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# Lakes Supplied by Springs: Selected Examples

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**Abstract:** The article discusses the influence of springs upon the physical properties of two postglacial lakes located in the Central European Lowland (lakes Kielskie and Wapienne), and one karst Lake Okońskie located in the Volhynia Polesiye (the Ukraine). The impact of the springs upon the postglacial lakes was restrained most frequently to a dozen or so meters, and was different during winters and summers. The author found big diversity of surface water layer temperatures (approx. 7-9°C in the section of merely 6 meters), and of water electrolytic conductivity (to over 40 μS $cm^{-1}$). Water reaction was significantly less diversified. On the other hand, Lake Okońskie is entirely influenced by waters coming out from the springs. There is the so-called crenogenic mixis, so typical of limnocrene springs.

**Keywords:** lake, spring lake, lake supply

## Introduction

When a lake basin "intersects" the outcrop of the aquifer, lake waters are supplied by springs. In such places groundwater mix with "proper" lake water, and the phenomenon is called crenogenic mixis. This phenomenon can even be observed directly on the lake surface. When springs are of exceptionally big yield, and when the lake is usually of smaller depth at the place of the spring effluent. It is visible on the lake surface in the form of gurgling water. Moreover, it is possible to identify crenogenic mixis (its extent) on the grounds of the analysis of the changeability of water temperature in the zone of the effluent as compared to the distribution of temperature in the remaining water mass of the lake. It is also possible to locate springs at the bottom of the lake taking into account the results of the investigations of the changes in the chemical composition of the water over a particular area, and also during the periods with ice phenomena. In winter at the places of underwater effluents, ice cover thickness is considerably smaller as compared to the remaining part of the lake, or ice cover does not exist at all.

It is difficult to determine how common the phenomenon of the occurrence of springs in the lake basins is due to complex detectability. Even if crenogenic mixis is common in the zones of considerable depths, its location is most frequently "veiled" by water layers of bigger thickness values. Hence, the effect of crenogenic mixis is not often visible on the surface. This particularly refers to postglacial lakes.

The Polish literature of the subject describes only several examples of springs located in lake basins. Choiński (1995) mentions Lake Brzezie (Plusze) near Sława (in the Sławskie Lakeland) and Lake Kobyleckie near Wągrowiec (in the Chodzieskie Lakeland), whereas Szczucińska (2008) quotes Lake Jelito near Krosno Odrzańskie (in the Lubuskie Lakeland). A smaller spring, which is periodically located underwater, was detected near the shore of Lake Raduńskie Dolne (Gaweł 2008). In summer and autumn, when the water stage is low there, the spring is located away from the shoreline of this lake. A strong influence of the springs upon lake supply in Wola Uhruska is reported by Chmiel et al. (2003) and Dawidek and Turczyński (2006). This is, however a limnocrene, also defined as an avulsion lake. Małecka and Małecki (1998) focus upon the limnocrenes located in the central part of Poland. However, all the above quoted research works do not discuss the degree of the influence of a single spring upon a lake but rather present the chemical composition of the entire spring lake (a limnocrene) indicating its dissimilarity from other types of the lakes.

This primary objective of this work is to document the extent and the effects of the influence of the springs located at he bottom of the lakes that are not limnocrenes. This problem was discussed as compared to Lake Okońskie, which is a typical limnocrene.

## Methods

The investigations were carried out during winter and summer periods. They involved measuring spatial distribution (changeability) of temperature, electrolytic conductivity and water reaction of the surface layer, around the place of a spring effluent. This enabled the author to determine the extent of the influence the spring had upon lake waters. During the winter period the investigations were restrained to the places with no ice cover. The occurrence of those places was solely related to the water effluents from the springs located at the bottom of the lake.

The work presents three examples of the springs located at the bottom of the lakes. The first example – Lake Kielskie with the area of 137.5 ha – is located in the Bytowskie Lakeland, to the southwest of Lipusz. Lake Wapienne, with the area of 25 ha, lies near Gryżyn in the Lubuskie Lakeland. The third example – Lake Okońskie – is located near Maniewicze in the Volhynia Polesiye (the Ukraine), approximately 60 km to the north of Lutsk. It is a relatively small lake with the area below 1 ha. The River Okonka flows out from the lake, and goes to the River Styr.

## Results

Several springs were identified at the bottom of Lake Kielskie, near its southern shore. One of those springs can be found at the depth of 0.5 m, at 54°01'276" N and 17°30'315" E. The extent of the influence this spring has upon the lake waters is rather small, as it is limited to several meters only. This spring was built around, which made it possible to estimate its yield at around 2 dm$^3$ s$^{-1}$. In winter the water flowing out from the spring is 7.9°C, and warms up the nearest zone, which causes permanent loss of ice cover within a few-meter radius from the spring. In summer the situation is opposite. The water flowing out from the spring with temperature of 7.4°C cools down lake waters within a few-meter radius. The mean value of water temperature on the lake surface equaled 18.4°C during the measurement period. The difference of water temperature over the section of approx. 6 m reaches 7-9°C, depending upon the season of the year (Fig. 1).

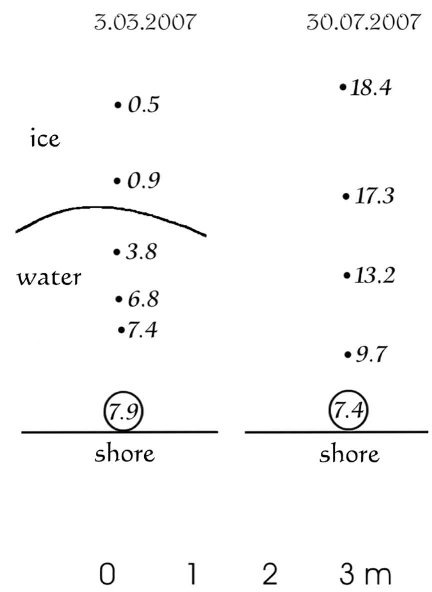


Fig. 1. Diversity of temperature of the surface water layer of Lake Kielskie during the winter (3rd March 2007) and the summer (30th July 2007). The location of the spring effluent marked with a circle.

The measurements of water electrolytic conductivity make it possible to determine the extent of the spring's influence. In this case, the electrolytic conductivity of water in the zone of the spring was 280 μS cm$^{-1}$ both in winter and summer. With the increasing distance from the effluent it declined gradually, reaching 235 μS cm$^{-1}$ below the ice cover, i.e. at approx. 4 m from the spring. The situation was similar in summer. The electrolytic conductivity of water measured 226 μS cm$^{-1}$ approx. 3 m from the spring (Fig. 2)

Reaction values vary in a similar way. In winter water reaction equaled 7.5 pH at the spring. With the increasing distance from it the value rose, reaching 7.8 pH at approx. 4 m from the effluent. In summer water reaction values varied in a similar way (Fig. 3).

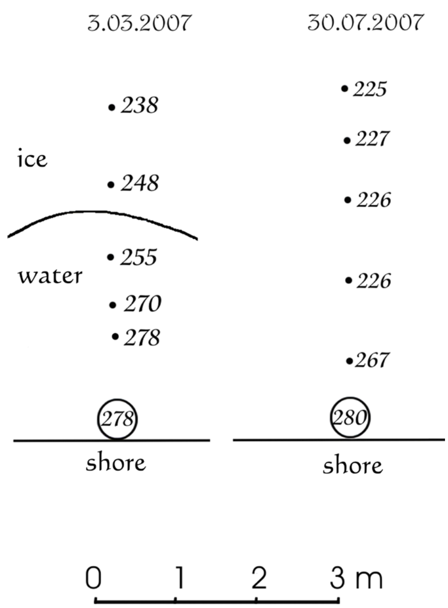


Fig. 2. Diversity of electrolytic conductivity of the surface water layer of Lake Kielskie during the winter (3rd March 2007) and the summer (30th July 2007). The location of the spring effluent marked with a circle.

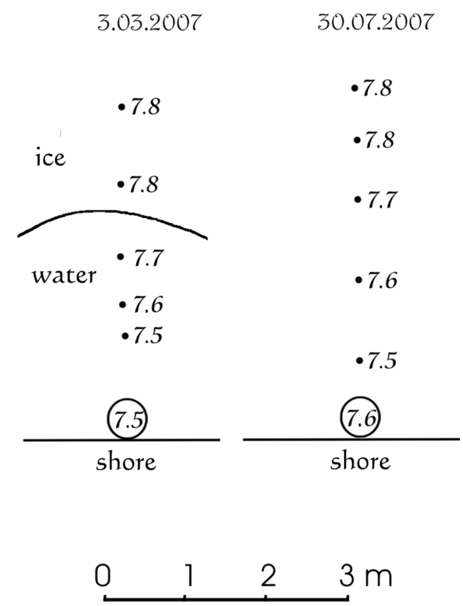


Fig. 3. Diversity of water reaction of the surface layer of Lake Kielskie during the winter (3rd March 2007) and the summer (30th July 2007). The location of the effluent marked with a circle.

Moreover, several other springs were identified at the bottom of Lake Kielskie. They were found in the distance of approximately 50 m from the shore. In winter there was no ice cover in the places where they were determined (Photos 1 and 2). The influence of water flowing out of the springs upon the physical properties of the lake surface waters was smaller in summer.

The spring in Lake Wapienne is located 2 m from the shore at 52°10'9" N and 15°16'50" E. It was found at the depth of merely 10 cm below the water surface during the observation period (at the end of July 2008). The water stage in the lake was very low at that time, which was easy to determine on the grounds of the changes in the colors of macrophytes (Photo 3). Similarly to Lake Kielskie, the extent of the influence of the spring waters was rather small, and reached just several meters. The effluent itself is marked at the bottom of Lake Wapienne by pulse movements of the bottom deposits, which are made of fine sands in this place. Visually, this phenomenon reminds "a boiling liquid". Water gurgles in several points closely located. The effluent's yield is difficult to determine. It can only be estimated at approximately 1 $dm^3\ s^{-1}$. The temperature of water at the effluent measured 9.8°C, and increased gradually with the distance, reaching 23.1°C on the surface of the entire lake (Fig. 4). The changes in water temperature are still noticeable 3 meters from the spring.

The extent of the influence of the spring upon the lake was also documented on the grounds of the measurements of electrolytic conductivity of the lake waters. It measured 400 $\mu S \cdot cm^{-1}$ at the place of the effluent (Fig. 4). Water reaction values varied in a similar, though less noticeable way. At the place of the effluent water reaction was 6.8 pH, and was 7.5 pH a meter away from it. It remained at the level of 7.6 pH farther away (Fig. 4).

The bottom of Lake Okońskie is supplied by springs of considerable yields, which is clearly noticeable on the lake surface (Photo 4). These are yielding karst springs flowing out from the shallow Cretaceous formations. Water coming form those springs has a stable temperature value of nearly 8°C throughout a yearly course. Due to this considerable yield of the springs (and simultaneously smaller lake volume), the entire water mass in Lake Okońskie shows a stable temperature value throughout a year. This is the so-called effect of crenogenic mixis. That is why, ice phenomena are not recorded on this lake. Owing to its purity and water oxygenation, the lake is used for trout breeding. Moreover, the waters at the outflow

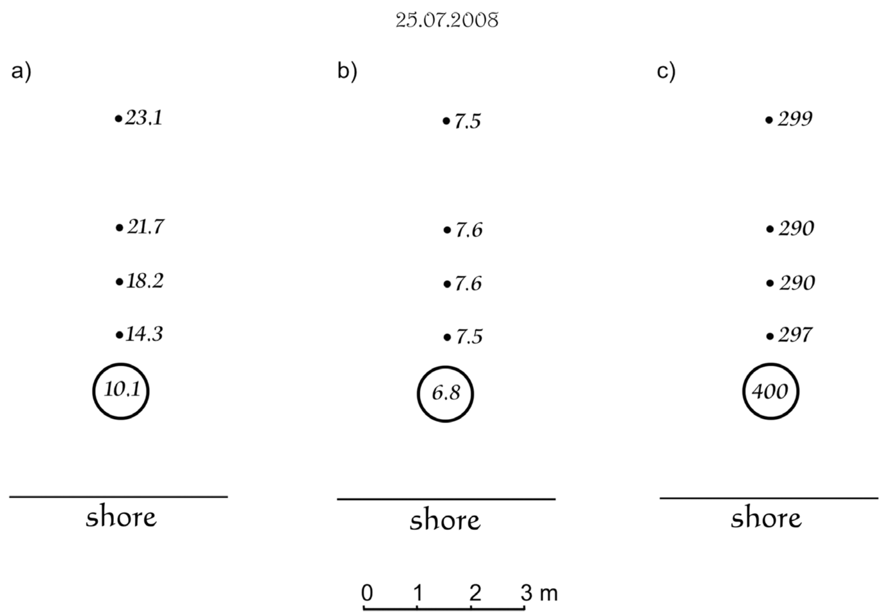


Fig. 4. Diversity of water temperature (a), water reaction (b) and electrolytic conductivity of the surface layer (c) of Lake Wapienne during summer. The location of the effluent marked with a circle.

from the lake supply a complex of breeding ponds on the River Okonka.

The phenomenon of crenogenic mixis is very common in the Volhynia Polesiye. It occurs due to quite shallow artesian waters, which often flow out in the beds of the lake basins. As many as 145 cases similar to Lake Okońskie have been identified there.

## Conclusion

The investigation results presented in this work indicate considerable differences of physical properties of the lake waters in the places of supplying them with waters flowing out from the springs. This statement mainly refers to the lakes, which are not limnocrene, in which the influence of the spring effluent is of a local character. So far, such an influence of the spring effluents (for instance, upon postglacial lakes) has only been mentioned.

Insufficient examination of lake basins supply with water flowing out from the springs makes it necessary to widen research into this subject. Apart from classical research methods, i.e. physical and chemical measurements of water parameters, intense dyes should be applied in future, e.g. a fluoresceine dye. This will certainly make it possible to define a visual extent of the influence of the spring waters upon the water mass of the entire lake.

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Photo. 1. Effluent of one of the springs in Lake Kielskie (Bytowskie Lakeland)

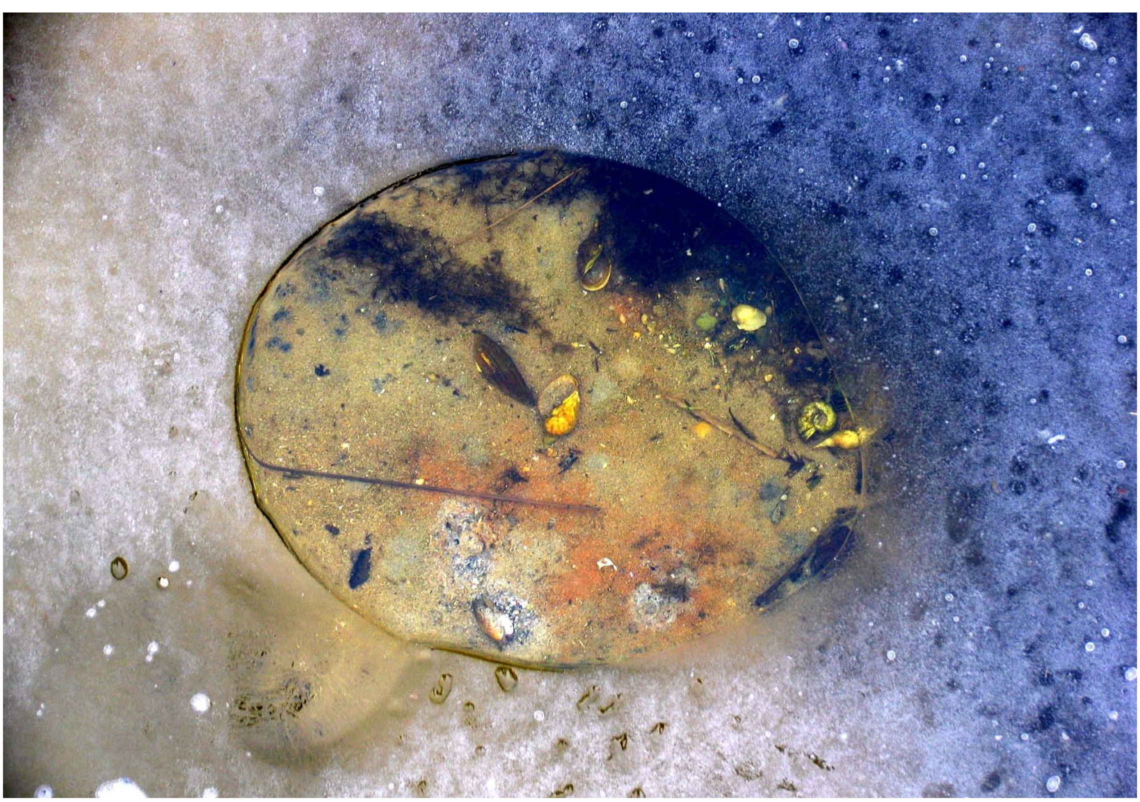

Photo. 2. Lack of ice cover over a small spring (Lake Kielskie, March 2007)

Photo. 3. Spring effluent in Lake Wapienne

Photo. 4. Effluents of the springs in Lake Okońskie