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# Effect of climate change and mollusc invasion on eutrophication and algae blooms in the lagoon ecosystems of the Baltic Sea

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Coastal lagoons are most vulnerable to impacts of natural environmental and anthropogenic factors. The Curonian Lagoon and Vistula Lagoon are the largest coastal lagoons of the Baltic Sea, relating to the most highly productive water bodies of Europe. The Curonian Lagoon is choke mostly freshwater lagoon, while the Vistula Lagoon is restricted brackish water lagoon. In the last decades the nutrients loading changes, warming trend and biological invasions are observed. The researches (chlorophyll, primary production, nutrients, phytoplankton, benthos, etc) were carried out monthly since 1991 to 2014. The database includes 1600 stations in the Curonian Lagoon, 1650 stations in the Vistula Lagoon. Eutrophication and algae blooms are most important problems. Multiple reductions of nutrients loading from the watershed area in 1990s did not result in considerable improvement of the ecological situation in the lagoons.

The Curonian Lagoon may be characterized as hypertrophic water body with "poor" water quality. Climate change in 1990s-2000s combined with other factors (freshwater, slow-flow exchange, high nutrients concentrations) creates conditions for Cyanobacteria “hyperblooms”. Hyperbloom of Cyanophyta (average for the growing season Chl > 100 $\mu$g/l) were observed during 4 years in 1990s and 7 years in 2000s. The summer water temperature is the key environmental factor determining the seasonal and long-term variability of the primary production and algae blooms. Mean annual primary production in 2010-2014 (600 gC·m-2·year-1) is considerable higher, than in the middle of 1970s (300 gC·m-2·year-1). The local climate warming in the Baltic region caused ongoing eutrophication and harmful algae blooms in the Curonian Lagoon despite of significant reduction of nutrients loading in 1990s-2000s. Harmful algal blooms in July-October (chlorophyll to 700-3400 $\mu$g/l) result in deterioration of the water chemical parameters, death of fish in the coastal zone and pollution with toxins, symptoms of exposure are observed at different trophic levels (zooplankton, fish). "Hyperblooms" of Cyanobacteria is the most dangerous for coastal towns (Polessk, Zelenogradsk) and tourist resorts (UNESCO National Park "Curonian Spit").

Also, unfavorable effects of eutrophication have been observed in restricted Vistula Lagoon. Mean annual temperature increased by 1.4° for 40 years, and water warming combined with other factors created conditions for phytoplankton “hyperblooms” (70-80 $\mu$g Chl/l) in 1995-2010. Mean annual primary production in 2000s (430 gC·m-2·year-1) is considerable higher, than in the middle of 1970s (300 gC·m-2·year-1). The climate warming was cause ongoing eutrophication and harmful algal blooms in summer in 1990-2010 despite of significant reduction of nutrients loading in the lagoon. After the invasion of the North American filter-feeding bivalve Rangia cuneata the benthic biomass increased by 8 times (360 g/m2), and chlorophyll decreased by 3.5 times (10 $\mu$g/l) in 2011. Water quality is significantly improved from “poor” to “satisfactory” level in 2011-2014, e.g., transparency increased by 2 times. The phytoplankton assimilation numbers increased to maximum (300-400 mgC·mgChl-1·day-1), which are discover in aquatic ecosystems, and primary production remained at previous level. Therefore mollusc invasion improved water quality, but Vistula lagoon ecosystem remained at eutrophic-hypertrophic level. This allowed the function to other trophic groups (zooplankton, fish) at a stable long-term level.