Proc. Zool, Inst. Russ. Acad. Sci., 296, 2002: 39-46

Zoobenthos and ice distribution in the Arctic seas

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The study of ice as an important component of marine ecosystems has a relatively short history. The earlier opinion about hostility of sea ice proper and ice formation to all living things is still widely distributed, although it is already known, that it not true. Ice - an environment for the numerous animals and plants – is structural and functional basis of the so-called cryopelagic ecosystems. The numerous microalgae, living on the bottom surface and inside ice, serve as food for habitat there crustaceans, which in turn supply food for small fish. Fish is eaten by sea birds and the seals providing with food of polar bears and arctic foxes frequently accompanying them. On ice the seals give refuge to their brooding. Whales, walruses and benthos feeding birds are concentrating along the ice edge, as along a natural barrier.

Information about the role of sea ice in the life of sea bottom organisms until now was very poor. It was only known that on shoals of the Arctic seas the drifting ice could destroy wide fields of kelp and settlements of invertebrates. Small animals frozen into the ice at long can be transported on a huge distance from the shoals by currents. After the ice melting they frequently occur, still alive, in the areas unusual for their habitation and thus create biogeographic puzzles for zoologists.

The idea that sea ice is a major factor providing high productivity of zoobenthos communities in the Arctic seas, seems, to put it mildly, is unscientific. This may be accounted for by both, subjective, and objective reasons.

Thus, the Russian data on detailed position of seasonal ice edge were not mildly in order to because to avoid an opportunity of commercial use by hydrometeorological services and relative organizations. Access to this information has cardinally changed after the beginning of regular publication of results of the satellite images received, basically by foreign oceanographic agencies and institutes.

The biological processes occurring under the ice and along the edge also were poorly investigated because of inaccessibility of the appropriate areas for common research vessels. During a long time only open waters, and only in summer period, were investigated in Arctic regions whereas the areas covered with seasonal or multiyear ice, began to be studied only during the last 10-15 years from icebreaking vessels. Research of the water areas covered with ice was considered uninviting, and there was standard opinion that any life under the ice is slowed down or stops, as primary production under the ice is insignificant because of lack of light and low temperature.

Our attention has been attracted by distribution of zoobenthos biomass in some Arctic seas, which is insufficient explained by the influence of such common marine factors as temperature, salinity, oxygen and sediments.

In our analysis the archive materials on quantitative observations of bottom fauna in the Barents, Kara, Laptev, East-Siberian and Chukchi seas, collected in total at 950 stations in 1932-1935, 1968-1970, 1975-1986 and 1993-1995, were used. Also the results of long-term observations over ice edge position during a light season in the seas of Russian Arctic (Shlitcer, 2002) were involved.

On the maps of ice edge distribution and distribution of a zoobenthos biomass, constructed by us, the areas of high biomass values are matching well with isolines showing the longest duration of average multiyear ice cover with 20 % consolidation and positions of stationary polynias (Fig.). The casual probability of this match for five seas is equal 3 %.

The revealed features of zoobenthos distribution may be caused only by the high values of plankton primary production and an intensive sedimentation of organic material on the bottom, which are in turn determined by set of other reasons. As has been found by analysis of the information published in literature, especially for last 10-15 years, the ice edge areas have the same, or higher, values of primary production as in the areas of constantly open water. Thus, for example, in the Bering and in the Barents seas phytoplankton communities of the ice edge zones may form 40-50 % of regional annual primary production (McRoy and Goering, 1976). That fact takes place, because this is promoted by functioning of some mechanisms and factors, characteristic of ice edge zones or zones of floating ice. Some of them resolve the problem of nutrient depletion in stratified edge waters, others solve the problem of effective delivery of phytodetritus to the bottom Table).

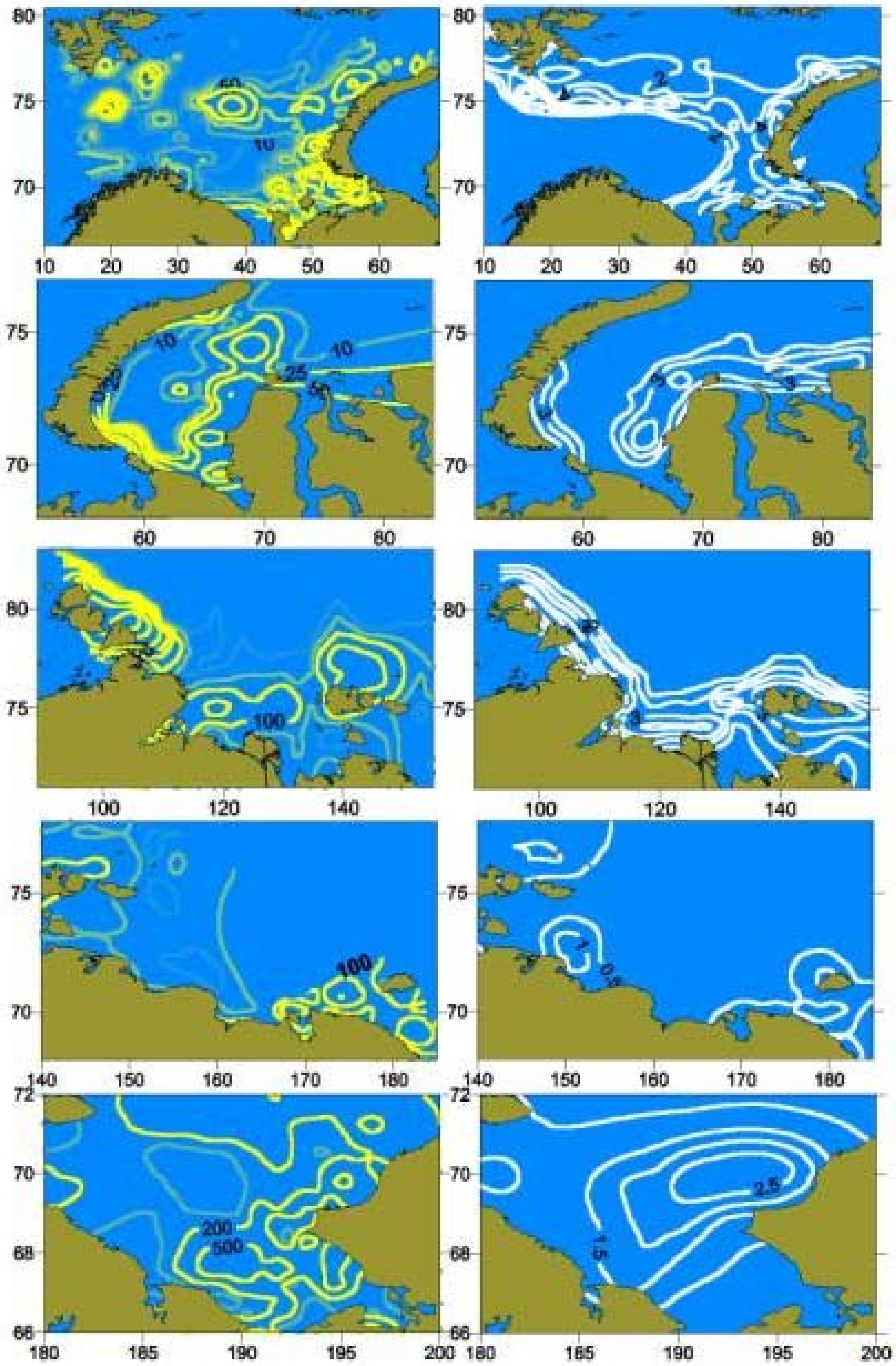

Fig. Distribution of zoobenthos biomass (left panel, g/m^2)* and average multiyear duration of 20% ice cover (right panel, month)** in the Barents, Kara, Laptev, East-Sibirian and Chukchi seas.

*calculated on the base of IORAN, PINRO, MMBI, ZIN archive data;

**calculated on the base of Shlitcer's "Ocean Data View" (2002).

Factors and phenomenon increasing primary production and phytodetritus sedimentation in the areas of seasonal ice edge and permanent polynyas

FACTORS AND PHENOMENONS	PERMANENTLY OPEN WATERS	SEASONAL ICE EDGE AND POLYNYAS
Upwellings and downwelligns	?	+
Turbulent hydrological formations	?	+
Photosynthesis below pycnocline	--	+
Ice algae	--	+
Enrichment of the photosynthesis layer by the nutrients from the melting ice	--	+
Phytoplankton vegetation up to the new ice formation	--	+
Fast phytoplankton sinking	--	+
Low grazing of phytoplankton	--	+

High primary production in the areas of floating rarefied ice can be supported by the edge upwellings (Smith, 1987), providing constant inflow of nutrients during the whole season of vegetation. The similar phenomenon is observed in zones of permanent polynias in case of sufficient insolation (Hirche et al., 1991) where formed downwelligns promote horizontal transport of phytodetritus outside polynia area (Honjo, 1990), and replacing water masses provide inflow of nutrients in zone of production.

The other factor providing the high primary production in the ice edge zones is formation of a certain vertical hydrological structure of water column. The ice edge in the Arctic seas, as a rule, corresponds to position of polar front, if it is present. The distance between front and edge in the Barents Sea reaches, on the average, several tens of kilometres (Zabruskova, 1989), where the interaction of frontal water masses takes place, and where the Atlantic waters, denser and rich in nutrients, are deepening under less saline Arctic waters. The turbulent whirlwinds, caused by orography of sea bed, provoke the mixing of adjoining layers of different water masses, resulting in enrichment by nutrients of the top stratified freshened layer of the Arctic waters along the ice edge owing to the higher content of nutrients in the Atlantic waters. Such mechanism of ice edge water enrichment by nutrients, obviously, takes place not only in the Barents Sea (Slagstad, 1984), but also in the Bering Sea (Alexander and Neibauer, 1981), and also in Eastern Greenland Sea (Backley et al., 1979). Thanks to this mechanism, duration of the vegetative period in the ice edge zone is prolonged and is less dependent from nutrient budget in freshened photosynthetic layer.

The following reason of high initial production in ice edge zones may be the increased transparency of the Arctic waters in surface freshened layer formed owing to ice melting. In absence of the vertical mixing, necessary for recycling of nutrients, initially intensive ice edge bloom of microalgae quickly fades. At the same time under pycnoclyne, in the deeper layers photosynthetic zone, owing to steady and sufficient inflow of nutrients, phytoplankton continues to vegetate (Savinov, 1997), and microalgae, sinking to the sea floor, are becoming a stable food source for zoobenthos communities.

At the same time more and more data occur, testifying that under sufficient insolation conditions and when snow cover is thin or absent on ice, the production of ice microalgae may be enough high, and its development is not limited by deficiency of nutrients, up to the beginning of intensive ice melting (Grossmann, Gleitz, 1997; Makarevich, 1998; Zernova et al., 2000). Thus, due to ice microalgae the bloom in ice edge areas, as a rule, outstrips the bloom in permanently free of ice areas by 1-2 months (Strass, Nothig, 1996).

The ice melting also raises concentration of nutrients in ice edge surface layer of the Arctic waters, as concentration of nutrients in the ice proper greatly exceeds those in water.

The above mechanisms support intensive, as in spring, phytoplankton bloom in the ice edge zones till the formation of new ice (Hegseth, 1997). The increase of ice consolidation over 20 % probably limits the insolation and inhibits the vegetation. The evidence told above allows to make conclusion, that high primary production of plankton is typical feature of the ice edge zones.

The mechanism of effective delivery of organic substance produced by phytoplankton to the bottom in the ice edge zones has been described, and it has been established, that when a certain concentration of phytoplankton cells in water is achieved, they begin to produce more polysaccharides and stick together in flakes that sink to the bottom much faster than single cells. Formations of phytoplankton conglomerations exclude a possibility to be eaten by zooplankton or to be the destroyed by bacteria during sinking (Smetacek, 1985).

It was noted that at identical values of production the intensity of phytodetritus sedimentation to the bottom is higher after cold winters. This occurs because till spring a dispersed wintering zooplankton survives, and zooplankton from warmer areas has no time to follow a receding ice edge and has no possibility to feed on phytoplankton of these areas.

The mechanisms described are absent or are not typical of permanently ice free waters, and some of them may be absent or work less effectively in concrete ice edge zones.

In the Barents Sea, which becomes almost completely free from the ice every year, the areas of high zoobenthos biomass coinciding with a zone of 20 % of ice edge, stretch along the line: Spitsbergen – Bear Island – Novaya Zemlya - southeastern part of the sea are situated. In these areas because of a weak river runoff and a high transparency of waters, the development of rich benthic fauna is provided by development and functioning of ice microalgae, primary production under pycnoclyne layer and ice edge phytoplankton bloom.

In the Kara Sea, which is seldom completely free from ice, the floating rarefied ice and open water usually occupy southwestern shoals and the central part of the sea, where the areas with the highest zoobenthos biomass also correlate with ice edge. However, owing to huge inflow of river waters with high concentration of suspended particles, blocked primary production producing under a pycnoclyne layer, the development of rich benthic fauna should be determined basically by the successful development of ice algae and ice edge phytoplankton bloom.

In the Laptev and East-Siberian seas, partly free from ice in summer time, maximum zoobenthos biomass also coincides with the zone of floating ice in the southern parts and with sites of permanent polynias. Because of a small transparency of seawaters owing to a powerful river runoff, the formation of high biomass of bottom fauna is caused only by development ice algae and ice edge phytoplankton bloom.

The situation with formation of high zoobenthos biomass in the Chukchi Sea apparently is close to those in the Barents Sea. In both seas, where the river runoff is insignificant and transparency of waters is high, the development of rich zoobenthos is provided not only by the ice edge phytoplankton bloom and ice algae functioning, and also by the primary production formation under pycnoclyne layer.

Thus, the seasonal ice edge should be considered as a major factor increasing the primary production of plankton and intensity of phytodetritus sinking. In combination both factors provide the existence of regional maximas of zoobenthos productivity in the open areas of the Arctic seas. The importance of seasonal ice edge for other animals was noted above and it is clear now, that the ice edge zone is the major component of Arctic ecosystems, and that its any essential fluctuation, significantly exceeding the seasonal variations, may provoke very negative global consequences.

Nevertheless, such opportunity is quite real at the moment. According to the supervision results of climate changes in the Northern Hemisphere the temperature of air has increased almost everywhere by 1-3°C during the last thirty years. If this tendency will continue, according to forecasts of five leading world climatic centres, the temperature in the current century will rise by 4-5°C on the average, that, undoubtedly, will cause significant reduction of the extending of polar ice. In the Barents Sea the deviation of ice edge further to the north to shelf edge will cause not only displacement of traditional fishery in the same direction, but also will result in noticeable reduction of stocks benthos-feeding fish, such as American plaice, haddock, catfish and some others

REFERENCES

Alexander V., Niebauer H.J. et al. 1981. Oceanography of the eastern Bering Sea ice-edge zone in spring. Limnology and oceanography. 26(6): 1111-1125.

Grossman S., Gleitz M. 1997. Primary and microheterotrophic productivity within ice-associated habitats. Ber. Polarforschung. 226:73-79.

Hegseth E.N. 1997. Phytoplankton of the Barents Sea – the end of growth season. Polar Biol. 17: 235-241.

Hirche H.-J., Baumann M.E.M., Kattner G., Gradinger R. 1991. Plankton distribution and the impact of copepod grazing on primary production in Fram Strait. Greenland Sea. J. Mar. Syst. 2: 477-494.

Honjo S. 1990. Particle Fluxes and Modern Sedimentation in the Polar Oceans. Polar Oceanography, Part B: Chemistry, Biology, and Geology. Academic Press, Inc. 688-739.

Makarevich P.R. 1998. The vernal state or the microphytoplankton community in the ice-covered areas of the southeastern Barents and the southwestern Kara seas. In: Biology and oceanography of the Kara and Barents Seas (along the Northern Marine route). Apatity, KSC RAS. 138-149 (in Russian).

McRoy, C.P., Goering, J.J. et al. 1976. Annual budget of primary production in the Bering Sea. Marine science communications. 2(5): 255-267.

Savinov V.M. 1997. Photosynthetic pigments and primary production in the Barents Sea: spatial distribution. In: Plankton West Arctic Seas. Apatity, KSC RAS. 127-145 (in Russian).

Schlitzer R. 2002.Ocean Data View, http://www.awi-bremerhaven.de/GEO/ODV.

Smetacek V. 1985. Role of sinking in diatom life-history cycles: ecological, evolutionary and geological significance. Mar. Biol., 84: 239-251.

Smith W.0. 1987. Phytoplankton dynamics in marginal ice zones. Oceanograph. Mar. Biol. 25: 11-38.

Strass V.H., Nothig E.-M. 1996. Seasonal shifts in the ice edge phytoplankton blooms in the Barents Sea related to the water column stability. Polar Biol. 16: 409-422.

Zabruskova M.M. 1989. Structure and variability of frontier zone in the Barents Sea. In: Life and environment of Polar Seas. Leningrad, Nauka. 30-36 (in Russian).

Zernova V.V., Nothig E.M., Shevchenko V.P. 2000. Vertical microalgae flux in the northern Laptev Sea (from the data collected by the yearlong sediment trap). Oceanology. 40 (6): 801-808.