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Algae in the annual sea ice at Hooker Island, Franz Josef Land, in August 1991

ABSTRACT: Eight samples of the ice algae were collected from the annual ice in Tikhaia Bay, Hooker Island, Franz Josef Land. Species composition included 58 diatoms (and some *Navicula*, *Nitzschia* and other Pennatophyceae unidentified species), 2 dinoflagellates, 2 chrysophyceans, 1 chlorophycean, 1 cyanophycean and possible dinoflagellate and chrysophycean cysts. The maximum quantity was 132300 cells/l. In 4 samples *Aulacoseira granulata* prevailed, in other samples *Nitzschia frigida*, *N. cylindrus*, *Rhizoclonium* sp. and dinoflagellate cysts dominated. *Xanthiopyxis polaris* found by Gran (1904) in Arctic sea ice and referred to the diatoms is, possibly, the dinoflagellate cyst. On the whole, the ice community consisted of benthic and planktonic-benthic species of mainly marine and brackishwater-marine pennate diatoms, their resting stages, freshwater unicellular algae and marine chlorophycean.

K e y w o r d s: Arctic, Franz Josef Land, phycology, sea-ice algae.

Introduction

Studies on the microscopic algae of Franz Josef Land have been carried out since the end of the 19th century (Grunov 1884, Cleve 1898, Borge 1899, Širšov 1935, Wiktor and Zajączkowski 1992). Only P.T. Cleve (1898) dealt with so called ice algae, which were collected on an ice-floe near Bell Isle. It is known that ice algae are of importance in seasonally ice-covered seas. The purpose of the article is to give a list of species found in ice samples and to present the data on their abundance. Preliminary results of the study were published elsewhere (Okolodkov 1992a).

Material and methods

The algae were collected during the Second Soviet–Norwegian–Polish Expedition to Franz Josef Land on August 27 and 28, 1991. Eight samples of

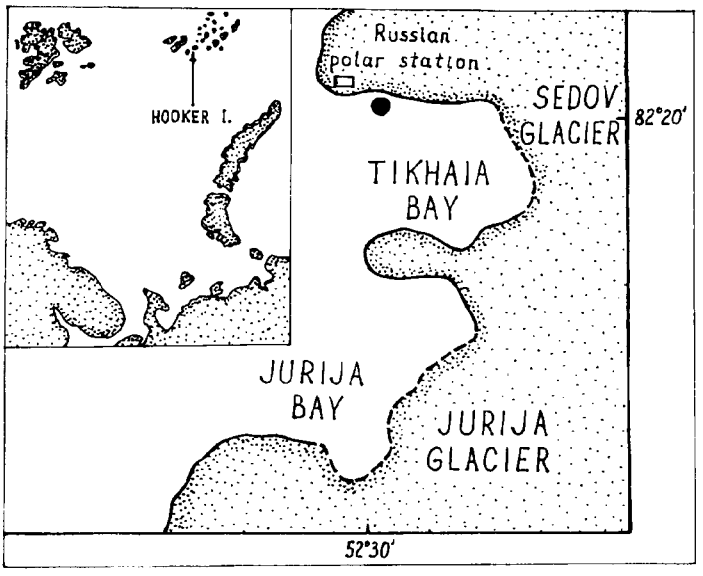

Fig. 1. Sea-ice algae sampling area in August 1991 (marked with black circle)

the annual ice, 1 to 2 m thick, were taken in shallow water, in a distance of 20 m from the coast of Tikhaia Bay (Fig. 1). The sampling area was about 0.04 squ.km at the depth of 2 m. A large piece of ice from the lower part of drifting ice was chopped out to obtain 30 × 30 cm sample. Then the ice was put into a polyethylene bag and submerged in the container with warm (ca. 40°C) fresh water; after ice melted the 1 litre samples were collected from the bags. Each sample was fixed with formaldehyde to obtain 4% solution.

The algae were identified, at first, in combined plate chambers under the inverted microscope ID-03, Opton, FRG, and then in permanent slides under the standard microscope Biolam R7 using the anoptral contrast microscopic device MFA-2, LOMO, USSR. Permanent slides of silicon-containing algae were prepared after treating them with the concentrated sulphuric acid. The algae were mounted into Èl'jašev's medium having a refractive index of ca. 1.68 (Èl'jašev 1957). The counts were made by Utermöhl method using combined plate chambers (Utermöhl 1931, 1958, Hasle 1978). Samples of 25 ml were settled down for 48 hours. A large amount of sediments deriving from ice made counting difficult, therefore, the quantitative data are to be considered underestimated rather than overestimated.

Results

The list of species is given in Table I. Freshwater species are marked by an asterisk (*) and fossil species — by two asterisks (**). The rest of the species (marine and brackishwater-marine) have no special mark. For the algae listed in

Table I

List of the algal taxa discovered in the annual sea ice
at Hooker Island, Franz Josef Land
(see remarks in text)

CYANOPHYTA

* *Nostoc* sp.

DINOPHYTA

Gymnodinium sp.
Protoperidinium sp.
Cysts, diam. 16 – 33 μm

CHRYSOPHYTA

Dictyocha speculum Ehr.
Dinobryon petiolatum Willen
Cysts (?), diam. 21 – 24 μm

BACILLARIOPHYTA

* *Aulacoseira granulata* (Ehr.) Sim.
Centrophyceae gen. sp. (unidentified)
Chaetoceros borealis Bail.
C. debilis Cl., with resting spores
C. decipiens Cl.
C. diadema (Ehr.) Gran, with resting spores
C. furcellatus Bail., resting spores
C. teres Cl.; resting spores
Cocconeis scutellum Ehr. var. *stauroneiformis* Grun.
* *Cyclotella meneghiniana* Kütz. (Cleve, 1898)
Cylindrotheca closterium (Ehr.) Reimann et Lewin
Diploneis litoralis (Donk.) Cl. var. *arctica* Cl. (Cleve, 1898)
D. litoralis var. *clathrata* (Ostr.) Cl.
Diploneis sp. cf. *hersonensis* (Grun.) Cl.
Entomoneis kjellmanii (Cl.) Poul. et Card.
* *Eunotia monodon* Ehr. (Širšov, 1935)
* *E. pectinalis* (Dillw.? Kütz.) Rbh. var. *minor* (Kütz). Rbh. (Širšov, 1935)
* *E. praepruta* Ehr. var. *muscicola* Boye-Pet.
Gomphonema acuminatum Ehr. (Cleve, 1898)
Gomphonema sp.
Gonioceros septentrionale (Ost.) Round, epiphytic
Gyrosigma concilians (Cl.) Okol.
Hantzschia amphioxys (Ehr.) Grun. (Cleve, 1898; Širšov, 1935)
Haslea kjellmanii (Cl.) Sim.
** *Hemiaulus* sp. cf. *kittonii* Grun.
Licmophora abbreviata Ag.
Navicula cryptocephala Kütz.
N. directa (W.Sm.) Ralf in Pritchard
N. forcipata Grev. var. densestriata A.S.
N. glacialis (Cl.) Grun. var. *hudsonii* Poul et. Card.
* *N. gracilis* Ehr.
* *N. hungarica* Grun. var. *linearis* Ost.
N. kariana Grun. in Cl. et Grun.
N. solitaria Cl.
N. transitans Cl. var. *derasa* (Grun.) Cl.

Table I cd.

List of the algal taxa discovered in the annual sea ice
at Hooker Island, Franz Josef Land
(see remarks in text)

Navicula sp. cf. *lanceolata* (Ag.) Kutz.
Navicula sp. cf. *placentula* (Ehr.) Grun.
Navicula sp. cf. *subinflata* Grun.
Navicula sp. cf. *trigonocephala* Cl.
Navicula spp.
Nitzschia cylindrus (Grun.) Hasle
N. frigida Grun. in Cl. et Grun.
N. grunowii Hasle
N. polaris Cl.
Nitzschia sp. cf. *promare* Medlin
Nitzschia spp.
Pennatophyceae gen. sp. (unidentified)
* *Pinnularia gibba* Ehr.
P. globiceps Greg.
P. interrupta W.Sm. f. *minutissima* Hust. (Širšov, 1935)
P. quadratarea A.S.
Pseudogomphonema groenlandicum (Ost.) Medlin
Rhizosolenia hebetata Bail. f. *hebetata*
* *Stauroneis anceps* Ehr. (Širšov, 1935)
Stauroneis sp. cf. *radissonii* Poul. et Card.
Surirella ovalis Breb.
* *Synedra ulna* (Nitzsch) Ehr. (Cleve, 1898)
Thalassiosira eccentrica (Ehr.) Cl.
T. kryophila (Grun.) Jörg.
T. nordenskioeldii Cl. (Cleve, 1898)
Thalassiosira sp. cf. *antarctica* Comber
Trachyneis aspera (Ehr.) Cl.

CHLOROPHYTA
Rhizoclonium sp., fragments of colonies

Tab. I and registered by Cleve (1898) on a floe of drifting ice near Bell Isle and by Širšov (1935) in the puddles at Hooker Island the references are given in parentheses. *Aulacoseira granulata, Nitzschia frigida, N. cylindrus, Rhizoclonium* sp. and the dinoflagellate cysts dominated. The cysts prevailed in four samples, other species dominated in one or two samples. Maximal cell numbers in a litre of melted water were as follows: *Aulacoseira granulata* — 111800 (the dominance in a sample 84.5%), *Nitzschia frigida* — 35000 (47.6%), *N. cylindrus* — 10100 (36.7%), *Rhizoclonium* sp. — 9800 (19.2%), dinoflagellate cysts — 32200 (97.8%). Diatom cells were presented by empty frustules (20 to 98% per sample) or by frustules with the remains of chloroplasts and cytoplasm. The cells with reliably normal contents have not been found. The densities of cells in successive samples were as follows: 27500, 31800, 45900, 62300, 73300, 73500, 98000, 132300 cells/l.

Discussion

Pennate diatom species prevailed in number, that is one of the characteristic features of sea-ice flora, the genera *Navicula* Bory and *Nitzschia* Hass. being the most important. These genera include about a third or even a half of the species composition of lower ice surface flora in the Siberian seas (Okolodkov 1989, 1990, 1992 b, c). The centric diatoms are represented by the genera: *Aulacoseira* Thw., *Chaetoceros* Ehr., *Gonioceros* Round, *Rhizosolenia* (Ehr.) Brightw. and *Thalassiosira* Cl. On the whole, the diatoms constituted about 88% of the total number of species (if *Navicula, Nitzschia* and other Pennatophyceae unidentified species are not taken into account). Širšov (1935) listed 108 species collected from the puddles formed by a stream in the plateau of Hooker Island and the moss puddles at the shore of Tikhaia Bay; his list included also 6 freshwater diatom species found by the author of the present paper. The *Eunotia* Ehr. and *Pinnularia* Ehr. species were considered by Širšov (1935) as typical ones for acid marsh waters; they were called a marsh diatom community. Therefore, freshwater forms found in our samples along with numerous marine and brackishwater-marine forms, testify to the local origin of the ice investigated.

There was a wide range of cell numbers and the dominating species were not always the same, although the sampling area was rather small. The most prominent feature was the predominance of the dinoflagellate cysts as well as a considerable numbers of *Chaetoceros diadema* resting spores (up to 2000 cells/l). Organisms preliminary identified never been observed in ice samples collected by the author in the Siberian seas.

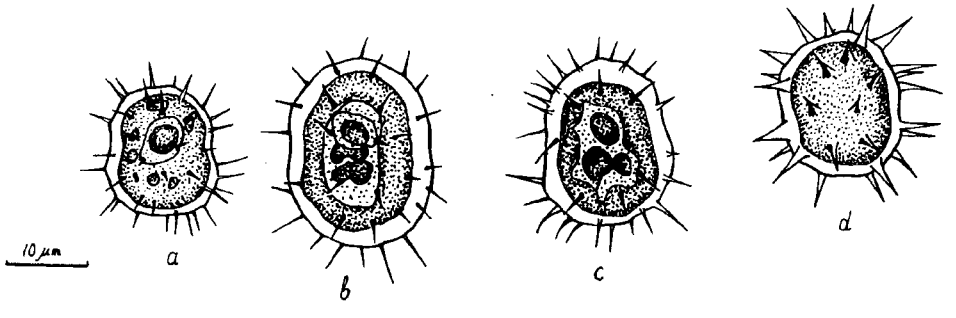

Fig. 2a–d. Dinoflagellate cysts (?) from Tikhaia Bay

What was identified as dinoflagellate cysts (Fig. 2a–d) is much similar to *Xanthiopyxis polaris* Gran, described by Gran (1904) and referred to the diatom genus *Xanthiopyxis* Ehr. of vague systematic position (Fig. 3a–c). *X. polaris* was found on the ice-floes in the Arctic Ocean, in the area from 81°15′ to 81°30′N and from 125°01′ to 125°25′E on July 22–27, 1894. Gran (1904) supposed *Xanthiopyxis* to be a quiescent stage of some diatom, the length with

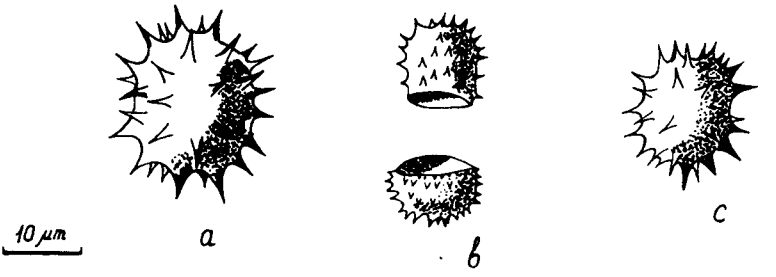

Fig. 3a–c. *Xanthiopyxis polaris*, after Gran (1904)

spines being 19 to 26 µm. Resistance of the cell wall to the treatment with acid was considered to be the evidence for the species belonging to the diatoms. However, the silicates are known to be the components of theca of the dinoflagellate *Prorocentrum micans* Ehr. (Gorjunova and Kabanova 1958). On the other hand, it is known that the dinoflagellate organic cyst walls may be resistant to laboratory acid treatments. Moreover, various parts within one cyst may show different degrees of resistance. Dinoflagellate mineralized cysts are found as well. In particular, siliceous cysts are known from the fossil record (Dale 1983).

The *Chaetoceros* and *Thalassiosira* species as well as *Rhizosolenia hebetata* f. *hebetata* seem to be the remnants of the group of species frozen into the ice from below in autumn.

Unlike our data on ice algae from the Siberian seas (Okolodkov 1989, 1990, 1992 a, b, c), comparatively significant part of the species existed in the ice at Hooker Island as the resting stages (Tab. I). After Priddle, Jordan and Medlin (1990), *Rhizosolenia hebetata* f. *hebetata* is probably the resting spores of *R. hebetata* f. *semispina* (Hensen) Gran. In literature on Arctic sea ice, 6 or 7 species belonging to the genera *Chaetoceros* and *Thalassiosira* were found as the resting spores, their frustules or their parent cells (Poreckij 1939, Horner 1976, Okolodkov 1992 c). It allowed to conclude that sea ice was a biotope for surviving of the neritic planktonic diatoms.

One more peculiarity is not only the presence, but even abundance of the chlorophycean *Rhizoclonium* sp. in the ice from Tikhaia Bay. Evidently, it reflects the coastal conditions of ice formation.

Thus, the ice community in Tikhaia Bay was represented by (1) benthic and planktonic-benthic (e.g. *Cylindrotheca closterium*) species of mainly marine and brackishwater-marine pennate diatoms, (2) their associated epiphytes (*Gonioceros septentrionale*), (3) marine neritic planktonic algae with their resting stages, (4) freshwater unicellular algae, (5) marine chlorophycean (*Rhizoclonium* sp.). Judging from single finding of the fossil species of the genus *Hemiaulus* Ehr., the ice may be theoretically a place for thanatocoenoses. Although the vertical distribution of the algae in the ice is not discussed here, the community described has the most differentiated structure among those observed in the Russian Arctic.

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Streszczenie

Osiem prób glonów z rocznego lodu morskiego zebrano w Zatoce Cichej (Wyspa Hookera, Archipelag Franciszka Józefa). W próbach oznaczono 58 gatunków okrzemek (nie uwzględniając nieoznaczonych Pennatae), 2 gatunki bruzdnic, 2 złotowiciowców, 1 zielenic i 1 sinic; ponadto cysty bruzdnic i złotowiciowców. Maksymalne zagęszczenie wyniosło 132300 komórek/l. W 4 próbach dominował *Aulacoseira granulata*, w innych *Nitzschia frigida, N. cylindrus* i bentosowe *Rhizoclonium* sp. wraz z cystami bruzdnic. *Xanthiopyxis polaris*, opisany przez Gran (1904) z arktycznego lodu morskiego jako okrzemka, jest prawdopodobnie cystą bruzdnicy. Zbiorowisko glonów lodu morskiego składało się z gatunków bentosowych i planktonowych, przeważnie morskich i słonowodnych okrzemek z grupy Pennatae, ich epifitów, morskich nerytycznych glonów wraz ze stadiami przetrwalnikowymi, słodkowodnych glonów jednokomórkowych i z jednego gatunku morskich zielenic.