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SHORT COMMUNICATION

How do differences in the nutritional and hydrological background influence phytoplankton in the Vistula Lagoon during a hot summer day?

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Summary The aim of this work was to find out whether the difference between the central Vistula Lagoon (the southern Baltic Sea) and the western lagoon was reflected in the relationships between nutrients and phytoplankton during one-day hot summer conditions when the water temperature exceeded 20°C. Significant differences in Soluble Reactive Phosphorus (SRP) and Dissolved Inorganic Nitrogen (DIN) concentrations, and also in the biomass of the dominant phytoplankton assemblage of Cyanoprokaryota, were noted in the studied parts of the lagoon. No such differences were found for the nitrogen to phosphorus ratio (N:P) or for the biomasses of Bacillariophyta and Chlorophyta. The very low values of N:P (on average 2.8 and 3.4) indicated strong nitrogen limitation. The Correspondence Canonical Analysis (CCA) showed that the central part of the lagoon could be defined as positively related to DIN and to N:P, and western part could be characterized by correlation with temperature, dissolved oxygen and SRP concentrations. Competition for the limited resources of Dissolved Inorganic Nitrogen in the western, shallower part of the lagoon was in favour of Cyanoprokaryota, to the detriment of other phytoplankton assemblages. In contrast, the Cyanoprokaryota biomass in the central part of the lagoon, where DIN concentrations were increased, was lower, and Bacillariophyta in particular prospered at their expense. Here, the competition for Soluble Reactive Phosphorus was not so clear-cut.

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1. Introduction

The eutrophication of shallow coastal lagoons and bays has recently become a leading topic in the ecology and biogeochemistry of temperate shelf seas (Lloret et al., 2008; Nixon, 1995; Su et al., 2015; Vidal et al., 1999). A number of research projects focus on the relations between nutrients like phosphorus (P) and nitrogen (N), and the consequent rapid increase in the primary production of phytoplankton, which manifests itself in blooms of Cyanoprokaryota, undesirable from the sanitary and economic state of seas worldwide (Nixon et al., 2001), including shallow coastal waters of the Baltic Sea (Pliński, 2005). The present work addresses this global phenomenon and attempts to demonstrate the spatial differentiation in the nutrient supply and its consequences for the relations between the main phytoplankton assemblages in the summer phase of their reproductive cycles in shallow coastal waters, which are characteristic for such shelf, semi-closed and catchment-dependent seas as the Baltic Sea. This study also refers to a number of publications on the effects of eutrophication in Baltic Sea coastal waters (Pilkaitytė and Razinkovas, 2006; Seppälä and Balode, 1999; Włodarska-Kowalczuk et al., 2014), and points out the spatial hydrological aspect of relationships between the distribution of nutrients and phytoplankton production and structure.

The horizontal distribution of algae in open oceanic waters is regulated by hydrodynamic processes like Kelvin waves and advection, chemical ones such as the differences in nutrient concentrations, and biological ones associated with the dynamics of grazing (Bidigare and Ondrusek, 1996; Lucas et al., 1999). The differences in the phytoplankton assemblage biomasses can also be found as an effect of competition among them for resources (Carey et al., 2014; Chakraborty and Feudel, 2014). The spatial distribution of phytoplankton structure and biomass in shallower coastal sea waters, like the Gulf of Riga (Baltic Sea), depends above all on the levels of nutrients supplied by river waters and subsequently disseminated by sea currents (Seppälä and Balode, 1999).

The general aim of the present work was to show the effect of the uneven distribution of assimilable P and N forms on the relations between the biomasses of the main phytoplankton taxonomic groups. It was achieved by comparing the various levels of N and P species in the two parts of the lagoon with the differences in the phytoplankton assemblage. The particular objectives of this work were to verify a hypothesis on whether the differentiation in water exchange between two parts of the shallow Baltic lagoon was reflected: (1) in the distribution patterns of biomass and dominant species, Cyanoprokaryota, Bacillariophyta and Chlorophyta correlated with N and P compounds and other basic environmental parameters, (2) in the relations between Dissolved Inorganic Nitrogen (DIN) and Soluble Reactive Phosphorus (SRP) and the biomass of the main phytoplankton assemblages during a hot summer day, when the water temperature in the lagoon exceeds 20°C.

The areas of the Vistula Lagoon to be compared in this respect were its shallower western part, influenced by inflows of inland waters but relatively isolated from the effects of the open sea, and its central part, which is deeper and whose waters are exchanged rather more quickly with the open Baltic. We expected to find different nutritional factors responsible for phytoplankton structure, including Cyanoprokaryota domination, in relation to varied exchange of waters in shallow lagoons in the Baltic Sea. This can serve to expand our knowledge of the spatial hydrological causes of harmful algal blooms in shallow coastal water bodies and to find pointers for eliminating these undesirable phenomena.

2. Material and methods

2.1. Study area

The Vistula Lagoon is a shallow coastal water body with specific hydrodynamic and trophic properties. A characteristic feature of the water exchange between the lagoon and the Baltic Sea is the presence of the only connection, the Baltiysk Strait, which cuts through the northern end of the Vistula Spit. The velocity of water movement in and out of the lagoon differs strongly: it is relatively fast mainly in the Russian part of the lagoon, but slow in the more enclosed Polish part. According to Bielecka and Kaźmierski (2003), the speed of inflowing or outflowing lagoon waters off Mamonovo (Kaliningrad Oblast) is 0.04—0.05 m s^{-1}, off Frombork ca. 0.02 m s^{-1} and near the Żuławy Wiślane (Vistula Delta lowlands) less than 0.01 m s^{-1}. One consequence of this slowing down of current flows coming in from the sea and the flows of freshwater from the land is the salinity gradient in the Polish part of the lagoon (Bielecka and Kaźmierski, 2003). The depth of the lagoon and the nature of the bottom sediments are different too: in the deeper (3—4 m) eastern and central parts the sediments consist mainly of mineral matter such as sands and clays, whereas in the shallower (ca. 2 m) western part the emphasis shifts to organic alluvial deposits (Uścinowicz and Zachowicz, 1996).

2.2. Field and laboratory methods

The fieldwork in the Vistula Lagoon was carried out in August 2011, a year with a typical hot summer when water temperature exceeded 20°C from July to the beginning of September: mean water temperature in August amounted 21.5°C near Nowa Pasłęka according to an ecohydrodynamical model simulation (Institute of Oceanography, University of Gdańsk) and phytoplankton growth was intensive. Samples were taken on one day (15 August) in the same meteorological condition and hydrodynamic relations, which guaranteed the high comparability of samples. Twenty-one sampling stations were designated in the two areas of the Polish part of the lagoon. Eleven sampling stations were located in the eastern area, between Frombork and Tolkmicko on the southern shore and Piaski and Krynica Morska on the northern one, and ten such stations were situated in the shallower western area bordering on the Vistula Delta lowlands (Fig. 1). Depth, Secchi Disc visibility, water temperature and dissolved oxygen content (by Hach LDO oxygen probe) were measured at each sampling station in situ.

The volume of 1 dm^3 of surface water (0—0.5 m depth) was taken using a vertical point water sampler at each point for chemical analysis in the laboratory. Samples were collected into dark bottles and cooled. Then, no more than a dozen or so hours later, the water samples were passed through a GF/C (1.2 μm) Whatman glass fibre filter. The