cryptomonas sp.		+	+	?
Fragilaria sp.		+	+	?
Eucampia groenlandica Cleve		+	+	b
Gymnodinium arcticum Wulff		+	+	b
Gymnodinium simplex (Lochmann) Kofoid *et* Swezy		+	+	b
Navicula septentrionalis (Östrup) Cleve		+	+	b
Gymnodinium sp.		+	+	?
Gyrodinium sp.		+	+	?
Navicula sp.		+	+	?
Nitzschia longissima (Brébisson) Ralfs		+	+	?
Nitzschia sp.		+	+	?
Pennatae < 50 μm		+	+	?
Pleurosigma sp.		+	+	?
Pyramimonas sp.		+	+	?
Synedra sp.		+	+	?
Thalassiosira antarctica Comber		+	+	b
Thalassiosira nordenskioeldii Cleve		+	+	m
Thalassiosira sp.		+	+	?
Amphidinium sphaenoides Wulff		+		b
Amphidinium sp.		+		?
Armoured dinoflagellates		+		?
Amphora holsatica Hustedt	+			b
Amphora ovalis Kützing	+			b
Anabaena flos-aquae (Lyngb.) Brébisson	+			b
Aphanizomenon flos-aquae (L.) Ralfs	+			f, b
Asterionella formosa Hassall.	+			f
Asterionella gracillima (Hantzsch) Heiberg	+			f
Aulacoseira granulata (Ehrenberg) Simonsen	+			f
Aulacoseira islandica (O.Müller) Simonsen	+			f
Aulacoseira italica (Ehrenberg) Simonsen	+			f
Fragilaria arcus (Ehrenberg) Cleve	+			f
Chaetoceros gracilis Shütt	+			b
Chaetoceros holsaticus Shütt	+			b
Chaetoceros subtilis Cleve	+			b
Coscinodiscus argus Ehrenberg	+			m
Cyclotella striata (Kützing) Grunow	+			b
Diatoma cf. *hiemale* (Lyngbye) Heiberg	+			f
Diatoma elongatum (Lyngbye) Agardh	+			b
Dinobryon sociale Ehrenberg	+			f
Eunotia pectinalis (Dillw.? Kütz.) Rabenh.	+			f
Fragilaria capucina Desm.	+			f
Fragilaria crotonensis Kitt.	+			f
Fragilaria virescens Ralfs	+			b
Leptocinclis ovum (Ehrenberg) Mink.	+			f
Melosira moniliformis (O. Müller) Agardh	+			b
Meridion circulare Agardh	+			f
Nitzschia sigma (Kützing) W. Smith	+			b

Table 1 – *continued.*

Oscillatoria agardhii Gomont	+			f
Pediastrum duplex Meyen	+			f
Scenedesmus quadricauda (Turpin) Brébisson	+			f
Spirulina sp.	+			f
Synedra acus Kützing	+			f
Synedra ulna (Nitzsch) Ehrenberg	+			f
Tabellaria fenestrata (Lyngb.) Kützing	+			f
Chaetoceros cf. *holsaticus* Shütt		+		b
Chaetoceros cf. *pseudocrinitus* Ostenfeld		+		b
Chaetoceros furcellatus Bailey		+		b
Coscinodiscus sp.		+		?
Eutreptiella sp.		+		b
Flagellatae nd.		+		?
Fragilariopsis spp.		+		m, b
Gonioceros septentrionale (Östrup) Round		+		b
Gymnodinium sp. small		+		?
Heterocapsa cf. *minima* Pomroy		+		?
Leptocylindrus sp.		+		?
Leucocryptos marina (Braarud) Butcher		+		m, b
Melosira sp.		+		?
Navicula cf. *transitans* Cleve		+		b
Nitzschia frigida Grunow		+		b
Pseudo-nitzschia cf. *seriata* Cleve		+		?
Nitzschia sp. < 50 µm		+		?
Nitzschia neofrigida Medlin		+		b
Nitzschia promare Medlin		+		b
Pseudo-nitzschia delicatissima (Cleve) Heiden		+		?
Navicula vanhoeffenii Gran		+		?
Protoperidinium sp.		+		?
Thalassiosira sp. < 50 µm		+		?
Thalassiosira bioculata (Grunow) Ostenfeld		+		m
Thalassiosira cf. *rotula* Meunier		+		m
Amphidinium cf. *extensum* Wulff			+	m
Bacterosira bathyomphala (Cleve) Syvertsen *et* Hasle			+	b
Odontella aurita (Lyngbye) Brébisson			+	b
Cerataulina pelagica (Cleve) Hendey			+	m
Chaetoceros affinis Lauder			+	?
Chaetoceros atlanticus Cleve			+	m
Chaetoceros borealis Bailey			+	m
Chaetoceros brevis Shütt			+	?
Chaetoceros ceratosporus Ostenfeld			+	?
Chaetoceros teres Cleve			+	?
Chaetoceros constrictus Gran			+	b
Chaetoceros debilis Cleve			+	b
Chaetoceros densus (Cleve) Cleve			+	b
Chaetoceros decipiens Cleve			+	m
Chaetoceros laciniosus Shütt			+	m
Cochlodinium helix (Pouchet) Lemmermann			+	m
Coscinodiscus cf. *concinnus* W. Smith			+	b

Table 1 – *continued.*

Dictyocha speculum Ehrenberg			+	m
Dinophysis norvegica Claparéde *et* Lachmann			+	b
Dinophysis rotundata Claparéde *et* Lachmann			+	?
Diplopsalis lenticula Bergh			+	b
Distephanus speculum (Ehrenberg) Haeckel			+	?
Emiliania huxleyi (Lohm.) Mohler			+	?
Entomoneis paludosa (Grunow *et* Cleve) Poulin *et* Cardinal			+	b
Euglena sp.			+	?
Gymnodinium wulffii Schill.			+	b
Gyrodinium aureolum Hulburt			+	?
Gyrodinium cf. *fusiforme* Kofoid *et* Swezy			+	m
Gyrosigma fasciola (Ehrenberg) Griffith *et* Henfrey			+	?
Katodinium rotundatum (Lohmmann) Loeblich			+	b
Lauderia glacialis Gran			+	b
Licmophora sp.			+	?
Lyngbya aestuarii (Mert.) Liebm.			+	?
Minuscula bipes Lebour			+	?
Navicula pelagica Cl.			+	b
Navicula cf. *peregrina* (Ehrenberg) Kützing			+	?
Navicula cf. *radiosa* Kützing			+	m
Nitzschia cf. *seriata* Cleve			+	?
Nodularia spumigena Mert.			+	?
Oscillatoria sp.			+	?
Oxytoxum belgicum Meunier			+	?
Oxytoxum sp.			+	?
Peridinium granii Ostf.			+	?
Peridinium oceanicum Vanh.			+	?
Peridinium pallidum Ostenfeld			+	?
Peridinium sp.			+	?
Phalacroma rotundatum (Claparéde *et* Lachmann) Kofoid *et* Michener			+	?
Phormidium sp.			+	?
Pleurosigma cf. *stuxbergii* Cl.			+	b
Proboscia alata Sundström			+	m
Protoperidinium brevipes (Paulsen) Balech			+	m
Protoperidinium curvipes (Ostenfeld) Balech			+	b
Protoperidinium depressum (Bailey) Balech			+	m
Protoperidinium divergens (Ehrenberg) Balech			+	b
Peridinium excentricum Pauls.			+	?
Protoperidinium islandicum (Paulsen) Balech			+	b
Peridinium minutum Kof.			+	?
Protoperidinium pellucidum Bergh			+	b
Rhizosolenia borealis Sundström			+	m
Rhizosolenia hebetata Bailey			+	m
Rhizosolenia setigera Brightwell			+	b
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot			+	?
Scenedesmus acuminatus (Lagerh.) Hod.			+	?
Skeletonema costatum (Greville) Cleve.			+	b
Stauroneis sp.			+	?

Table 1 – *continued.*

Thalassionema nitzschioides Grunow			+	b
Thalassiosira gravida Cleve			+	m
Thalassiosira hyalina (Grunow) Gran			+	m
Thalassiosira levanderi Van Goor			+	b
Thalassiothrix longissima Cleve *et* Grunow			+	m
Tropidoneis sp.			+	?
Woloszynskia sp.			+	?
Number of taxa	46	61	103	

Discussion

Suspensions and salinity

Tidal glacier areas are known to discharge very high loads of fine particles (see Urbański *et al.* 1980, Elverhoi *et al.* 1983, Gorlich *et al.* 1987, and Wiktor and Zajączkowski 1992). The just-mentioned authors presented similar profiles of suspension concentrations, with peak values in the freshened surface water. Data on suspension concentrations from the pack ice areas are less numerous and some authors emphasise the importance of ice-rafted suspensions (Dethleff *et al.* 1993). A statistically important correlation between the amount of suspended matter and salinity drop was found in Antarctic coastal waters, in the presence of tidal glaciers (Jonasz 1984). The thickness of the surface, desalted layer was reported to extend to the upper 7 m only in the Lena river estuary (Timokhov 1994). Suspended matter profiles presented for the Lena river mouth show an extremely low amount of suspensions ranging from 1 to 4 mg/dm^3 (Burenkov 1993). Their vertical distribution shows all possible cases (suspension concentrations at the surface, on the halocline, and close to the bottom), and the horizontal extension does not exceed 150 km from the mouth area (Burenkov 1993). High loads of suspensions in rivers on the Taymyr peninsula (20 to 600 mg/dm^3) were reported by Bolshyanov and Hubberten (1996). The horizontal extension of turbid waters originating from the Pechora was presented on a satellite image (AVHRR) by Pfirmann *et al.* (1995). Their picture, taken in August 1988, is very similar to our results as presented on Fig. 4. Successful employment of AVHRR imagery for surface suspension tracking was also used for Arctic fjords (Krężel 1997). However, high turbidity of river mouths and very differentiated material carried by the rivers makes the extrapolations more difficult, as compared to glacial discharge.

Light attenuation

The light attenuation caused by suspensions in surface Arctic waters in the summer reduces the euphotic layer (1% of light at the surface) to less than 1m in Arctic fjords (Halldal and Halldal 1973, Sagan *et al.* 1993, Beszczyńska-Moller *et al.* 1997), 2–3 meters in Siberian river mouths and 20–25 meters in North

East Greenland Polynya (Węsławski *et al.* 1997). Respective values of light attenuation coefficient "c" per 1 m maximally reached 8 to 10 units. The low amount of suspensions reported from the Lena river mouth resulted in light attenuation between 2 and 4 $/m^{-1}$ (Burenkov 1993). Such a value, low when compared with our data from Siberia and from Svalbard (Sagan *et al.* 1993), is in the range of light attenuation observed in coastal turbid waters at the Vistula river mouth in Baltic Sea (Sagan 1991).

Phytoplankton

It is generally accepted that river run-off reduces the primary production and phytoplankton diversity in marine coastal areas (Skreslet 1986). However, a river may supply brackish sea with important freshwater phytoplankton components, as is the case of the Vistula river in the Baltic Sea (Wiktor and Kruk-Dowgiałło 1993). In the case of coastal Arctic ecosystems the freshwater discharge may reduce the phytoplankton in the following ways:

1) by flushing out marine surface water
2) by salinity shock in stenohaline marine taxa
3) by light attenuation
4) by increase rate of sinking cells through agglutination of fine particles to cells' walls.

The difficulty in assessing the role of freshwater in reduction of the phytoplankton is the complicated seasonality of the Arctic environment. Our Spitsbergen samples were collected in May–July, which fits in late biological spring, while the same time on NE Greenland is early spring bloom, which in Siberian seas may take place well before. The number of phytoplankton taxa depends on the season of sampling. The amount of phytoplankton in surface brackish water is strongly reduced in Spitsbergen fjords in the summer, compared to the spring situation with almost full salinity and low concentration of suspensions. In Adventfjorden 46 phytoplankton taxa were noted before the light/salinity drop, while only 15 taxa were found afterwards (Wiktor, *in prep.*). The same situation was observed in samples collected from low brackish surface waters of the Pechora and Ob river mouths in the peak of summer (11 taxa noted in summer versus over 60 in the early season). This suggest a direct link between the light conditions and phytoplankton biodiversity. The relation between the light attenuation caused by river water discharge has been described in the Arctic (Legendre *et al.* 1996). Phytoplankton taxa found in our samples are only a small fraction of the potential pool of species known from the Barents Sea (over 200 species – Wiktor and Okolodkov 1995), Canadian Arctic ice algae (over 190 species – Hsiao 1987), or Kara Sea phytoplankton (78 species – Zenkevitch 1963). On the other hand, a single collection of samples usually reveals 40–60 species (Hsiao 1987, Węsławski *et al.* 1991b, Wiktor, *in prep.*). The year-to-year variations in the taxa occurrence are known from Arctic waters, where the dominant species used to be variable (Sakshaug *et* *al.* 1992). The material presented shows the unexpectedly small group of widely dispersed taxa, as well as the group of regionally specific taxa, which may serve as water masses indicators.

Answering to the questions raised in the introduction, the following conclusions might be drawn:

1. Freshwater volume in the Arctic coastal areas is positively correlated with the amount of suspensions in the case of glacial fed fjords. Less saline, sediment-ladened waters are limited to surface layers and might be detected from satellite imagery. This is not the case of riverine areas, where the resuspension and turbidity distributes suspensions all over the water column. Use of satellite imagery for tracking surface suspensions in river mouths might be misleading. Surface waters of Siberian estuaries are often more transparent than glacial fjords waters

2. Freshwater and suspension inflows decrease phytoplankton diversity in coastal Arctic ecosystems. However, this process does not lead to the domination of cosmopolitan, eurytopic algae. From over 200 phytoplankton species determined in our samples from brackish Arctic coastal ecosystems, only 8 were found in all investigated regions, otherwise phytoplankton assemblages were diverse. Light penetration is markedly reduced in glacial areas, less in river estuaries, and barely existent in the ice pack edge, what suggest consequent reduction in primary productivity.

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References

AAGARD K. and CARMACK E.C. 1989. The role of sea ice and other fresh water in the Arctic Circulation. — JGR, 94: 14485–14498.

AOSB, 1996. Arctic Ocean Sciences Board, XVth annual meeting, Helsinki. — NSF Geoscience, Washington.

BESZCZYŃSKA-MOLLER A., WĘSŁAWSKI J.M., WALCZOWSKI W. and ZAJĄCZKOWSKI M. 1997. Estimation of glacial meltwater discharge into Svalbard coastal waters. — Oceanologia, 39: 289–298.

BOLSHYANOV D.Y. and HUBBERTEN H.W. 1996. Russian-German cooperation project. The Expedition Taymyr 1995. — Ber. Polarforsch., 211: 1–209.

BURENKOV V.I. 1993. Optical properties of the Laptev Sea near the Lena River delta. — SPIE, 2048: 175–183 .

DETHLEFF D., NURNBERG D., REIMNITZ E., SAARSO M. and SAVCHENKO Y.P. 1993. East Siberian Arctic Region Expedition 1992. The Laptiev Sea. — Ber. Polarforsch., 120: 3–44.

ELVERHOI A., LONNE O. and SELAND R. 1983. Glaciomarine sedimentation in a modern fjord environment, Spitsbergen. — Polar Res., 1: 127–150.

GORLICH K.A., WĘSŁAWSKI J.M. and ZAJĄCZKOWSKI M. 1987. Suspensions settling effect on macrobenthos biomass distribution in the Hornsund fjord, Spitsbergen. — Polar Res., 5: 175–192.

HALLADAL P. and HALLADAL K. 1973. Phytoplankton, chlorophyll and submarine light conditions in Kings Bay. Spitsbergen, July 1971. — Norwegian J. Bot., 20: 99–108.

HSIAO S.I.C. 1987. Quantative composition, distribution community structure and standing stock of sea ice microalgae in the Canadian Arctic. — Arctic, 33: 768–793.

JONASZ M. 1984. Particulate matter in Ezcurra inlet: concentration and size distribution. — Oceanologia, 15: 65–74.

KRĘŻEL A. 1997. Identyfikacja mezoskalowych anomalii hydrofizycznych w morzu płytkim metodami szerokopasmowej teledetekcji satelitarnej. Wyd. Uniw. Gdańskiego, Gdańsk: 1–174.

LEGENDRE L., ROBINEAU B., GOSSELIN M., INGRAM R.G., FORTIER L., THIERRAULT J.C., DEMERS S. and MONTI D. 1996. Impact of freshwater on a subarctic coastal ecosystem under seasonal sea ice (southeastern Hudson Bay, Canada) II. Production and export of microalgae. — J. Mar. Systems, 7: 233–250.

PFIRMAN S.L., KOGELER J. and ANSELME B. 1995. Coastal environment of the West Kara Sea and East Barents Sea. — Deep Sea Res., 42: 1391–1412.

SAGAN S. 1991. Transmisja światła w wodach Południowego Bałtyku. Rozprawy i monografie IO PAN, 2: 149 pp.

SAGAN S., KOWALCZUK P. and ZAJĄCZKOWSKI M. 1993. Optical properties of waters around Svalbard and Franz Josef Land. — SPIE, 2048: 64–72.

SAKSHAUG E., BJORGE A., GULLIKSEN B., LOENG H. and MEHLUM F. 1992. Okosystem Barenshavet. — PRO MARE, Trondheim: 304 pp.

SCHLOSSER P., BAUCH D., FAIRBANKS R. and BONISH G. 1994. Arctic river runoff mean residence time on the shelves and in the halocline. — Deep-Sea Res., 41: 1053–1068.

SKRESLET S. 1986. The role of freshwater outflow in coastal marine ecosystems. — NATO ASI G7.

SMETACEK V.S. 1986. Impact of freshwater discharge on production and transfer of materials in the marine environment. *In*: S. Skreslet (ed.), *The role of freshwater outflow in coastal marine ecosystems*. — NATO ASI G7: 85–106.

TIMOKVOV L.A. 1994. Regional characteristics of the Laptiev and East Siberian seas. Climate, topography, ice phases, thermohalyne regions, circulation. — Ber. Polarforsch., 144: 15–32.

URBAŃSKI J., NEUGEBAUER E., SPACJER R. and FALKOWSKA L. 1980. Physico-chemical characteristic of the waters of Hornsund Fjord on south-west Spitsbergen (Svalbard Archipelago) in the summer season 1979. — Pol. Polar Res., 1: 43–52.

WĘSŁAWSKI J.M., JANKOWSKI A., KWAŚNIEWSKI S., SWERPEL S. and RYG M. 1991a. Summer hydrology and zooplankton in two Svalbard fiords. — Pol. Polar Res., 12: 445–460.

WĘSŁAWSKI J.M., WIKTOR J. and KWAŚNIEWSKI S. 1991b. R/v "Oceania" cruises to Norwegian and Greenland seas in 1987–1989. Plankton species composition. — SIMO, 58: 187–202.

WĘSŁAWSKI J.M., KWAŚNIEWSKI S., WIKTOR J. and ZAJĄCZKOWSKI M., 1993. Observations on the fast ice biota in the fjords of Spitsbergen. Pol. Polar Res., 14: 331–343.

WĘSŁAWSKI J.M., KOSZTEYN J., ZAJĄCZKOWSKI M., WIKTOR J. and KWAŚNIEWSKI S. 1995. Fresh water in Svalbard fjord ecosystems. *In*: C.C. Hopkins, K.E. Erikstad and H.P. Leinaas (eds), *Ecology of fjord and coastal waters*. — Elsevier Sci BV: 229–241.

WĘSŁAWSKI J.M., WIKTOR J., KOSZTEYN J., ZAJĄCZKOWSKI M., WIECZOREK P. and KOTWICKI L. 1997. The coastal edge of the Northeast Water polynya in spring 1993. — J. Mar. Systems, 10: 429–444.

WIKTOR J. and KRUK-DOWGIAŁŁO L. 1992. Phytoplankton species composition and distribution in the southern Baltic Sea in 1979-1983. — SIMO, 60: 5–17.

WIKTOR K. and OKOLODKOV J.B. 1995. Phytoplankton. *In*: R.Z. Klekowski and J.M. Węsławski (eds), *Atlas of Southern Spitsbergen Marine Flora*. — IO PAN, Sopot: 9–291.

WIKTOR K. and ZAJĄCZKOWSKI M. 1992. Suspensions and sedimentation in Tikhaia Bay, Franz Josef Land. — Meddelelser om NPI 120: 14–18.

ZENKEVITCH L.B. 1963. Biologija morej SSSR. — Nauka, Moskwa; 340 pp.

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Streszczenie

Zawiesiny, fitoplankton i osłabienie światła były mierzone w czasie ekspedycji na Płn. Wschodnią Grenlandię, Svalbard i ujścia rzek syberyjskich. Koncentracje zawiesin mineralnych były dobrze skorelowane z odpływem wód słodkich w przypadku zatok lodowcowych na Spitsbergenie, podobne zależności nie były obserwowane w ujściach rzek i w pobliżu paku lodowego. Gatunki słodkowodnego fitoplanktonu były znalezione tylko w bezpośrednim sąsiedztwie ujść rzecznych. W wodach roztopowych z lodu lodowcowego i morskiego, gatunków słodkowodnych nie znaleziono. Osłabienie światła związane z transportem zawiesin w wodach roztopowych jest głównym czynnikiem limitującym latem produkcję pierwotną w wodach przybrzeżnych Arktyki. Koncentracja zawiesin mineralnych jest dobrze skorelowana z obniżeniem zasolenia w wodach Svalbardu. Estuaria rzek syberyjskich niosą wody tak wymieszane, że podobnej korelacji nie znaleziono ani w odniesieniu do intensywności spływu ani do głębokości.