ISSN 0001-4370, Oceanology, 2017, Vol. 57, No. 1, pp. 222–224. © Pleiades Publishing, Inc., 2017.
Original Russian Text ©A.F. Sazhin, S.A. Mosharov, N.D. Romanova, N.A. Belyaev, P.V. Khlebopashev, M.A. Pavlova, E.I. Druzhkova, M.V. Flint, A.I. Kopylov, E.A. Zabotkina, D.G. Ishkulov, P.R. Makarevich, A.F. Pasternak, P.N. Makkaveev, A.N. Drozdova, 2017, published in Okeanologiya, 2017, Vol. 57, No. 1, pp. 246–248.

INFORMATION

The Plankton Community of the Kara Sea in Early Spring

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Received July 27, 2016

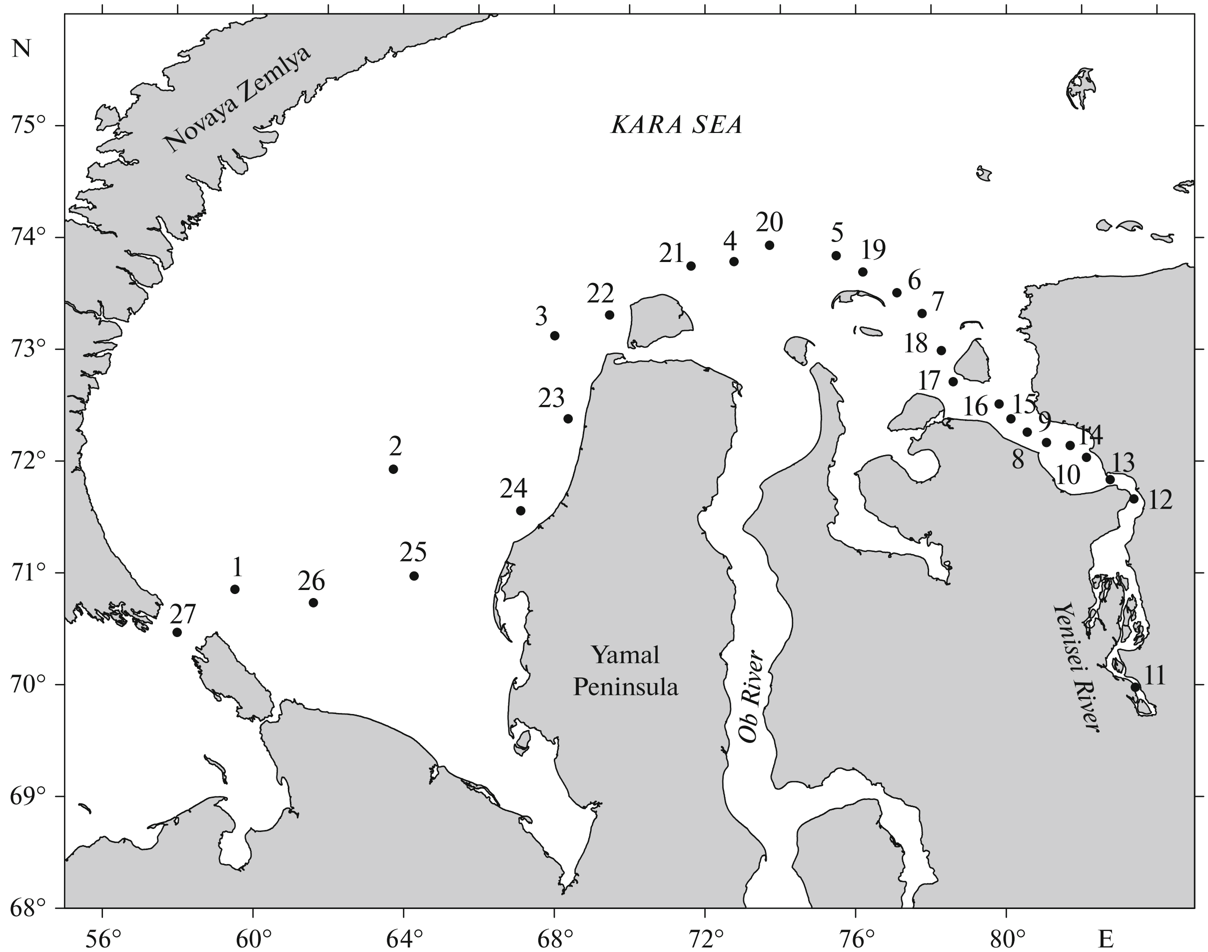
DOI: 10.1134/S0001437017010179

The almost complete absence of information about the state of the Kara Sea plankton community in early spring prevents reconstruction of the seasonal cycle for the ecosystem of this basin and assessment of the effect of current climate changes in the Arctic. Studies performed during March 29–April 08, 2016 on the vessel *Noril'skii nikel'* yielded data that to a certain degree fill this gap. Samples for assessing the plankton structural and production characteristics were taken at 27 stations (figure) and hydrophysical, hydrochemical, and productivity parameters were recorded in the sea surface layer. The following characteristics were measured: temperature, conductance, illumination, alkalinity, and the concentrations of oxygen, silicon, phosphates, nitrates, total suspended solid material, and suspended and dissolved organic carbon. The spectral distribution of fluorescence and its intensity were recorded for colored dissolved organic matter. The species composition; abundance; and biomass of the autotrophic and heterotrophic picoplankton, nanoplankton, and microplankton; chlorophyll *a* concentration; assimilation number; primary and bacterial production; concentrations of virioplankton and bacterioplankton in water; and abundance of viruses associated with bacterial cells were determined. Total samples of zooplankton from the sea bottom to surface were collected at two stations.

Along the sailing line of the vessel, the Kara Sea was covered with ice (thickness, 30–50 cm with different degrees of consolidation); some areas of open water were present, mainly near the westernmost part of the Yamal Peninsula and in the Kara Strait. Air temperature did not rise above 0°C; the water temperature in the surface layer changed from –1.9 to 0°C; salinity fell in the range of 0.12 (station 11, Yenisei River) to 35.43 psu (station 23, western coast of the Yamal Peninsula). The alkalinity of seawater was 2.1–2.3 μg-atom/L, and of Yenisei River water, 1.6–1.7 μg-atom/L. The silicon concentration in seawater was 1.2–41.3 μg-atom/L; phosphate concentration, 0.15–0.65 μg-atom/L; nitrite, 0–0.1 μg-atom/L; and nitrate concentration 3.0–7.2 μg-atom/L. The concentration of silicon in Yenisei River water increased to 113–135 μg-atom/L; of phosphates, to 0.36–0.61 μg-atom/L; and of nitrates, to 12.2–16.8 μg-atom/L. Thus, the content of nutrients in the sea surface layer at the end of March–beginning of April could not be the factor that limited plankton development in both the marine and estuarine biotopes. The oxygen saturation in seawater amounted to 87–100%, and in river water, to 73–78%.

The average concentration of suspended solids in the Kara Sea surface layer was 1500 μg/L, varying from 260 to 5040 μg/L, which results from low river discharge in the end of March–beginning of April. The variation in the content of suspended solids in the early spring was higher than the summer–spring season, which is most likely determined by sorption/desorption of suspended solid material during ice formation and melting. The same is also true for suspended organic carbon. The average concentration of organic carbon in suspended material was 133 μg/L (range, 12.8–621 μg/L). The average concentration of dissolved organic carbon in the surface layer was 3.8 mg/L, changing in the range of 1.9–5.1 mg/L. Colored dissolved organic carbon is mainly represented by terrigenous humic matter, which are dominant in dissolved organic matter in the riverine and estuarine Yenisei River regions. The influence of the Ob and Yenisei river discharges to the west of Yamal Peninsula is insignificant, and the role of autochthonic organic matter in the surface water increases.

The chlorophyll *a* concentration during the study period varied from 0.08 to 3.223 μg/L with an average of 0.624 μg/L and increased to 9.483 μg/L only in the Kara Strait. The average share of pheophytin in seawater was 41% of the sum of chlorophyll and pheophytin, reaching 97% (stations 8 and 9) at individual river stations. The primary product in the water areas



Scheme of stations in Kara Sea in March–April 2016 (vessel *Noril'skii nikel'*).

covered with ice on average amounted to 0.040 mgC/m^3 h^{-1} and was fourfold higher (0.15 mgC/m^3 h^{-1}) in ice-free areas. The region of the Kara Strait (station 27) was an exception; the primary product there reached 6.73 mgC/m^3 h^{-1} for an autotrophic plankton biomass of 457 mgC/m^3, being the maximum value recorded during this season. All stations fall into three groups according to the abundance, biomass, and species composition of phytoplankton and protists, namely, the stations with a high level of autotrophic algae (stations 3 and 27); stations with a low abundance of phytoplankton but dominance of autotrophic organisms (stations 1, 2, 4, 5, 18, 21, and 23–26); and stations with prevalence of heterotrophic component in the microplankton (stations 7, 8, 14, 16, 19, 20, and 22). Autotrophic algae were prevalent in the southwestern part of the Kara Sea; their biomass varied from 2.01 to 11.53 mgC/m^3 at a heterotrophic plankton (microalgae and infusoria) biomass of 0.31–2.01 mgC/m^3. The dominant species among the autotrophic algae were *Fragilariopsis oceanica, F. cylindrus, Thalassiosira* spp., *Rhodomonas salina, Dicrateria inornata,* and *Pauliella taeniata* as well as *Nitzschia frigida* and *Entomoneis paludosa,* most likely reaching water from the lower ice surface. Heterotrophic algae and infusoria were prevalent in the estuarine regions of the Ob and Yenisei rivers (stations 7, 19, 20, and 22); their biomass varied from 1.25 to 2.01 mgC/m^3 for an autotrophic phytoplankton biomass of 0.62–1.35 mgC/m^3. As for stations 4, 5, 18, and 21, autotrophic phytoplankton there was the major contributor to microplankton. Its biomass varied in the range of 0.70–6.78 mgC/m^3 and *Navicula* spp., *Melosira arctica, Teleaulax acuta,* and *Pyramimonas marina* were the most abundant species. Heterotrophic flagellate algae ad infusoria were prevalent in the microplankton of the Yenisei River area (stations 8, 14, and 16); its biomass varied from 0.62 to 5.14 mgC/m^3, while autotrophic algae constituted only 0.31–0.54 mgC/m^3.

The abundance of bacterioplankton in early spring varied in the range of 72–354 × 10^3 cells/mL with a biomass of 1.27–6.57 mgC/m^3. The daily bacterial production did not exceed 6.18 mgC/m^3. The counts of free viruses in Kara Sea surface water varied in the range of 1.05–8.47 × 10^6 particles/mL with an average of 4.04 ± 0.91 × 10^6 particles/mL. The rate of bacteria with attached virus particles varied from 14.2 to 24.8% of the total bacterial count with an average of 19.6 ± 1.2%. The infected bacterial cells contained up to 78 phages/cell. The average virus-induced lethality rate for bacterioplankton was 7.8 ± 0.8% of bacterial production.

The zooplankton at stations 20 and 24 (depth of approximately 10 m) almost completely consisted of *Pseudocalanus acuspes,* mainly represented by stage IV and V copepodites. Stage I–IV copepodites of *Oithona similis* were considerably less abundant. The total abundance of zooplankton at all examined stations was 2200–3310 ind/m^2 and biomass, 143–870 mg fresh weight/m^2. The physiological state of zooplankton corresponded to the end of winter; oocyte development started in the gonads of only part of *P. acuspes* females (31%).

During fieldwork, diatom blooming on the lower ice surface had already ended in the examined regions of the Kara Sea. This is demonstrated by both the general appearance of the lower ice edge, colored brown, and the remains of characteristic ice algal colonies, mainly, *Nitzschia frigida,* in the surface water samples. Intensive blooming of phytoplankton with the prevalence of diatoms was observed only near the northernmost part of the Yamal Peninsula under a 40–50-cm ice layer and in open water areas in the Kara Strait, where *Phaeocystis pouchetii* started to bloom (but had not yet reached the blooming maximum) on the background of a diatom outbreak. *Phaeocystis pouchetii* blooming was recorded for the first time in the boundary area between the Kara and Barents Seas. The phytoplankton in the Ob River estuary comprised exclusively marine species; no freshwater *Aulacoseira* spp. were recorded in the surface samples.

For now, we can only state that the mechanisms that trigger intensive seasonal development of particular algal species or groups in the Kara Sea are rather vague. A few available data suggest that intensive sea phytoplankton growth starts as early as the end of February both at the lower ice edge and in the water under ice. This appears in a spotlike manner and is rather independent of the state of ice cover. Species associated with desalination become prevalent in the Yenisei and Ob river estuaries with the beginning of spring flood, while algae preferring high salinity play a secondary part.

ACKNOWLEDGMENTS

The field work and sampling were supported by the Russian Science Foundation (project no. 14-17-00681) and the Russian Foundation for Basic Research (project no. 14-05-05003 Kar_a). and sample assays, by the Russian Foundation for Basic Research (project nos. 14-05-00028a, 14-04-00130a, and 16-35-60032 mol-a-dk).

Translated by G. Chirikova