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INFORMATION

Oceanological Research of the Baltic Sea in the 51st Cruise of the PV *Akademik Sergey Vavilov* (June–July 2021)

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Abstract—The 51st cruise of the PV *Akademik Sergey Vavilov* (June 30–July 14, 2021) included the study of redox conditions in the Baltic Sea deeps. Water temperature in the upper quasi-uniform layer significantly exceeded average climatic values for July, especially in the Gulf of Finland (by 7–7.5°C) due to abnormally hot weather. A setup of cyanobacterial aggregates from the subsurface layer to the surface was observed, it occurred earlier than normal. In cooperation with the Immanuel Kant Baltic Federal University an integrated survey was carried out at the Kaliningrad carbon polygon and the IV International Summer School "Coastal Sea Zone: Research, Management and Perspectives" was held.

Keywords: Baltic Sea, Gotland Deep, Gdansk Deep, Gulf of Finland, anoxic conditions, hypoxic conditions, carbon polygon

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A comprehensive environmental survey of the Baltic Sea was carried out during the 51st cruise of the PV *Akademik Sergey Vavilov* (June 30–July 14, 2021) (Fig. 1). Within the framework of the pilot project of the Ministry of Education and Science of the Russian Federation to create polygons for the development and testing of carbon control technologies, a comprehensive oceanological survey was carried out at the offshore site of the Kaliningrad carbon polygon. The operator of the polygon is the Immanuel Kant Baltic Federal University (IKBFU). The Atlantic Branch of the Shirshov Institute of Oceanology RAS (AB IO RAS) is a participant of this research programme. Several parts of the expedition programme were carried out jointly with the Atlantic Branch of the Russian Federal Research Institute of Fisheries and Oceanography, the A. P. Karpinsky Russian Geological Research Institute and the Russian State Hydrometeorological University.

MATHERIALS AND METHODS

Hydrophysical measurements were taken at the stations and from the moving vessel using Sea&Sun Tech CTD 90M and Idronaut Ocean Seven 316 Plus probes in a free fall mode. Water samples for hydrochemical analyses were taken at the stations using hydrological complex Hydrobios MWS12 Slimline equipped with Niskin bottles. The content of oxygen and carbon dioxide, reduced sulphur compounds, chlorides, sulphates and pH were determined onboard. Water samples for nutrients, oil products, suspended matter and iron content were taken to onshore laboratories for analysis.

Underway surveys of the bottom sediments acoustic structure were carried out with the Kongsberg EA600 (12 kHz) vessel-mounted echosounder. Bottom sediments were sampled with corers, including a hermetic one to obtain undisturbed upper part of the sediment along with bottom water, and with a Van Veen grab. A lithological description of the sediments, pH and Eh measurements, sorting (special packing for dissolved gases determination, geochemical and grain-size compositions) were carried out onboard. Sediment samples were also collected for subsequent DNA extraction, 16S rRNA gene amplification and sequencing on the Illumina MiSeq platform, as well as fixation and extraction of total DNA from ferromanganese nodules and underlying sediment.

Hydrobiological studies included chlorophyll *a* and primary production analysis, sampling of bacterioplankton, phytoplankton, zooplankton, ichthyoplankton, meio- and macrozoobenthos. Juday plankton net (Ø50 cm, 100 μm), ICS-80 net (Ø80 cm, 500 and 330 μm) and WP-2 net (Ø60 cm, 100 μm) with a trapdoor, as well as Van Veen grab (0.1 m^2) were used for sampling.

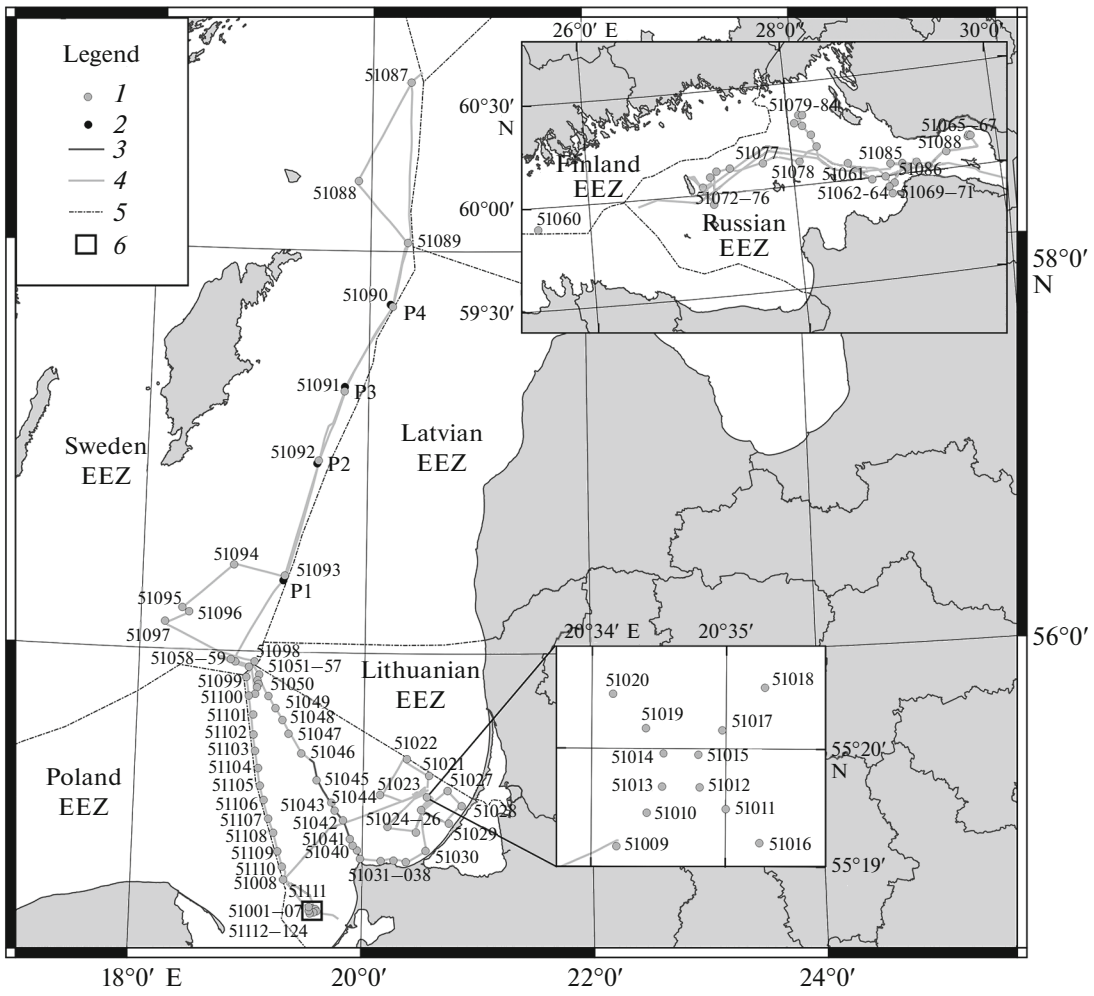

Fig. 1. Area and types of cruise work during cruise 51 of the PV *Akademik Sergey Vavilov*: (*1*) oceanological stations (ASV), (*2*) points of downstream measurements, (*3*) continuous hydrophysical profiles, (*4*) downstream geoacoustic profiling, (*5*) boundaries of exclusive economic zones, (*6*) Kaliningrad carbon polygon.

Data for estimating carbon fluxes in the marine environment was obtained at the offshore site of the Kaliningrad carbon polygon. A drift sediment trap has been tested to study vertical fluxes of organic carbon.

PRELIMINARY RESULTS

The expedition was carried out in abnormally warm conditions for July: coastal waters of the South-Eastern Baltic Sea had warmed up to 21–22°C, which is typical for mid-August. The temperature of the upper quasi-homogeneous layer has exceeded the average climatic values for July (for 1955–2018): by 5–6°C in the South-Eastern Baltic Sea, by 3.5–4°C in the central Baltic, and by 7–7.5°C in the Gulf of Finland.

The first stage of the expedition was carried out between Kaliningrad and St. Petersburg, and a subsurface phase of the cyanobacterial sea bloom was observed above the seasonal thermocline (depths ~0–10 m). Potentially toxic *Aphanizomenon flosaquae* and *Nodularia spumigena* have dominated in the open sea. *Dolichospermum* sp., *Microcystis* sp. were recorded in the Gulf of Finland. Aggregates of cyanobacterial cells were observed in the sea surface layer locally and only in shallow coastal waters of the South-Eastern Baltic Sea and the Gulf of Finland. In comparison with 2020, a surface algae bloom was observed in the same area in July [1]. The blooming has reached the surface phase with mostly dominance of *Nodularia spumigena* only in 7–10 days, during the vessel way back.

The Baltic Proper experiences further bottom salinity decrease due to absence Major Baltic Inflows. Compared to August 2020, salinity was 0.4–0.6 PSU lower in the Gdansk Deep and 0.1–0.2 PSU lower on the slope of the East Gotland Deep and above the Gdansk–Gotland Sill. The Gotland Deep anoxic conditions were noticed at the horizon of 30–40 m above the bottom, and the Gdansk Deep anoxic conditions has started at the depth 10 m above the bottom.

In the erosional trench on the Gdansk–Gotland Sill, again, as in 2020 [2], the bivalve mollusk *Astarte borealis* was noticed, indicating at least the periodic oxygenation.

The dissolved oxygen content was gradually decreasing with depth within the shallow part of the Eastern Gulf of Finland. There was no subsurface maximum, and oxygen saturation of water sharply decreased in the thermocline. The deep part of the gulf had a subsurface dissolved oxygen content maximum (layer 5–20 m), the pronounced oxycline (25–30 m), and the near-bottom layer of low dissolved oxygen content (up to hypoxia).

A number of elongated meridional-trending swell-like relief forms, that were formed by eolian processes during sea level changes in the Holocene were noticed on Bolshoy Tyuters Island. Thus, an extensive and thick dune ridge (up to 20–30 m) could have been formed under conditions of rapid sea level decrease and exposure of a large bottom area with sandy sediments for subsequent eolian transport and redeposition.

In accordance with the concept of the "Floating University", the IV International Summer School "Coastal zone of the sea: research, management and prospects" was held, organized by the IKBFU with the assistance of AB IO RAS.

FUNDING

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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