EFFECT OF CLIMATE CHANGE AND ALGAL BLOOMS ON pH IN THE LAGOON OF THE BALTIC SEA

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INTRODUCTION

The Curonian and Vistula Lagoons are the largest lagoons of the Baltic Sea. The Curonian Lagoon is choke mostly freshwater lagoon, while the Vistula Lagoon is restricted brackish water lagoon. Ongoing eutrophication is one of the most important problems. The purpose of this research is analysis of long-term changes of chemical and biological parameters in the Lagoons and impact of environmental factors (e.g. climate change), eutrophication and harmful algal blooms on pH in lagoons.

MATERIAL AND METHODS

The researches of hydrological, chemical and biological parameters, including primary production (PP), chlorophyll (Chl), phytoplankton, nutrients, pH and others were carried out monthly in 1981-1982 and 1991-2014 from March to November at 12 stations in the Curonian Lagoon and at 9 stations in the Vistula Lagoon Location of this stations corresponds to hydrological and hydrochemical division and covers the Russian waters (fig. 1).

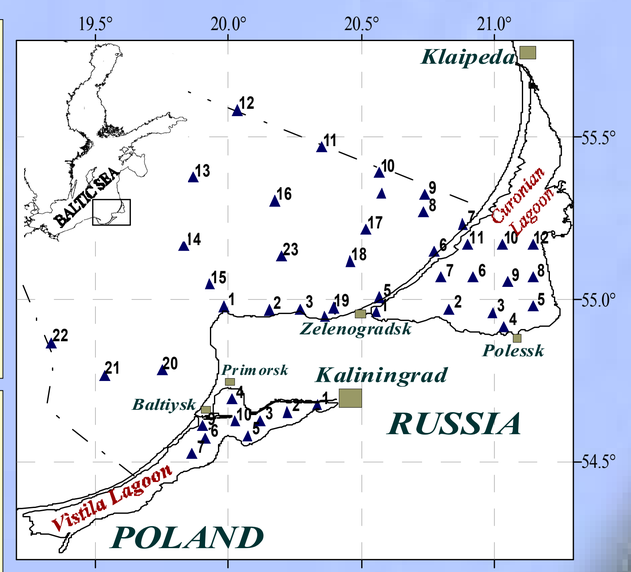

Fig. 1. Monitoring stations in the Baltic Sea, Vistula and Curonian Lagoons

RESULTS

The Curonian Lagoon may be characterized as a hypertrophic water body and Vistula Lagoon as a eutrophic-hypertrophic water body.

Climate change in 1990-2000's combined with other factors (high nutrients concentrations and their ratio (N:P<7 in summer)), low salinity 0-5‰) created conditions for summer "hyperblooming" of Cyanobacteria, eutrophication and increased primary production (360-668 gC·m^{-2}·year^{-1}). The eutrophication of the lagoons affects at all trophic levels and primarily the intensity of phytoplankton development.

The annual cycles of primary production, chlorophyll concentrations and pH are characterized by summer maximum, which corresponds to maximal temperature of water and blooming of Cyanobacteria (Fig. 2).

At present, in these lagoons averages for the water area pH change from 8.0-8.1 in winter to 9.2-9.5 in the spring-summer. In 1981-1982 average for the period April-October pH was 8.33-8.37.

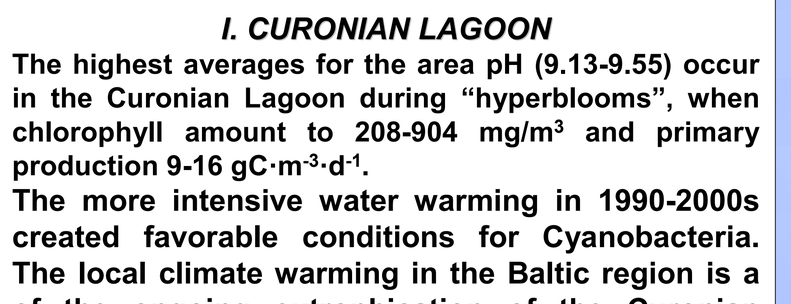

Fig. 2. Seasonal changes of the pH and Chl a concentrations mean for the period 1991 -2014 in the Vistula Lagoon and Curonian Lagoon

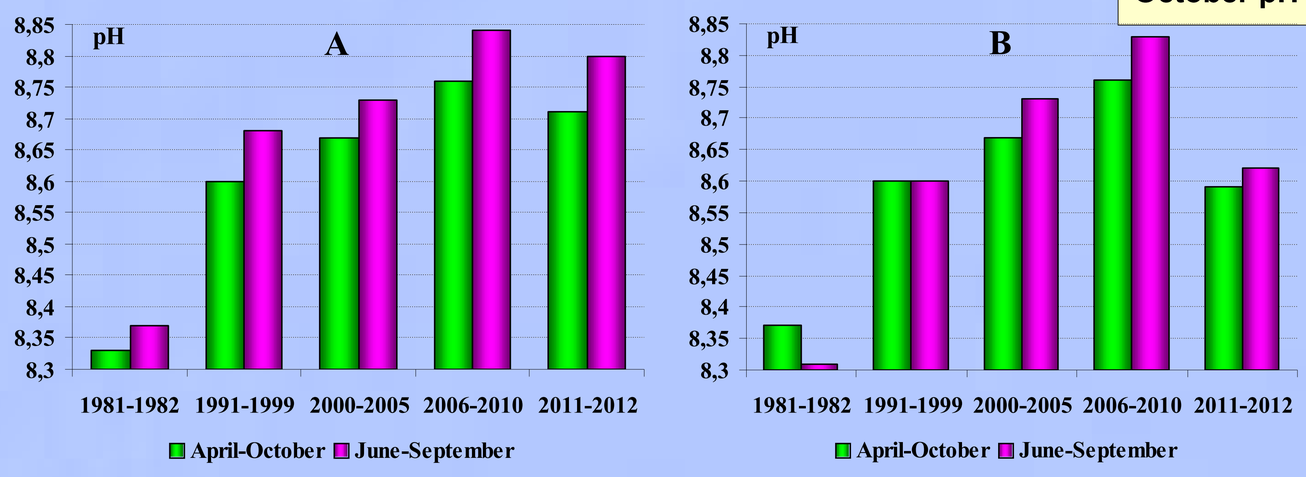

Fig. 4. The mean for the growing season (April - October) and summer period (June-September) pH in the Curonian Lagoons (A) and Vistula Lagoon (B)

I. CURONIAN LAGOON

The highest averages for the area pH (9.13-9.55) occur in the Curonian Lagoon during "hyperblooms", when chlorophyll amount to 208-904 mg/m^3 and primary production 9-16 gC·m^{-3}·d^{-1}.

The more intensive water warming in 1990-2000s created favorable conditions for Cyanobacteria. The local climate warming in the Baltic region is a of the ongoing eutrophication of the Curonian Lagoon.

In the Curonian Lagoon "hyperblooming" of Cyanobacteria was observed during 3 years in 1980s, while 11 years "hyperblooming" of Cyanobacteria were observed in 1990s and 2000s.

Owing to eutrophication and "hyperblooms" of Cyanobacteria, in the Curonian Lagoon average for April-October pH increased from 8.33 in 1981-1982 to 8.60 in 1991-1999, 8.67 in 2000-2005, 8.76 in 2006-2010 and 8,71 in 2011-2014 (fig. 4a).

I. VISTULA LAGOON

Due to climate change and eutrophication in the Vistula Lagoon, pH average for April-October also increased from 8.37 in 1981-1982 to 8.61 in 1991-1999, 8.67 in 2000-2005 and 8.76 in 2006-2010 (fig. 4b).

In the Vistula Lagoon after the invasion of the North American filter-feeding bivalve *Rangia cuneata* the benthic biomass increased by 17 times (to 496 g/m^2), and Chl decreased by 2 times (to 20 µg/l) in 2011-2014 (Fig. 5). Water quality is improved from "poor" to "passable" level in 2011-2014 (Fig. 6). Due to the reduction of eutrophication of water, pH also decreased to 8.58 were observed in 2011-2014 (fig. 4b, 7).

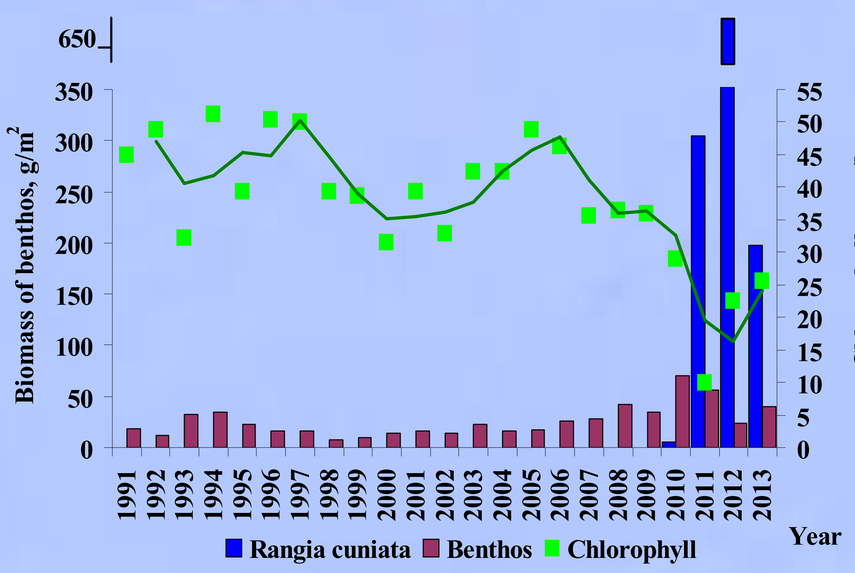

Fig. 5. Long-term change biomass of benthos and Chl "a" concentrations in the Vistula Lagoon in 1991-2013

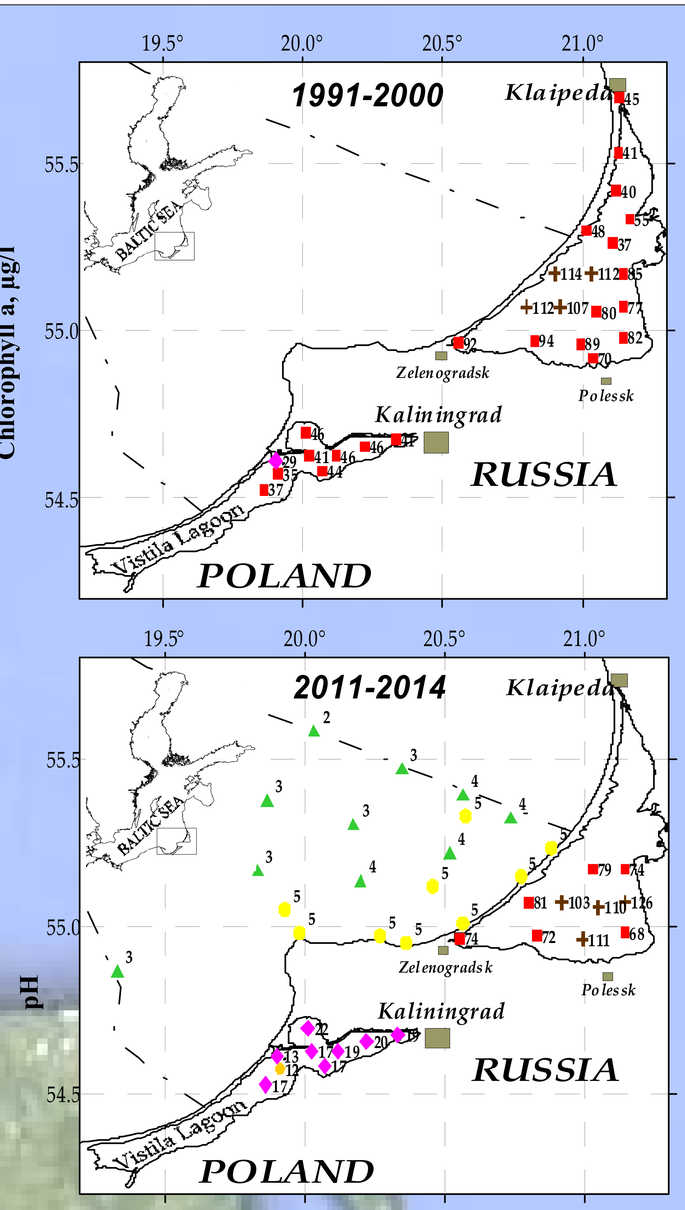

Fig. 6. Water quality in the Vistula Lagoon, Curonian Lagoon, South-Eastern Baltic Sea (based on the average for year Chl a)

(Data on Chl in the Lithuanian part in 1991-2000 from "Baltic sea phytoplankton database")

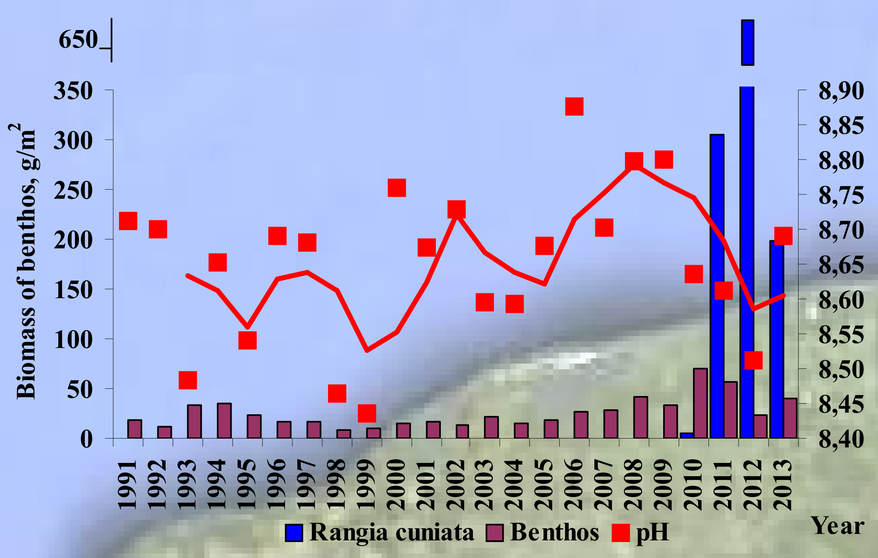

Fig. 7. Biomass of benthos and pH in the Vistula Lagoons in 1991-2013

Classification of water quality in the Baltic Sea (Vuoristo, 1998)

Water quality	Chl *a*, mg/m^3
Excellent	< 2
Good	2 – 4
Satisfactory	4–12
Passable	12 – 30
Poor	30-100
	> 100

CONCLUSION

Thus, in lagoons the increase eutrophication and primary production due to climatic changes can significantly increase the pH, but biological invasions can promote improvement of quality of waters and decrease in pH.

Considerable water exchange between the lagoons and sea can promote to maintain of stable state of the pH in coastal areas of Baltic Sea despite of global processes of ocean acidification

The waters of the Baltic Sea on the concentration of nutrients, chlorophyll and phytoplankton biomass can be characterized as *mesotrophic*, especially in offshore part.

For the Baltic Sea in 2005-2006 average for the growing season surface pH was 8.07-8.10 that correspond to the average pH in the world's oceans.