Original Research

Lake Infill as the Main Factor Leading to Lake's Disappearance

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Abstract

It has been shown that the disappearance of lakes is understood as a decrease in water resources and not only as the shrinkage of their area. It is mainly a result of the process of infill of lake basins. The conclusion is based on observational data collected for 25 lakes. In a period of over 50 years the area of lakes has decreased by 5.6% (compared to IIF data), while volume has decreased by 9.9%.

Keywords: physical limnology, lake shrinkage, changes in lake volume

Introduction

Lake disappearance is a result of two parallel processes: changes in the water level and the infill of the lake basins. Seasonal and multi-year scales of changes in these parameters in the conditions of Poland are discussed in [1-3]. Lakes forming in land depressions are naturally likely to collect the allochtonic deposits circulating in the catchment area and autochtonic mass produced in the lake.

The total mass supplied to the lake basin depends on natural and anthropogenic factors. The amount of the biogenic substance supplied determines the primary production and its extent determines the size of deposition on the bottom of a given lake in a given year. It has been confirmed by analysis of the intensity of anthropogenic pressure and the rate of disappearance of lake areas. This relation is particularly pronounced in the Wielkopolska region, where the process of lake disappearance is much faster (15.21% from 1920 to 1975) than for examples in the Pomeranian Lake District (9.69% in the same period) or Mazurian Lake District (9.98% in the same period), where the level of anthropopressure was much lower [2]. Introduction of toxic compounds, suspensions or biogenic substance is relatively easy, but the opposite process of restoring the original equilibrium is long and often difficult. An excellent example of the latter is the long-lasting and tedious recultivation of strongly degraded Lake Długie in Olsztyn [4]. Similarly long and difficult are the processes of recultivation of the majority of strongly degenerated lakes.

In Polish literature the problem of lake disappearance has been treated chiefly in one aspect: the disappearance is understood as the shrinkage of the area of a lake. Although the problem of the rate of lake infill has been signalled, it has not been treated in a comprehensive monograph. The papers on limnic deposits have concerned mainly their classification, genesis, etc., as in [5-7].

Recently, problems related to the contents of heavy metals, biogens or other selected elements in sediments have been considered in [8-15]. To establish the character of relationship between the sedimentation and sedentation and a decrease in the freshwater resources of inland reservoirs, 15 lakes in the Mazurian Lake District and Pomeranian Lake District were analyzed [16]. Results of his analysis have shown that the infill of lakes plays a crucial role in disappearance of lakes understood as a decrease in their volume.

Table 1. Comparison of the parameters of selected lakes over the period 1871-75.

Lake	Area in ha (%)			Volume in thousand m³		Maximum depth in m		Mean depth in m		Altitude in m a. s. l.		
	Map 1:25,000 (1870-1910)	IIF[1] (about 1960)	Catalogue1 (about 1975)	Map 1:25,000	IIF[2]	Map 1:25,000	IIF	Map 1:25,000	IIF	Map[3] 1:25,000	IIF	Catalogue
Greater Poland-Kujawy Lake District												
Rogoźno	140.0 (100%)	125.0 (89.2%)	131.0 (93.5%)	5083.3 (100%)	3808.5 (74.9%)	6.5	5.8	3.6	3.0	68.3	69.7	69.2
Chodzieskie	120.0 (100%)	115.6 (96.6%)	112.5 (93.7%)	3941.0 (100%)	3533.2 (89.6%)	7.2	6.7	3.2	3.0	54.2	54.2	54.3
Wiatrowskie	31.8 (100%)	26.9 (84.5%)	23.5 (73.8%)	1171.8 (100%)	1082.5 (92.3%)	11.7	11.7	3.6	4.0	77.8	77.8	76.4
Karczewnik	33.7 (100%)	33.2 (95.8%)	32.5 (96.4%)	1370.8 (100%)	1271.8 (92.7%)	6.0	6.5	4.0	3.8	60.8	60.8	60.8
Starskie	72.5 (100%)	67.5 (93.1%)	53.5 (73.7%)	4079.5 (100%)	3809.8 (93.3%)	13.5	14.0	5.6	5.6	77.0	75.3	74.9
Strzeleckie	18.1 (100%)	16.0 (88.3%)	13.5 (74.5%)	556.0 (100%)	536.1 (96.4%)	4.7	5.3	3.0	3.4	64.3	65.2	-
Mazurian Lake District												
Sitno	63.7 (100%)	48.3 (75.8%)	51.0 (80.0%)	1582.8 (100%)	541.1 (34.1%)	3.4	3.0	2.4	1.1	-	95.7	-
Zamkowe	72.5 (100%)	69.6 (96.0%)	70.0 (96.5%)	5765.7 (100%)	4132.8 (71.6%)	20.1	18.0	7.9	5.9	-	94.8	93.0
Frydek	29.3 (100%)	25.4 (86.6%)	26.0 (88.7%)	2453.1 (100%)	1829.1 (74.5%)	29.2	24.0	8.3	7.0	-	94.7	-
Legińskie	250.0 (100%)	230.0 (92.0%)	220.0 (88.0%)	32426.0 (100%)	27813.3 (85.7%)	31.8	37.2	12.9	12.1	-	103.2	-
Dadaj	989.0 (100%)	976.0 (98.6%)	975.0 (98.5%)	140607.5 (100%)	120784.0 (85.9%)	37.2	39.8	14.2	12.0	-	122.9	122.5
Nałódź	66.3 (100%)	59.0 (88.9%)	52.5 (79.1%)	4524.4 (100%)	3929.5 (86.8%)	29.0	30.5	6.8	6.8	-	144.4	144.0
Jełmuń	133.7 (100%)	131.4 (98.2%)	117.5 (87.8%)	5488.1 (100%)	5317.4 (96.1%)	6.7	7.3	4.1	4.1	-	161.0	-
Tejstymy	237.5 (100%)	198.0 (83.3%)	208.5 (87.7%)	20617.7 (100%)	19826.9 (96.1%)	34.0	33.0	8.6	10.0	-	130.4	128.7
Kalwa	571.1 (100%)	562.6 (98.5%)	561.0 (98.2%)	39717.0 (100%)	39468.6 (99.3%)	27.0	31.7	6.8	7.0	-	137.0	136.9
Serwent	249.0 (100%)	244.3 (98.1%)	243.5 (97.7%)	24236.4 (100%)	24167.0 (99.7%)	24.0	26.2	9.7	9.8	-	132.8	132.8

1- Contribution in % as compared to the area on the map 1:25,000;
2- Contribution in % as compared to the volume on the map 1:25,000;
3- According to [18].

Table 1. Continued.

Lake	Area in ha (%)			Volume in thousand m³		Maximum depth in m		Mean depth in m		Altitude in m a. s. l.		
	Map 1:25,000 (1870-1910)	IIF[1] (about 1960)	Catalogue1 (about 1975)	Map 1:25,000	IIF[2]	Map 1:25,000	IIF	Map 1:25,000	IIF	Map[3] 1:25,000	IIF	Catalogue
Pomeranian Lake District												
Łobez	48.7 (100%)	45.5 (93.4%)	46.0 (94.4%)	3472.9 (100%)	2563.7 (73.8%)	15.0	17.0	7.1	5.6	153.8	154.2	154.7
Cięszęcino	118.7 (100%)	102.2 (86.0%)	106.0 (89.3%)	17365.6 (100%)	13790.1 (79.4%)	31.0	38.0	14.6	13.5	156.1	154.2	155.5
Żeńsko	30.6 (100%)	31.1 (101.6%)	25.0 (81.6%)	1618.7 (100%)	1396.3 (86.2%)	12.0	10.6	5.3	4.5	53.7	53.7	-
Trzebiechowo	93.7 (100%)	89.2 (95.1%)	82.5 (88.9%)	3437.5 (100%)	3107.3 (90.3%)	8.0	8.0	3.6	3.5	139.0	139.5	139.0
Raduń	100.4 (100%)	106.8 (106.8%)	97.5 (97.1%)	4747.2 (100%)	4302.4 (90.6%)	12.0	11.4	4.7	4.0	53.8	-	-
Dębno	76.2 (100%)	68.0 (89.2%)	62.5 (82.0%)	3072.9 (100%)	2791.0 (90.8%)	12.0	14.9	4.0	4.1	141.0	140.9	140.2
Płoń	830.0 (100%)	790.7 (95.2%)	738.5 (88.9%)	23655.0 (100%)	22306.8 (94.3%)	4.7	4.5	2.8	2.8	16.5	16.8	16.1
Klukom	86.2 (100%)	85.2 (98.8%)	77.5 (89.9%)	7183.3 (100%)	6990.3 (97.3%)	17.0	17.9	8.3	8.2	53.7	53.7	53.5
Wierzchowo	766.0 (100%)	731.0 (95.4%)	712.5 (93.1%)	70368.7 (100%)	70212.5 (99.7%)	22.0	26.5	9.1	9.6	140.6	139.5	139.0

1- Contribution in % as compared to the area on the map 1:25,000;
2- Contribution in % as compared to the volume on the map 1:25,000;
3- According to [18].

The author applied the cartographic method (less expensive and tedious than methods based on drills). The method of drill analysis permits dating of sediments and estimation of the annual scale of their accumulation, but owing to the above features this method cannot be commonly used. The much cheaper cartographic method is fully suitable for the purpose of following changes in the capacity of the lake basins and estimation of the rate of these changes. The study reported in this paper is based on the cartographic method of data collection.

Method

The question arises why the cartographic method has not been applied earlier for the purpose of lake infill investigation. The scarcity of reports on the infill of lake basins is undoubtedly the result of a small number of initial data. In the cartographic method the changes in the area of lakes are usually analyzed on the basis of topographic maps. Comparative analysis of maps made at different times permits an easy estimation of changes in lake areas. Cartographic maps are by far more available and cover longer time periods than bathymetric plans. To draw reliable conclusions from comparisons between the bathymetric data of the same water reservoirs, the bathymetric data should cover the longest possible time period, at least of several dozen years. The analysis presented in this paper meets this condition. We used for comparative purposes the bathymetric plans from the Prussian geological-soil maps made at the turn of the 19th and 20th centuries. The second set of data came from the bathymetric plans from the Institute of Inland Fisheries in Olsztyn (IIF), made in the beginning of the 1960s, while the third set of data compared came from the Polish Lake Catalogue [17]. For reference purposes, the volume and area of the lakes as depicted in the Prussian maps issued by the Prussian Royal Geological Institute and Mining University, were assumed as 100%.

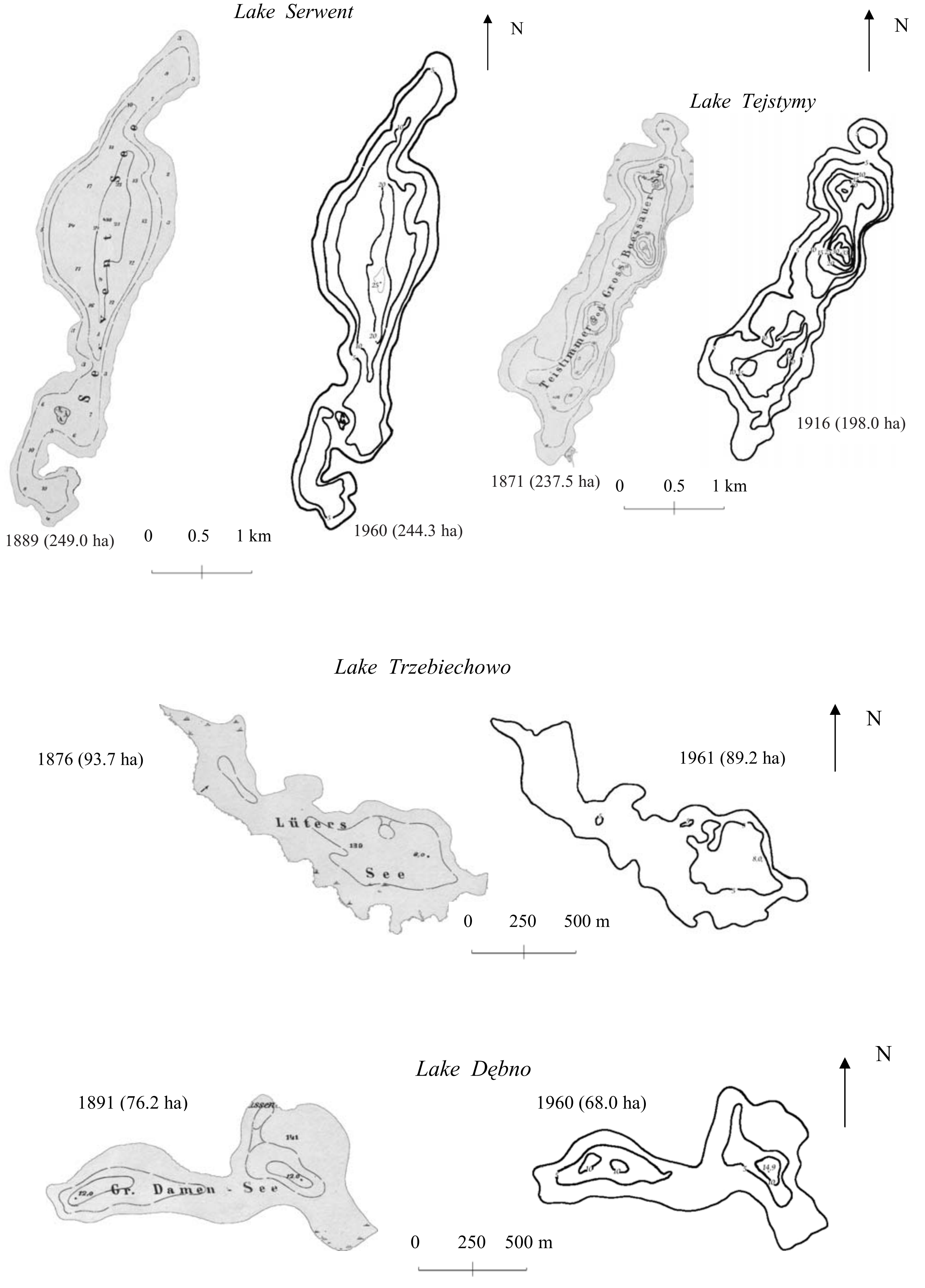

Fig. 1. Changes in lake areas and bathymetry illustrated for a few lakes.

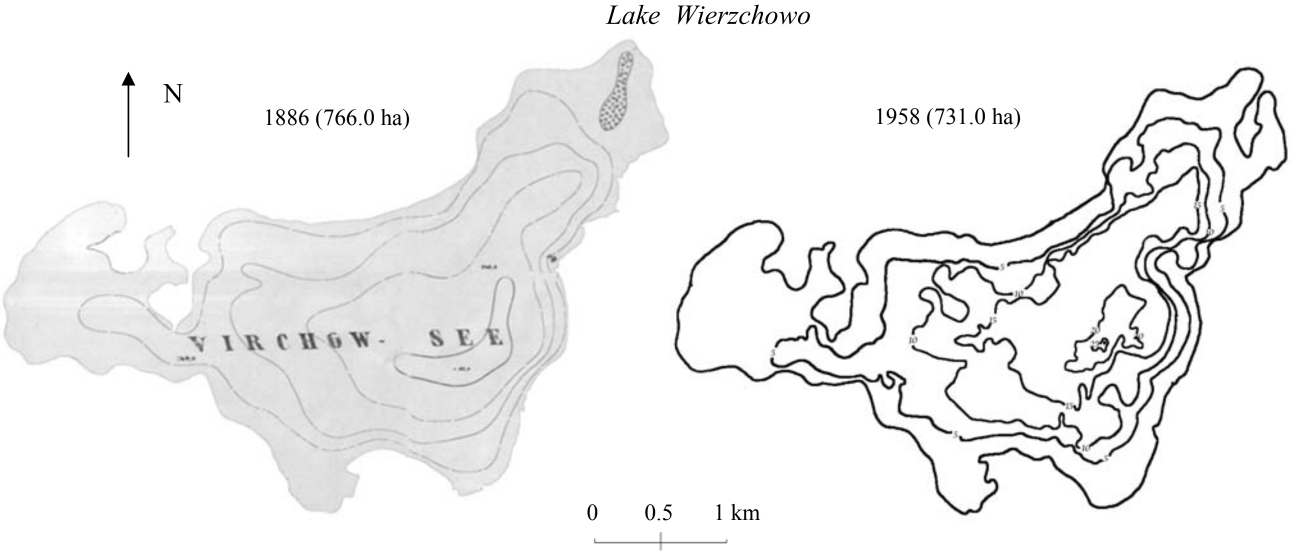

Fig. 1. Continued.

The assumption permits numerical estimation of the changes in the volumes and areas of the lakes studied, and their rates of change. It should be mentioned that information on lake bathymetry is rather scarce against the other information that can be read out from the map. The capacity of the lake was determined by Penck. According to this method the lake volume is a sum of partial volumes corresponding to the area between the subsequent isobaths. The volume is calculated as that of the truncated pyramid of the bases delineated by the two subsequent isobaths. The height of the pyramids equal to the difference between these two isobaths.

The volume of the deepest layer, lying below the isobath of the highest value, is calculated from the formula for the volume of a cone of the base equal to area of this isobath. The height of the cone is the difference between maximum depth and the value of this isobath. The volume of water in the lake basins was found by measuring the areas between the isobaths and their multiplication by the mean depth of the area of a given lake between two subsequent isobaths. It was assumed that the mean depth of the lake area delimited by the highest isobaths was the arithmetic mean of the sum of the isobaths and the maximum depth of a given lake. The analysis was performed for 25 lakes (Table 1) from Wielkopolska - Kujawy, Mazurian and Pomeranian Lake Districts. The lakes to be analyzed were chosen at random, i.e. according to no criteria of choice such as the area of the lake or genetic type of lake basin.

Results

The results are displayed in Table 1 according to the localization of the lakes in particular lake districts, and according to the greatest changes in lake water volume. Table 1 also presents data from the third source [17] on lake areas and the ordination of the water table. Along with the results of measurements performed on the maps, Table 1 also gives the estimated percentage changes in the parameters analyzed.

The changes taking place as a result of the lake infill on its bottom can be graphically illustrated by superposition of bathymetric plans from the two analyzed periods (Fig. 1).

Discussion

Analysis of the data collected in Table 1 leads to the following observations.

- For all lakes analyzed the volume of the lake water decreased; the greatest decrease of 65.9% was noted for Lake Sitno, while the smallest of 0.3% for Lake Serwent and Lake Wierzchowo.
- The maximum shrinkage of the lake areas (relative to IIF data) of 24.2% was noted for Lake Sitno.
- Area shrinkage was not observed for all lakes considered. For two lakes, Żeńsko and Raduń, an increase in their area was noted by 1.6% and 6.8%, respectively.
- The volume of water in all lakes (Institute of Inland Fisheries in Olsztyn data) is 9.9% smaller than that of the lakes presented on the Prussian geological maps.
- According to our results, the area of lakes (IIF data) is 5.6% smaller, while that of lakes in the Polish Lakes Catalogue is 8.9% smaller than that obtained on the basis of the Prussian geological maps.
- It should be assumed that the decrease in lake volume would be proportionally greater should we have the data from the middle 1970s.
- Maximum depth has not always been found to decrease; in a few lakes the maximum depth has increased. The maximum increase in the depth of 7.0 m was noted for Lake Cięszęcino, and can be a result of improved accuracy of measurements.

- The mean depths of 7 lakes have increased with the maximum increase of 1.4 m relative to the value concluded from the Prussian maps (Lake Tejstymy). A possible reason can be the reduction of the littoral zone relative to the deeper zone.
- The decreasing depth of the lake basins has been observed for all genetic types of lakes, including the deepest channel lakes.
- The predominant effect of decreasing depth over the shrinkage of lake areas is particularly evident when no changes in the water table are observed, e.g. lakes Trzebiechowo and Chodzieskie.

Conclusions

As follows from the above analysis, the starting point of considerations of the reasons for the lake disappearance, understood in terms of decreasing water resources, should be an analysis of bathymetric plans. The volumes of the lake basins (V) and the mean depths of the lakes (D_m) determined from the bathymetric data permit analysis of the changes taking place on the bottoms of the lakes and estimation of the rate of these changes. Having the above described data, covering about 50 years, it would be interesting to perform similar measurements at present. It is expected that the rate of changes in lake depth will be higher now. The anticipated greater increase in the bottom sediment volumes follows from increasing anthropopressure. The anthropogenic effect has developed particularly in agriculture (increased consumption of fertilizers, increased amount of biogenic substances flowing out of the fields into water reservoirs), industry (wastewater release, post-energy production waters), river regulation (increased erosion and deposition of erosion release in lake basins), etc.

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