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DOES BIOTIC PATCHINESS IN A LAKE CONFORM TO CHEMICAL HETEROGENEITY?

ABSTRACT: Analyses of lake water taken in discrete sites along a c. 2 km transect from a 1 m depth in a eutrophic Lake Mikołajskie revealed a uniform horizontal distribution of temperature and oxygen concentrations. Conductivity, soluble reactive phosphorus and particularly chlorophyll concentrations showed, however, a marked variability along the transect. Significant correlation between pH and conductivity suggests that a local photosynthetically induced calcite precipitation may be responsible for the observed horizontal variability of these parameters. Biotic response (inferred from chlorophyll concentrations) was not coupled with chemical differences. Different temporal scales of chemical processes and phytoplankton growth are assumed to explain this discrepancy.

KEY WORDS: nutrients, chlorophyll, spatial and temporal variability

Heterogeneity of lake water and patchiness of its biotic structure, though recognized earlier, have been intensively studied since the late sixties in both oceans (Platt 1972) and lakes (Harris *et al.* 1980a, 1980b). These studies gained a special momentum when measurements of *in vivo* fluorescence (IVF) of chlorophyll (as a measure of phytoplankton abundance) was put in common use (Lorenzen 1966). The method enabled to collect long series of records from lake or oceanic horizontal and vertical profiles. Obtained data served for building several models (a comparison e.g. in Okubo 1977), which associated chlorophyll patches with diffusion and advection in oceanic waters. The models predicted, among others, a critical phytoplankton patch size of ca. 100 m, below which water turbulence and diffusion should destroy any spatial heterogeneity. The conformity of chlorophyll to the hydrologic regime was often so good that the pigment was found to be a good water mass marker (Platt 1977). This is particularly true in oceans and large lakes, where phytoplankton patches of 1 km or larger size can often be found. In smaller lakes the situation is different. Dissipation of turbulent energy of wind forced waves is more complex here being affected by shore effects and thermal and density gradients. Persistence of phytoplankton patches is moreover influenced by zooplankton grazing, which is itself subject to the spatial heterogeneity (Patalas and Salki 1993, Masson and Pinel-Alloul 1998, White 1998). The existence of a phytoplankton cluster means also that nutrients are depleted faster in than outside the patch. This may lead to a local nutrient deficits and a temporal nutrient limitation. It is thus obvious that spatially differentiated nutrient uptake, nutrient release, grazing and excretion should result in

differentiated chemical composition of a given layer of water. This in turn should result in differentiated conditions for the growth of primary producers.

This paper is a report of preliminary analyses undertaken to check if and to what degree epilimnetic lake water might vary in its chemical composition and how chlorophyll concentrations (adopted as an indicator of phytoplankton biomass) are related to chemical heterogeneity. To do this we performed a set of analyses along a c.2 km transect run across Lake Mikołajskie, a 460 ha eutrophic water body of a maximum depth of 26 m and mean depth of 11 m in north-eastern Poland (Fig.1). The transect was set up so as to avoid littoral zone and the water depth at each site was not less than 6 m. Water samples in triplicate were taken in mid-August from 30 equally spanned sites along the transect from a depth of 1 m. Temperature, pH and oxygen concentrations were measured with a probe while sampling. All sampling was performed in mid-day within 2 hours to minimize any temporal variability. In the lab suspended solids, chlorophyll, soluble reactive phosphorus (SRP) and ammonium-nitrogen were determined with the standard limnological procedures.
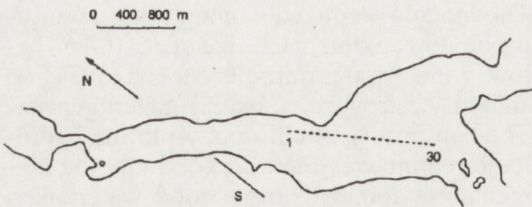

Fig. 1. A schematic map of Lake Mikołajskie. Transect is marked with a dashed line, numbers refer to the extreme sampling sites, the same as in all next figures.

Water temperature and oxygen content did not show any significant variability along the transect. Temperature differences between the two subsequent sites did not vary for more than 0.1°C, the accuracy of the measurements. pH showed a slight but constant decline along the transect and the difference between the extreme recorded values was 1.04 pH units.

Suspended solids concentration was rather uniform in analyzed samples but a scatter of records around the mean was greater in the south-eastern part of the transect. (Fig. 2).
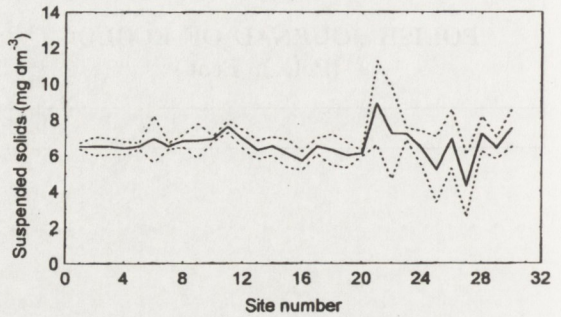

Fig. 2. Mean concentrations (solid line) of suspended solids in a 1 m deep water layer along the transect. Analytical accuracy was 0.1 mg dm^{-3}. Numbering of sites correspond to that in Fig. 1. For visual presentation of the in-site variability, dotted lines depict $\pm$ 1.5 standard error of the mean.

Conductivity, which is a measure of total ions in the sample (mostly Ca^{+2}, HCO_3^-, Mg^{+2} and SO_4^{-2}), was more uniform in the north-western part but variable and often higher in the south-eastern part of the transect (Fig. 3). In-site variability of water conductivity was generally low but in some sites (No. 3, 8 and 15) showed enormously high spread of records. Soluble reactive phosphorus was generally low approximating zero but peaked occasionally at the beginning of the transect, in site No 12 and at the south-eastern end of the transect (Fig. 4). Except for the first two sites, standard error of SRP determination was low and comparable with an accuracy of the analytical method.

Concentrations of ammonium-nitrogen varied from non-detectable to a maximum of 0.03 mg N dm^{-3}, which is three times the accuracy of an analytical method. That's why it is hard to analyze the variability of this element and why spatial distribution of ammonium-nitrogen is not presented.
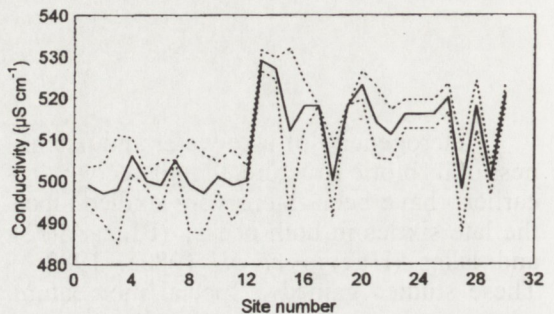

Fig. 3. Conductivity measurements in a 1 m deep water layer along the transect. Analytical accuracy was 1μS cm^{-1}. Number of sites and description of lines as in Fig. 2.
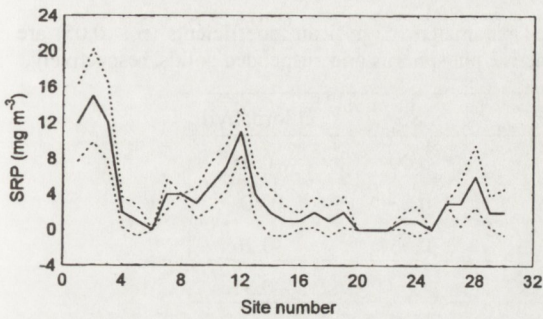
Fig. 4. Horizontal variability of soluble reactive phosphorus (SRP). Analytical accuracy was 1 mg m^{-3}. Numbers of sites and description of lines as in Fig. 2.

The results demonstrate that lake water at 1 m depth, though homogenous in some aspects (almost equal temperature, oxygen content and the concentrations of suspended solids) can vary considerably in concentrations of some dissolved components (SRP and conductivity = the sum of basic anions and cations).

The greatest spatial variability was found for chlorophyll concentrations in the 1m deep water layer (Fig. 5). Two subsequent sites c. 70 m apart could vary in chlorophyll concentrations by several times. There was no, however, any trend observable in chlorophyll concentrations. As the in-site variability was low, the differences between the respective sites were statistically significant.
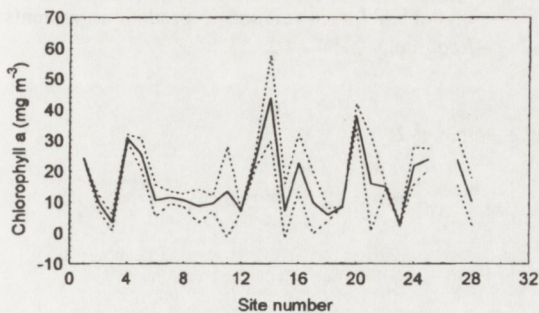

Fig. 5. Horizontal variability of chlorophyll a. Analytical accuracy was 0.1 mg m^{-3}. Numbers of sites and description of lines as in Fig. 2.

None of the measured parameters showed clear directional changes. Variations were rather random and of local character. A lack of marked variability of water temperature and oxygen concentration (within the accuracy of the method) may evidence for a physically uniform (mixed) conditions in the studied water layer. The reason for the observed variability of SRP, chlorophyll and conductivity should thus be looked for in a patchy character of the biota rather than in any possible gradients (inshore-offshore) though patches themselves might be driven by internal waves or eddies.

Differences in conductivity (sometimes reaching more than 20 µS cm^{-1} in two adjacent sites – see Fig. 3) were certainly associated with changes in the concentrations of major ions ($Ca^{=2}$ and HCO_3^-). These in turn could origin from a different bicarbonate uptake by algae and/or by a different local precipitation of calcium carbonate (Stabel 1986). A possibility of the latter was further supported by a significant negative correlation between pH and conductivity (Table 1). Following this hypothesis we should expect high primary production in sites (patches) of high pH and low conductivity (low calcium concentrations). Measurements of primary production were not performed in this study but chlorophyll concentrations showed quite opposite trend being higher in sites of high conductivity (see positive correlation between these variables in Table 1). Several explanations may be adopted here. The first is that chlorophyll was not a good representative of phytoplankton biomass (see e.g. Harris 1986, Chapter 6) and even worse of algal productivity. Differential grazing by spatially diversified zooplankton (White 1998) might be another reason for the discrepancy between recorded and expected algal response to variable chemical environment. But the most probable explanation lies in the temporal resolution of the patchy structure. Observed peaks of chlorophyll concentrations are of small size encompassing one or two sites, thus not larger than c.150–200 m (compare Figs 1 and 5). Cited above models predict the duration of such patches at no longer than 1 day. Whereas chemical reactions (supersaturation, precipitation) take place immediately, phytoplankton response is longer and, depending on the growth rate (doubling time), may take one to several days, especially in the case of cyanophytes dominating in Lake Mikołajskie in summer. Therefore, it is highly possible that places of nutrient/bicarbonate uptake and cell reproduction are separated by c. a hundred meters.

To conclude this preliminary report we may say that concentrations of some chemical parameters are significantly diversified in a 1 m deep water layer of Lake Mikołajskie.

Table 1. Coefficients of correlation between the measured parameters. Significant coefficients (p < 0.05) are marked with an asterisk. SRP and SS stand for soluble reactive phosphorus and suspended solids, respectively.

Parameters	conductivity	SRP	SS	chlorophyll
pH	−0.47*	0.48*	0.00	−0.05
conductivity		−0.45*	0.03	0.40*
SRP			0.06	−0.26
SS				−0.31

Chemical heterogeneity is, however, uncoupled from the biotic response, probably due to the different time scales of chemical reactions and the cell doubling time.

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