Diatoms and the Ecological Conditions of Their Growth in Sea Ice in the Arctic Ocean

Abstract. *A summer field survey off Point Barrow, Alaska, revealed that Arctic sea ice develops a growth of phytoplanktonic diatoms. The diatoms are found in a brine solution in microfissures between ice crystals on the underside of the ice. The chlorophyll content of this layer is 100 times more than that of the surrounding sea waters; this has led to a hypothesis that a considerable fraction of the primary production of the Arctic Sea may be carried out in sea ice, especially during the spring and early summer months.*

The primary productivity of the Arctic Ocean has been reported to be very low, or the smallest of any ocean area. It shows a contradiction with the abundance of sea animals and zooplankton in the area, and the possibility of heterotrophic organic supply from lower latitudes has been suggested. Sometimes blooming of phytoplankton in waters around sea ice was also reported, and this has led to a hypothesis that sea ice might contain some plankton growth factors.

Table 1. Diatoms found in plankton layer at the bottom of Arctic sea ice.

Amphiprora kryophila
Gomphonema exiguum v. arctica
Navicula algida
N. crucigeroides
N. directa
N. gracilis v. inaequalis
N. kjellmanii
N. obtusa
N. transitans
N. transitans v. derasa
N. transitans v. erosa
N. trigonocephla
N. valida
Nitzschia lavuensis
Pinnularia quadratarea
P. quadratarea v. biconstracta
P. quadratarea v. capitata
P. quadratarea v. stuxbergii
P. semiinflata
P. semiinflata v. decipiens
Pleurosigma stuxbergii
P. stuxbergii v. rhomboides
Stenoneis inconspiqua

Recently, in the Antarctic Ocean, diatoms were found growing in a sherbet-like layer between snow cover and 1-year-old ice in summer pack. Their high productivity and ecological conditions were studied by us (*1*) and by Burkholder (*2*). Another type of diatom community on the underside of sea ice was also studied by Bunt (*3*) near McMurdo Sound in the Antarctic. In the Arctic a high chlorophyll concentration in sea ice was reported in one June month by Appolonio (*4*) at Devon Island.

We report here our studies of phytoplankton in the underside of sea ice in the Arctic. These observations were made in July and August 1964, several miles off Point Barrow area, Alaska.

The profiles of sea ice were examined first when ice was broken and upset by the icebreaker. Then 13 sea ice cores were obtained by a Sipre core sampler which takes a cylindrical core 2 to 3 m long and 3 inches (7½ cm) in diameter. The colored ice layers were obtained mostly as fragments, because of their fragility.

The ice samples were melted and filtered to collect the phytoplankton on filter paper, which was immediately fixed by hot steam for a few minutes. It was then dried and stored in a dark desiccator for about 2 months, when the chlorophyll content was determined in our shore laboratory by the pheophytin-*a* method, with a spectrophotometer, according to the method of Saijo (*5*).

The phosphorus and silicone content of the diatoms on the filter paper was calculated from the chlorophyll-*a* content according to the method of Parson (*6*). The chlorinity, phosphate, and dissolved silicate of the filtrate were determined by electroconductivity, the standard molybdenum blue method, and the standard molybdenum yellow method, respectively (*5*), immediately after melting. Some of the colored ice samples were sectioned and photographed in the cold room. Samples of phytoplankton for taxonomic work were fixed with formalin.

The thickness of the phytoplankton layer was between 5 and 30 cm. The average chlorophyll-*a* content was 120 μg/liter, while the maximum observed was 427 μg/liter, which was approximately 100 times higher than the chlorophyll-*a* concentration of the sea water surrounding the ice.

The flora in the ice consists of diatoms (Table 1). Eleven species of *Navicula*, six species of *Pinnularia*, two species of *Pleurosigma*, and one species each of *Amphiprora, Gomphonema, Nitzschia*, and *Stenoneis* were identified.

Photomicrographs of the sectioned ice revealed that diatoms were dividing and forming colonies in brine cells between the vertical-lined ice crystals. The temperature of the microhabitat in the brine cells is a stable −1.75°C.

The salt depression of the freezing point was calculated and showed a high chlorinity and hence high osmotic pressure of the brine solution during the period of formation of the sea ice.

Table 2 shows the average chloride, phosphate, and dissolved silicate content of the upper portion of the sea ice and the phytoplankton layer, and the phosphorus and silicone content of diatom bodies. It is significant that phosphorus and silicate were highly concentrated in the phytoplankton layer in diatoms. The average chloride content of our summer sea ice was less than half that of the April ice reported by Malmgren (2.4 per mill) (*7*).

Our observations of the phytoplankton layer in sea ice lead us to the conclusion that this habitat is neither a closed frozen system that disallows transportation of nutrient substances nor a completely inactive biochemical habitat owing to the extremely low temperature.

The large size of the phytoplankton community is the result of the high illumination available and a scavenging of nutrient from the freezing water.

The enclosed brines taken up during rapid freezing in the winter months gradually descend down through fissures between fine ice crystals, and the nutrients in the upper layer of the sea ice are made available to the diatoms.

Table 2. Comparison of average salt content in two layers in Arctic sea ice in summer.

Source	Chloride (per mill)	Phosphate (μg-atom/liter)	Silicate (μg-atom/liter)
	Upper layer		
Dissolved in filtrate	0.92	0.3	8
	Bottom plankton layer		
Dissolved in filtrate	1.13	0.3 to 2.0 (av. 0.9)	7 to 35 (av. 15)
In diatoms or collected on filter		(6.5)*	(40 to 60)*

* These are the phosphorus and silicone contents, respectively, of the diatom bodies.

The unutilized salts are discharged into sea water below.

The season sequence governing plant growth is as follows: During winter months, as a result of rapid freezing, nutrients and seed diatoms are enclosed in new ice, which is soon covered with snow. During spring, with the decrease of snow cover and onset of radiation, enough light is transmitted to the bottom portion of the ice to allow the photosynthetic diatoms to grow, or a colored layer to develop. With increasing radiation during summer, melted ice forms pools of water on the surface of the ice, while at the base of the ice the colored layer absorbs solar energy selectively, and is then sloughed off into the surrounding sea water.

The extensive growth of diatoms in surface snow layers of sea ice in the Antarctic (*1*) is not found in the Arctic, probably because of the low precipitation and rapid ablation of snow cover in the Arctic (*8*). However, the Arctic ice habitat at Barrow resembles the Antarctic diatom community at the bottom of thicker sea ice near the shelf ice studied by Bunt (*3*) in its fragile water-in-ice microstructure, chlorophyll-*a* content, and diversity of dominant species, although individual species are not the same.

Judging from similarity of the process of formation in the Arctic and the Antarctic, the ice habitat is believed to exist in other ice-covered districts. Because of its light-absorbing efficiency and freedom from grazing, the ice habitat is more suitable for diatoms than the sea water below.

The average chlorophyll-*a* content of sea ice off Barrow reaches about 24 mg/m^2 by a rough calculation based on the average thickness of the layer and its average chlorophyll content. If the same size of plankton layer exists in other Arctic districts, the primary production of the Arctic Ocean is not the smallest of any ocean region, and in considerable part it may occur in sea ice, especially in spring and early summer.

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Sceloporus occidentalis: Preferred Body Temperature of the Western Fence Lizard

Abstract. *Given equal thermal opportunities during four seasonal test periods, western fence lizards active above ground preferred constant body temperature throughout the year. Lizards recovered from subsurface retreats in the fall exhibited a mean body temperature significantly lower than that for sequestered lizards recorded during winter, spring, and summer.*

Mean preferred body temperatures of lizards active on the surface of the ground have been reported for a large number of species (*1, 2*). Nearly all such reports are based on field temperatures collected during one portion of the year. Hence they give no indication of the degree of constancy of the mean throughout the year. In addition, there has been little work on preferred temperatures of buried or sequestered lizards (*2, 3*).

Mayhew obtained field body temperatures for the granite spiny lizard (*Sceloporus orcutti*) during 11 months of the year and reported (*4*) a significantly lower preferred mean in winter (January and February). He suggests that there may be a lowering of the preferred body temperature during winter and that lizards emerging from hibernation in late winter have to acclimate to higher spring temperatures. Stebbins, however, reported no significant shift in the preferred body temperature of surface-active striped plateau lizards (*Sceloporus virgatus*) (*3*); he tested these lizards in the laboratory on runways with photothermal gradients during winter, spring, and summer. The experiments discussed in my paper were designed to ascertain whether the preferred body temperature of the western fence lizard (*Sceloporus occidentalis*) remains constant throughout the year if the animals are given a choice of temperature during four seasonal test periods.

A 34-gauge copper wire noose attached to an 8-foot (2.5-m) flyrod was used for capturing lizards. Cloacal temperatures were taken within 20 seconds after capture with one of two calibrated Schultheis thermometers. The same two thermometers were used throughout the study. Laboratory tests were conducted in runways, 113 cm long and 15 cm wide, provided with a sand substratum 2.5 cm deep. A 100-watt light bulb with reflector was placed at each end of these runways, and all lights were turned on from 10 a.m. to 5 p.m. each day. A gradient of sand surface temperatures ranging from 50°C directly beneath the lights to about 20°C in the center of the enclosures persisted while the lights were on. A light gradient also existed between the center and ends of each runway but was not measured. During the 17 hours of each day when the lights were off, the sand substratum assumed the air temperature of the cold room in which the runways were kept (18°C). Food (*Tenebrio* larvae) and water were available in the center of each runway.

All lizards were obtained within a 50-mile (80-km) radius of Berkeley, California. Animals were transported to the laboratory on the day of capture and were placed in the runways at densities of four to six animals per enclosure. Each group was maintained undisturbed for 3 days. Then cloacal temperatures were taken over a second 3-day period during the latter two-thirds of each photothermal day. This