LAKE EVOLUTION IN THE ŻNIN REGION IN THE YEARS 1912–1960 (CENTRAL POLAND)

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ABSTRACT. The evolution of lakes, which, in the final stage, leads to their disappearance, is mainly based on the analysis of surface area change. However, there is one more, frequently overlooked process, which determines lake disappearance – namely the lake shallowing. The present paper presents the direction and rate of such evolution, taking both these processes into account. It is a comparative analysis of 9 lakes in the Żnin region – which has the greatest water deficit in the whole of Poland. Based on bathymetric plans from two periods (early 20th century and early 60's of the 20th century), the author was able not only to evaluate the scale of surface area change but also to determine the value of lake basins volume change. Both these values were negative and amounted 9.1% and 14.9% respectively. Assuming that the said processes are invariable, the prospective period of lake functioning is about 500 years when taking into consideration surface area change only, and is 150 years shorter when allowing for aquatic resources change. The presented approach to lake disappearance analysis, which treats this phenomenon as a decline in aquatic resources rather than a simple decrease in surface area, is more reliable and therefore, scientific works in this field should take the results of lake shallowing into consideration.

KEYWORDS: lake evolution, surface area change, shallowing, bathymetry

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1. Introduction

Lakes are one of the least durable landscape elements. The undergo continual evolution, as a result of which they ultimately disappear through terrestrialization or the outflow of water from lake basins. Kalinowska (1961) estimates that since the last glaciation, over 60% of lakes in the territory of Poland have ceased to exist, while 11.2% of them disappeared over about 70 years of the 20th century (Choiński 1995). In the near future, it may turn out that the only thing that lakelands and lakes have in common is the name. The disappearance of lakes will contribute to some irreversible changes, both in the abiotic environment (impact on water balance, the loss of a landscape-making element, etc.) and biotic environment (extinction of many plant and animal species). Lakes are an important economic phenomena in the region where they occur – to a large extent they determine the development of (agriculture, tourism, power industry, etc.).

For these and other reasons the subject of lake evolution is one of the main trends in limnology. Modern lake disappearance analyses usually focus on lake surface area changes (Lei *et al.* 1998, Yin et.al. 2005, Peng *et al.* 2005, Su *et al.* 2006, Gao *et al.* 2011, Guo *et al.* 2007, Du *et al.* 2011, Marszelewski *et al.* 2011, Choiński *et al.* 2011, Tarasenko *et al.* 2012, etc.) – overlooking or marginalizing the second factor which contributes to lake disappearance, i.e. the process of shallowing of lake. Yet another approach is based chiefly on paleolimnological research methods, where the evolution of lakes is analyzed on the basis of a shallowing scale (Anderson 1990, Friske 1996, Smoot J. P. & Joseph G.2002, Yemane G. D.& Nyambe I .2002, Ahn et.al.2006, Kossoni A.&-Giresse P. 2010, Sloss 2010, Bazarova et.al. 2011, Trabelsi et. al. 2012, etc.). Both these aspects, i.e. the assessment of the changes is surface area and the role of shallowing, have rarely been brought up together. As evident from the earlier works approaching the evolution of lakes in the manner referred to above (Choiński 2002, Choiński & Ptak 2009, Ławniczak *et al.* 2011), the rate of lake disappearance understood as the decline in aquatic resources is up to several dozen percent higher that the value of surface area decline „visible to the eye". The foregoing data encourage further analyses, which may develop the ideas of the evolution and future functioning of lakes.

Fig. 1. Location of the objects of study.

2. Study area and methods

The work presents an analysis of changes in the volume and surface area of lakes in the Żnin region (Fig. 1).

The indicated region is the least abundant in water in the country and has one of the greatest water deficits in Europe. The average annual rainfall in the years 1951–2000 was below 550 mm (Woś 2010). As early as in the first half of the 20th century, flora and fauna analyses revealed that the area was gradually turning into a steppe (Wodziczko 1947). Therefore, it is important to have the widest possible collection of data on the processes and phenomena which have an impact on the functioning of local surface waters. The waters which, in the near future, may determine the further development of e.g. agriculture (through limiting irrigation possibilities, etc.) in this water-deprived region. The most precise information on the rate of lake shallowing can be obtained through paleolimnological research and drilling. However, the said methods are quite costly and time-consuming, and, when it comes to determining the course and pace of evolution of natural bodies of water, they have a simpler alternative, consisting in a comparative analysis of the bathymetric plans of a given lake from two different periods (Choiński & Ptak 2009).

The lakes analyzed in the present paper were chosen based on the availability of historical data. Schutze's (1927) work presents a comparison of bathymetric plans (developed in the years 1912–1915) of nine lakes located in the region concerned. The data on these lakes were compared with the results of bathymetric studies carried out in the late 50's and early 60's of the 20th century at the request of the Institute of Inland Fisheries (IIF) in Olsztyn (Bathymetric...). The information from the two periods is comparable – in both cases the depth at the bottom was measured using identical methods (i.e. depth measurements from the level of ice cover, with several to several dozen holes drilled in the ice, depending on the size of the lake).

Based on the information on the surface area and volume of lake basins, and lakefloor relief from two periods (separated by 50 years), the author evaluated the changes which the said lakes underwent. Lake surface areas were established on the basis of carthometric calculations, while the volume of lake basins was calculated using Penck's method (a mathematical method for computing the volume of lakes, which is more accurate than the graphic method – the error which can occur when determining the bathygraphic curve is thus eliminated).

3. Results

All the nine bodies of water showed a decrease in surface area, amounting to 9.1% tota, and a 14.9% decrease in lake basin volume (tab. 1). Assuming that the surface area change rate of the aforesaid lakes is invariable, their prospective period of functioning in the environment is about 500 years. Their prospective existence is further reduced to 350 years when lake shallowing process is taken into consideration.

The largest decrease in surface area was observed for Small Żnin Lake (–18.2%), which was mainly the result of the most intense plant succession, while the greatest decrease in volume was observed for Great Żnin Lake (–9.6%), and was connected with the dropping level of water.

Two lakes, Skrzynka and Weneckie, immediately attract attention, as their water surface rose by 0.1 m and 0.4 m respectively, which, however, did not result in an increase in the surface area or volume of the lakes. It indicates the process of sediments build- up in the lake bottom.

The changes in surface area and volume have an impact on other lake features. The direct relation between these two parameters (understood as the quotient of volume and surface area) provides information on the average depth of a given lake. The most favorable conditions are found in deep lakes with small surface areas; in such lakes the amount of water is insulated from external factors is the largest.

The overall decrease in average depth for all the analyzed lakes is 0.6 m (–9.7%). It has a negative impact on the susceptibility of lakes to pollution. a decrease in the volume of lake water reduces its ability to dilute inflowing pollution. According to the system for evaluation of resistance of lakes to degradation (Kudelska *et al.* 1994), the average depth is one of the elements which determine such resistance. The adopted three-degree evaluation scale assigns the lowest – 3rd class of resistance to lakes with an average depth of up to 5 m. a direct relegation to a lower resistance class (from 2nd to 3rd) was recorded for Skarbińskie Lake and Weneckie Lake.

When analyzing lake depth in the foregoing examples over the 50-year period in question, it should be emphasized that one of the characteristic features is the movement of isobaths towards lake center. This is particularly true for isobaths with the lowest values, i.e. the ones which are closest to the shoreline. It is particularly evident in the northern and south-eastern part of the Small Żnin Lake, the western basin and the western part of eastern basin of Oświeckie Lake, and in the eastern part of Biskupińskie Lake. The deeper areas of the lakes, too, present a different distribution in relation to the baseline situation. As the water surface level remained the same, such changes are indicative of the importance of the processes connected with sediment accumulation and movement towards the deepest parts.

Table 1. Morphometric data of analyzed lakes.

Lake	Schutze (1927)				IIF (1960)			
	Altitude [m a.s.l.]	Area [ha]	Volume [mln m³]	Mean depth [m]	Altitude [m a.s.l.]	Area [ha]	Volume [mln m³]	Mean depth [m]
Biskupińskie	79.6	128.0	7.4	5.8	79.6	116.6	6.3	5.5
Godawskie	79.8	31.0	1.1	3.7	79.8	29.6	1.0	3.6
Gąsawskie	79.9	108.0	5.8	5.4	79.8	99.0	5.7	5.8
Skrzynka	79.7	29.0	2.7	9.4	79.8	27.9	2.4	8.7
Oćwieckie	81.9	151.0	15.7	10.4	81.9	142.7	12.9	9.1
Skarbińskie	79.4	75.0	4.8	6.4	79.4	64.0	3.0	4.8
Weneckie	79.6	151.0	7.6	5.0	80.0	131.7	6.0	4.6
Żnińskie Duże	78.7	458.0	32.5	7.1	78.0	431.6	29.4	6.8
Żnińskie Małe	78.9	165.0	4.3	2.6	78.9	135.1	3.0	2.3

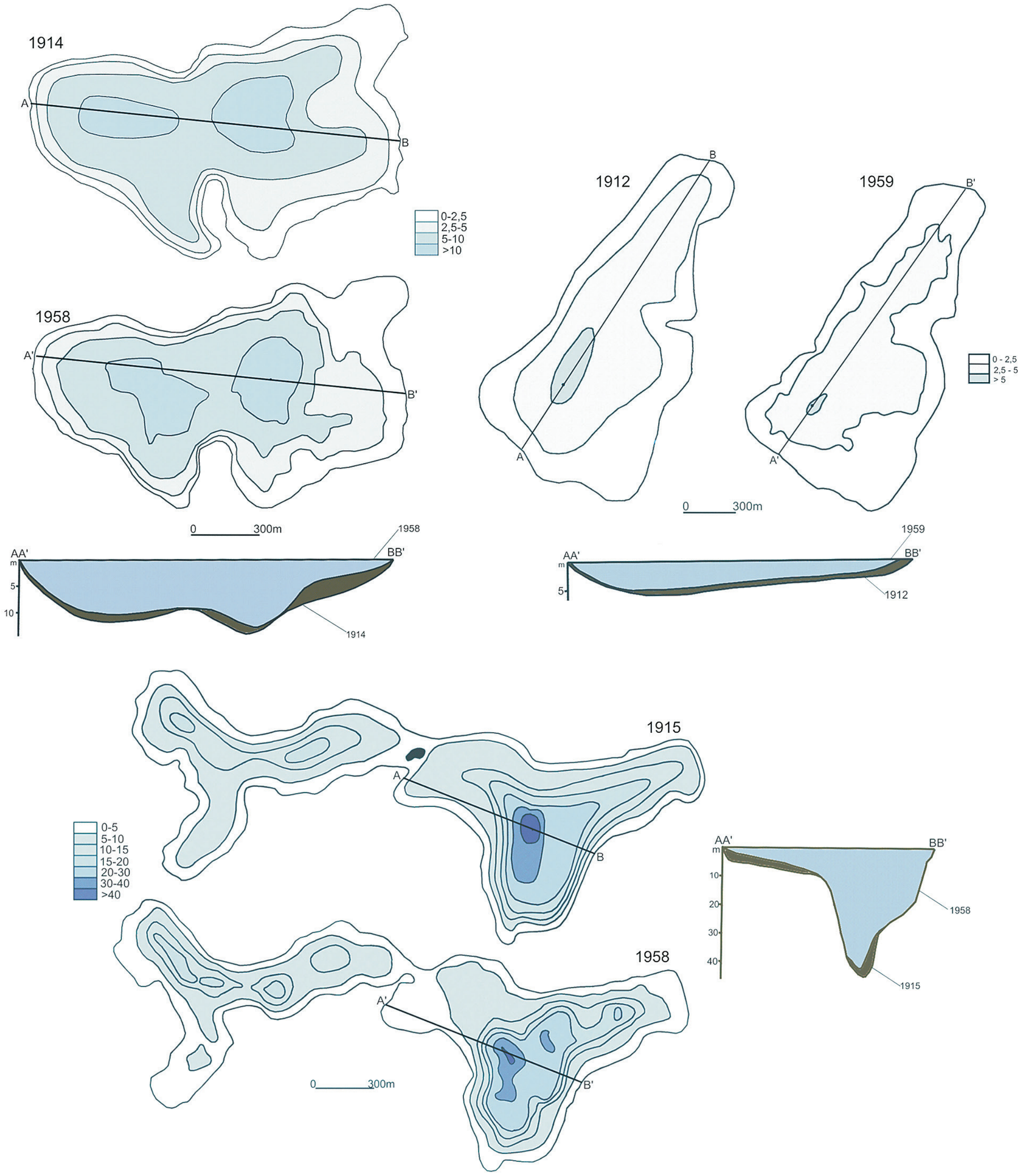

Fig. 2. Exemplary bathymetric changes in lakes together with transverse profiles.

An extensive littoral zone area, i.e. the most shallow area in a body of water, is yet another factor which has a negative effect in terms of lake disappearance. The littoral zone is where both autochtonic and allochtonic matter is most quickly deposited. An analysis of the surface area of such litoral zone (5 m, Ptak 2009) reveals that they grew in all three cases. The greatest growth was recorded for Oćwieckie Lake (+30.4%), followed by Biskupińskie Lake (+8.6%) and the Small Żnin Lake (+6.3%). As for the share of the littoral zone in the overall surface area of a lake, the greatest value was recorded for the Small Żnin Lake (98.7%), Biskupińskie Lake (51.4%) and Oćwieckie Lake (27.9%).

4. Conclusion

The conducted analysis of bathymetric plans of nine lakes in the Żnin region demonstrated that they are all disappearing. It is a natural process, which constitutes one of the stages of lake evolution and which ultimately leads to terrestrialization. Lake disappearance manifesting itself in a 9.1% decrease in lake surface area over the period of 50 years should be considered disadvantageous due to its high value. Over the same period, the recorded value of lake disappearance understood as a decrease in lake basin volume was even greater and amounted to nearly 15.0% (14.9%). The evolution of lakes can be presented in a quantifiable manner as a change in their volume, representing the direction and pace at which a given lake changes. This process is mainly dependent on the region (climate, geological structure, etc.) where a given lake is located and on the activity of men. Thus, changes in lake volume may be of various nature – both varied and constant over time. (Leverington et.al. 2002, Fedotov et.al. 2004, Rouwet et. al. 2004, Mohammed & Tarboton 2005, Rueger & Young 2005, Chernomorets et. al. 2007, Georgiou 2009, Jovanelly 2011, itd.). The results of the work are convergent with the results of similar studies (Choiński 2002, Wiśniewski & Wolski 2005, Choiński & Ptak 2009, Ławniczak et.al. 2011) – which jointly cover several dozen bodies of water. Therefore, the changes in the surface area and volume of the discussed lakes – and thus the possible time of their existence – are similar to those found in other post-glacial lakes located throughout Poland. However, a significant decline in aquatic resources (3.3%) may soon aggravate the water deficit problem in the region where the lakes under consideration are found.

The presented bathymetric plans of three lakes from two different periods demonstrate the scale of change affecting lake basins. Due to the continuous supply of deposits and the movement of semi-liquid sediment, a new distribution of all the isobaths was revealed. The greatest change was recorded for the 5-m isobath, marking the end of the littoral zone. In all cases, it moved towards the lake center.

The results obtained in the study correspond to the results of previous studies, where lake disappearance was analyzed as a product of two factors, i.e. surface area decline and shallowing. Such an approach to the problem does full justice to the scale of this phenomenon. In the light of the foregoing, it should be emphasized that the use of this approach (if made possible thanks to the availability of bathymetric plans) for broader analyses – covering whole reception basins or lake districts, is fully justifiable.

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