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Natural conditions for the development of lake tourism in Poland

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Abstract. There are about 6,800 lakes in the Polish Lowlands. They are a potential place for rest and recreation not only for the local population, but also for those coming from other regions of Poland and foreign guests. The work was based on the analysis of water temperature data in lakes in the years 1961–2020. The highest surface water temperatures in lakes occurred most often at the turn of the last decade of July and the first decade of August, reaching values above 2 °C in most lakes. In the daily cycle, the highest water temperatures in the surface water layer (up to 1.5 m deep) were recorded mostly between 14:00 and 17:00 (13:00–16:00 GMT). The beginning of the bathing season on lakes in Poland usually falls between May 20 and 25, while the end is in the second half of September, reaching an average of about 69 days, characterized by a positive trend in its duration. According to the Chief Sanitary Inspectorate in Poland, in 2020 there were 602 active bathing areas, most of which were organized on lakes.

Key words:
natural conditions
lakes,
bathing season,
Poland

Introduction

Tourism that exploits the attractiveness of surface waters, especially lakes, is undoubtedly one of the oldest forms of tourism. In the conditions of Poland's climate, water tourism is mainly limited to the warm half-year (Apr–Sep), and especially to the summer season (Jun–Aug), although winter tourism has been developing more and more boldly in recent decades. During the winter months (Dec–Feb), the formation of ice cover on lakes made it possible to practice winter sports (skating, ice boats) and ice fishing.

In many cases, the presence of lakes determines the choice of a place for summer recreation, both passive sunbathing and active water sports. However, not every lake is suitable for full tourist use, which is mainly determined by: appropriate water quality, development of the coastal zone, as well as the provision of appropriate infrastructure necessary to serve tourists.

In the contemporary literature on tourism related to lakes, a separate definition is given as "lake tourism", which can be called "limnotourism" (Choiński and Borkowski 2008). It is a new form of tourism, although the first ideas were born at the end of the 18th century.

Depending on the importance of the lake in the tourist experience, we can distinguish: tourism related to the lake itself, tourism whose development is related to the lake, and tourism for which the lake is only an addition. This covers all forms of tourist and recreational activity undertaken on the lake basin and in the surrounding land areas (Duda-Gromada 2009).

It should also be remembered that, in the system of tourism development, economic infrastructure is considered to be an important, and at the same time necessary and most effective, factor of local

development (Dolata 2010). The effectiveness of the impact of infrastructure equipment on the level of local development, especially tourism, depends on the synchronization of economic infrastructure planning and development with the condition and structure of the area's demand.

Study materials and methods

The basic material on which the characteristics of natural conditions was based were the data obtained from the Institute of Meteorology and Water Management. They concerned the surface water temperature and ice formation on 13 lakes in the years 1961–2020 located in the Polish Lowlands (Pomeranian – 5 lakes, Mazurian – 5 lakes, Wielkopolsko-Kujawskie – 2 lakes and Łęczyńsko-Włodawskie – 1 lake) (Fig. 1). Surface water temperature measurements were made using mercury thermometers in the coastal zone every day at 7:00 a.m. The selection of lakes for this study was dictated primarily by the full series of data in this period.

Further data concern experimental measurements of the vertical distribution of water temperature and its daily course on various lakes in May–September in the years 1971–2020. The location of the lakes in this case was uneven in individual physical and geographical units, and the choice was dictated mainly by morphometric parameters. In total, during the summer stagnation in this period, approximate measurements (thermal photos) were taken on over 550 lakes. Measurements of water temperature in the vertical distribution were carried out using electric thermometers at 1-m intervals in different zones of the lake. The extent of the area between the extreme lakes on which such measurements were carried out was about 780 km from west to east, and about 370 km from north to south.

The above material was supplemented with data on average monthly air temperatures in the years 1971–2020 from 12 stations and data on other features of natural conditions, such as: lake morphometry, water resources, precipitation, degree of continentalism and insolation, as well as data on information on bathing areas, which was taken from the literature and the Internet (Choiński 2007; Skowron 2011; Sobolewski et al. 2014, www.eea.europa.eu, http://sk.gis.gov.pl).

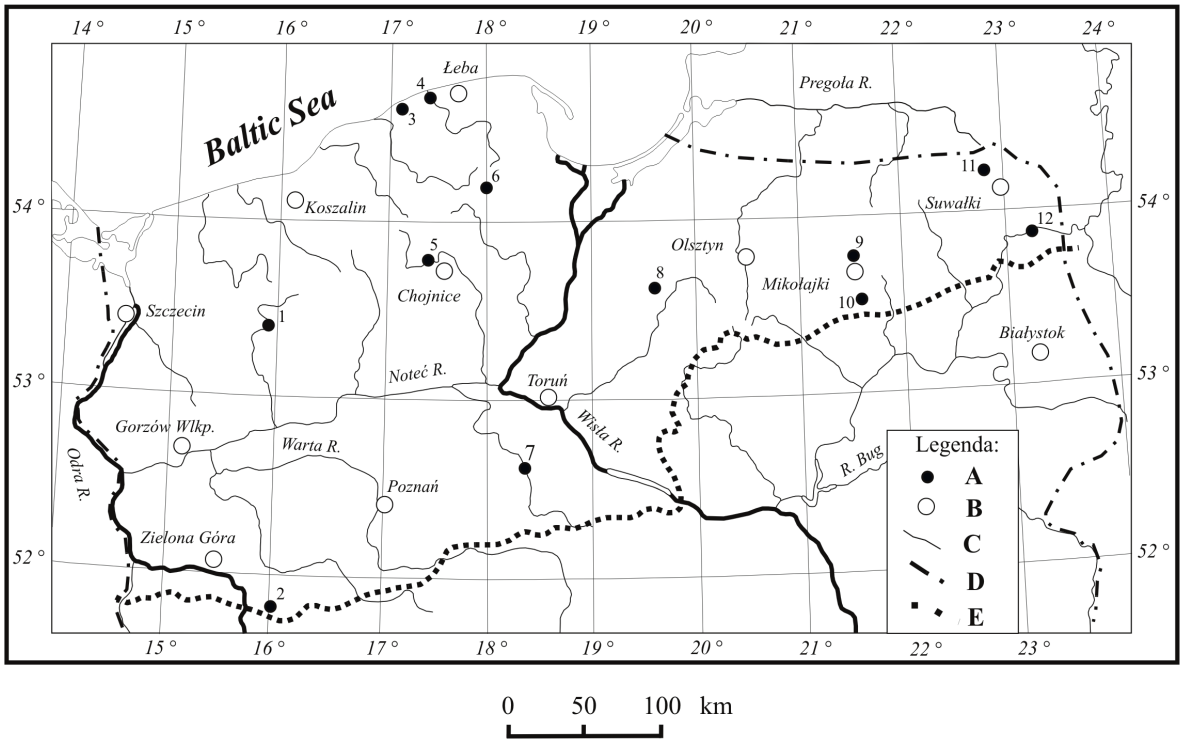

Fig. 1. Distribution of lakes covered by measurements of surface water temperature and ice in the years 1961–2020: A - lakes: 1. Lubie, 2. Sławskie, 3. Gardno, 4. Łebsko, 5. Charzykowskie, 6. Raduńskie Górne, 7. Gopło, 8. Jeziorak, 9. Mikołajskie, 10. Nidzkie, 11. Hańcza, 12. Studzieniczne; B - meteorological stations, C - rivers, D - Polish border, E - maximum extent of the Vistulian glaciation

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The aim of the article is to characterize the natural conditions conducive to the development of lake tourism in Poland and to differentiate the features of the thermal and ice regime of lakes within the Polish Lowlands and changes during the thermal summer. The work was based on the analysis of data on climatic conditions (12 stations), surface water temperature (12 lakes) and its vertical distribution (over 550 lakes) and ice cover (12 lakes) in the years 1961–2020. Therefore, this rich material allowed to present information on climatic conditions, thermal characteristics of water in lakes during the thermal summer, and lake ice formation, while showing their diversity and tourist attractiveness as well as landscape values in the Polish Lowlands.

Location and characteristics of the analyzed lakes

The relief of the lake district was shaped during the Pleistocene glaciations, especially during the last glaciation of the Vistula. After the ice sheet receded, the entire area of the Central European Plain was covered with post-glacial formations, which to this day create a very diverse young glacial landscape. The emergence of numerous and very clear post-glacial forms in this vast area created specific conditions determining the manner in which the hydrographic network, including lakes, was formed. Throughout the exposed area there are characteristic forms such as terminal moraine hills, ground moraine plateaus, moraine hills, sandurs and eskers, which are convex forms. The sequences of hills and hills occurring here testify to the long-term stagnation of the ice sheet and the deposition of large amounts of rock material at its front. The culmination heights of these hills exceed 300 meters above sea level. The highest of them is Wieżyca, located in the East Pomeranian Lake District, reaching 329 m a.s.l. Slightly lower, Szeska Góra, located in the Masurian Lake District, is 309 m a.s.l., and in the Chełmińsko-Dobrzyńskie Lake District, there is the third highest Dylewska Góra, rising 312 m a.s.l. There are also numerous concave forms, such as moraine gutters and depressions, smelting depressions and sections of proglacial valleys. Concave forms have in many cases been filled with water. In this way, post-glacial ribbon lakes and bottom moraine lakes were created (Kondracki 2011).

The most legible forms are found in the Pomeranian and Masurian Lake Districts, while in the Wielkopolskie Lake District they have already been partially erased. The visible forms in the landscape are gentler here, the depressions are shallower, and the hills are lower. The process of overgrowing and disappearing of lakes is also more advanced (Sobolewski et al. 2014).

Natural conditions for the development of lake tourism in Poland

The area of the Polish Lowlands is one of the largest lowland and lake regions in this part of Europe, with an area of over 110,000 ha. km^2, which is ~35% of the area of Poland. There are 6,793 lakes (with an area of over 1 ha) on it, which occupy ~2,770 km^2 (Choiński 2006). There are three separate lake districts in this area (Pomeranian, Masurian and Wielkopolsko-Kujawskie), with varied relief and altitude exceeding 300 m a.s.l. The landscape is dominated by small lakes with an area of less than 50 ha, of which there are 5,820, while there are 477 lakes with an area of 50–100 ha and only 28 lakes with an area of more than 1.00 ha (Choiński 2007) (Table 1).

It should be emphasized that the lakes are located in the Polish Lowlands and are characterized by relatively small areas. More than half of the lakes have an area of less than 5 ha. and only 468 have an area larger than 100 ha. Generally, only on lakes over 100 ha is it possible to practice sailing and motorboating, which, with the introduction of restrictions on swimming with internal combustion engines, largely limits the accessibility of many lakes. The total number of lakes exceeding 100 ha in individual lake districts is: Pomeranian – 150, Masurian – 222, Wielkopolsko-Kujawskie – 96, and in the Łęczyńsko-Włodawskie Lake District – 8 (Choiński 2006).

The analyzed lakes present a wide spectrum of morphometric, hydrological and mictic features. Their areas range from slightly above 5 ha (Czarne – 5.5 ha) to over 11,000 ha (Śniardwy – 11,487.5 ha). There are 20 lakes above 1,000 ha and they constitute as much as 66.7% of the area of all the analyzed lakes, while there are 39 lakes below 100 ha. In terms of lake depth, their maximum values range from 2 (Ruteckie) to 106.1 m (Hańcza). The average depth of the lake, which is a reliable indicator of depth relations, ranges from 0.9 m (Ruteckie) to 38.7 m (Hańcza). For 16 lakes, the average depth is greater than 15 m, and for 31 lakes it is less than 5 m.

Table 1. Number of lakes of area >1.0 ha within the Polish Lake Districts according to the Catalog of Polish Lakes (Choiński 2006)

Lake district	Number of lakes	Surface in ha	Volume in km^3	Average depth m
Pomeranian	3 385	104 197.3	7.129200	6.84
Masurian	2 061	130 481.0	10.118344	7.45
Wielkopolsko-Kujawskie	1 347	42 053.1	2.353458	5.70
The area south of the last glacial line	288	4 245.6	0.13389	4.34

Source: own elaboration

Lakes in Poland are characterized by increasing interest both among city dwellers and people living throughout southern Poland. The positive impact of these areas is indicated not only by the increasingly better service base, but mainly by: the condition of the natural environment, its landscape attractions, and large areas of forests, including National Parks, Landscape Parks, as well as historical sites.

Meteorological conditions in summer and thermal winter

The range of average annual air temperatures in the years 1961–2020 ranged from 6.6 (Suwałki) to 8.9°C (Zielona Góra). For the remaining stations it ranged from 6.9 to 8.4°C (Table 2). Their values in individual years of the analyzed period were clearly differentiated and fell within a relatively wide range of values from 3.9°C in 1987 (Suwałki) to 10.1°C in 2000 and 2001 (Zielona Góra and Gorzów Wielkopolski).

The spatial differentiation of the average annual air temperature in the area of the Polish Lowland is shown in Figure 2. The system of air temperature isotherms runs in a clear direction from north-west to south-east. The highest temperatures occur in the area to the west of the 8 °C isotherm and covering Pobrzeże Szczecińskie, Pojezierze Ińskie, the eastern part of Pojezierze Myśliborskie and most of Pojezierze Wielkopolskie. The area located east of the Great Masurian Lake District and a small

Table 2. Average monthly and annual air temperatures and amplitude (A, °C) at selected meteorological stations located within the Polish Lowlands, 1961–2020 (calculated on the basis of data from the Institute of Meteorology and Water Management National Research Institute)

Station	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Year	A
Zielona Góra	4.0	0.5	-1.0	0.1	3.6	8.7	13.6	17.0	18.6	18.2	14.1	9.2	8.9	21.5
Szczecin	4.5	1.2	-0.4	0.4	3.5	8.2	13.1	16.4	18.2	17.7	13.8	9.2	8.8	20.6
Gorzów Wielkopolski	4.0	0.5	-1.0	0.1	3.5	8.5	13.5	16.8	18.5	18.1	13.9	9.0	8.8	21.4
Koszalin	4.4	1.0	-0.5	0.0	2.8	7.0	11.9	15.2	17.1	17.0	13.5	9.1	8.2	19.7
Łeba	4.6	1.2	-0.6	-0.1	2.2	6.1	10.7	14.5	16.9	16.9	13.5	9.2	7.9	19.0
Chojnice	3.0	-0.6	-2.4	-1.5	1.7	7.0	12.2	15.4	17.2	16.8	12.7	7.9	7.4	21.5
Poznań	4.0	0.3	-1.3	-0.3	3.3	8.6	13.7	17.0	18.7	18.2	13.9	8.9	8.7	21.3
Toruń	3.6	-0.2	-2.0	-1.0	2.6	7.9	13.4	16.7	18.5	17.9	13.4	8.5	8.3	22.7
Olsztyn	2.7	-1.0	-2.8	-2.0	1.5	6.5	11.7	14.6	16.7	16.1	12.0	7.5	7.0	22.8
Mikołajki	3.0	-1.2	-3.4	-2.5	0.9	6.9	12.8	16.1	18.0	17.5	13.1	8.0	7.4	23.4
Suwałki	2.0	-2.2	-4.4	-3.7	0.1	6.5	12.4	15.6	17.3	16.7	12.0	6.8	6.6	24.0
Białystok	2.4	-1.7	-3.9	-2.9	1.0	7.3	12.9	16.2	17.8	16.9	12.4	7.2	7.1	23.8

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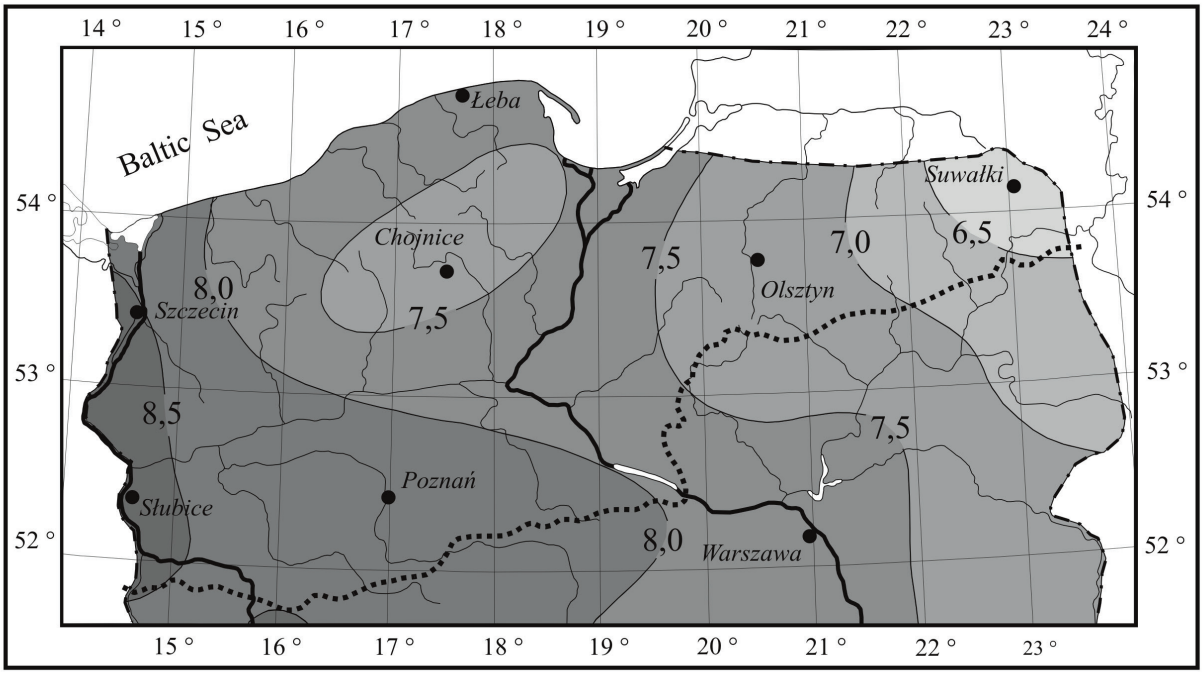

Fig. 2. Course of isotherms of mean annual air temperature (°C) in period 1971–2000 (after Lorenc 2005)

part of the Lithuanian Lake District are definitely the coldest. In addition, the highest elevated spring regions of the Parsęta, Wieprz, Łeba, Wda and Wierzyca river basins, covering the western part of the Kashubian Lake District, are cooler.

The warmest months were July and August, characterized by a poorly spatially diversified course of isotherms, close to latitudinal. The highest average monthly air temperatures were recorded in July and amounted to 18.72°C in Zielona Góra and 18.68°C in Gorzów Wielkopolski, while the lowest average values were in August in Suwałki, at 16.72 °C. The absolute highest air temperatures in the years 1961–2020 occurred in Słubice on July 30, 1994 (39.5°C), in Koło on July 21, 1998 (38.4°C) and in Krzyż on August 8, 2015 (38.3°C).

During the winter months, the air temperature was more varied. The average monthly temperature in December, January and February ranged from +0.4 °C in Szczecin to -3.4°C in Suwałki. Negative values characterized higher elevations in the Pomeranian Lake District (Chojnice -1.5°C). The absolute lowest average monthly air temperatures in the years 1961–2020 were recorded in January 1987 (-15.5°C Suwałki, -15.1°C Białystok) and in 1963 (-12.8°C Białystok, -12.6°C Suwałki). Differences in average temperatures, e.g. in January between stations located in the eastern and western parts of the Polish Lowlands, ranged from 3.5 to 4.0°C on average. The spatial differentiation of temperature in the Polish Lowland shows a roughly meridional system of isotherms.

The effect of thermal conditions in the entire area of the Polish lowlands is a different course of thermal summer and winter. The length of the thermal summer in the analyzed area, i.e. the period in which the average daily air temperature is above 15°C, varies slightly. It is generally assumed that the earliest period begins south of the 53°N parallel (before June 5), a little later, after June 15 in the Baltic coastal zone, and the latest (after June 25) in the Kashubian Lake District Time differences within the Polish Lowlands can reach up to 25 days (Table 3).

The period of thermal winter plays a special role in the natural environment, especially in the functioning of the lake ecosystem, understood as the period when the average daily air temperature is below 0°C. Its occurrence in the area of the Polish Lowland was clearly differentiated and referred to the course of air temperature from December to March (inclusive). The earliest thermal winter appeared in the Suwałki Lake District at the transition of November to December, while it entered the Baltic Coast region latest (after January 10). The time differences between the extreme regions exceeded 40 days (Table 4). The thermal winter was longest in the Suwałki Region (>100 days) and its duration gradually shortened towards the west. To the west of the Vistula, winter lasted less than 60 days, and

Table 3. Statistical characteristics of thermal summer at selected stations in the Polish Lowlands, 1961–2020

Stations	Average date		Length of thermal summer in days	Average temperature (°C)
	start	end		
Gorzów	26-05	04-09	102	17.56
Koszalin	08-06	03-09	86	17.07
Łeba	17-06	02-09	76	16.80
Chojnice	02-06	30-08	89	16.61
Toruń	28-05	04-09	99	17.49
Olsztyn	03-06	30-08	88	16.85
Suwałki	07-06	29-08	83	16.92

in the Baltic Sea and the Oder valley it decreased from 10 to 20 days (Lorenc 2005).

Thermal differences within the Polish Lowlands are also emphasized by air temperature amplitudes. The annual amplitude of air temperature is understood as the difference between the average temperature of the hottest and coldest months. In the area of the Polish Lowlands, it was clearly differentiated and ranged from 19°C in the coastal zone (Łeba) and the Lubuskie Lake District (Słubice) to 24.0°C in the east of Poland (Suwałki).

An important element of the natural environment, determining inland (lake) tourism, is the occurrence of precipitation. Their distribution in the course of the year largely favors or even determines the choice of the place and time of holidays for the vast majority of tourists.

Annual precipitation totals in Poland range from 550 mm on average (locally below 500 mm) in the central and western part of the lowlands (Szczecin 546.9 mm, Poznań 526.8 mm) to nearly 700 mm and above in the Lake District (Koszalin 721.4 mm) and the coast (Łeba 657 mm). Sums above 600 mm characterize the region of the Great Masurian Lakes (Olsztyn 640.4 mm, Mikołajki 601.7 mm) and the eastern part of Poland (Suwałki 600.4 mm, Białystok 600.8 mm). The decidedly larger part of the annual total falls on the summer half-year. The ratio of total precipitation from the summer (Apr–Sep) to the winter (Oct–Mar) half-year is below 1.5 only in the north-western and western parts of the country.

The amount of insolation is of great importance for the tourist attractiveness of each region. In Poland, the largest annual sum of hours with the sun is characteristic of the Mid-Polish Lowlands and the coastal belt, where it exceeds 1,650 hours per year (Kozłowska-Szczęsny et al. 2004). The lowest insolation values (below 1,500 hours per year) refer to the areas of the Drawskie, Kaszubskie and Krajeńskie Lake Districts (Lorenc 2005). Cloud cover also plays an important role among natural factors in the bathing season. The least cloud cover in lowland Poland occurs in August (56%), and the greatest in December (78%). This is significantly

Table 4. Statistical characteristics of thermal winter at selected stations in the Polish Lowland, 1961–2020

Stations	Average date		Length of thermal winter in days	Average temperature (°C)
	start	end		
Gorzów	20-12	13-02	55	-2.8
Koszalin	06-01	28-02	54	-2.9
Łeba	07-01	23-02	48	-1.7
Chojnice	10-12	27-02	80	-2.8
Toruń	19-12	22-02	65	-3.3
Olsztyn	9-12	1-03	82	-3.3
Suwałki	2-12	12-03	100	-3.9

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related to the North Atlantic Oscillation (NAO) index from June to October, mainly in July and August. Żmudzka (2007), analyzing the influence of atmospheric circulation on the amount of cloudiness over Poland, comes to the conclusion that, in the period of 1951–2000, a slight decrease of 0.04%·year^{-1} was observed.

The surface layer of lake water should be treated as the element most sensitive and susceptible to changes in meteorological conditions. The water surface in lakes is a boundary layer through which energy is exchanged between the lake and its surroundings; it is also a zone of solar radiation absorption and water circulation (Skowron 2011). In thermal terms, the "surface layer of lake water" should be understood as a layer with a thickness of 1 to 1.5 m (Skowron 1999, 2022; Sobolewski et al. 2014).

Research conducted on various lakes in Poland showed that its surface water layers, subjected to continuous mixing of water, are characterized by small differences in temperature within the lake. Differences in surface water temperature between the coastal zone (littoral) and parts of the open lake (pelagial) in summer (Jun–Aug) usually range between 0.8–1.5°C, rarely being greater (Skowron 2011, 2018).

The average course of the annual surface water temperature in 12 lakes of the Polish Lowlands in the years 1961–2020 indicated that its average annual values ranged from 8.42 °C (Hańcza) to 10.59°C (Sławskie). The highest values occurred in 2001–2005, when in seven lakes they were higher than 10°C, while the lowest temperatures were recorded in 1976–80, when in nine lakes they were lower than 9°C.

Calculations of average monthly surface water temperatures for the months of the summer half-year in the years 1961–2020 showed that the highest values occurred in July and August, and ranged from 18.49°C (Gardno) to 21.06°C (Bachotek). For the remaining lakes, the average surface water temperatures ranged between 19.5–20.5°C in July and 19.3–20.3°C in August (Table 5).

The course of the average surface water temperature for the summer period (tsum) in the multi-year period 1961–2020 showed spatial differentiation within the Polish Lowlands. The lowest water temperature in this period was in the following lakes: Gardno (17.60°C), Raduńskie Górne (17.81°C) and Łebsko (17.95°C), and the highest in: Sławskie (20.38°C), Bachotek (20.34°C) and Jeziorak (20.22°C).

The absolute highest values of surface water temperature were recorded at the turn of July and August 1994, whenm at 7:00 a.m., they exceeded 25°C in eight lakes. The record water temperature reached 30.2°C and 29.2°C, respectively, in the Nakielno and Jeziorak lakes (Skowron 2009b, 2011). It should be remembered, however, that in

Table 5. Monthly (Apr-Oct) and annual (R) mean surface water temperatures (°C) in 1961–2020 in the analyzed lakes of the Polish lowlands

No	Lake	Apr	May	Jun	Jul	Aug	Sep	Oct	Year
1	Lubie	6.46	12.65	17.51	19.69	19.42	15.53	10.85	9.69
2	Sławskie	8.71	14.99	19.22	20.96	20.81	17.06	11.97	10.83
3	Gardno	7.01	12.86	16.67	18.47	17.78	13.75	9.01	8.90
4	Łebsko	7.61	13.13	16.86	18.75	18.13	14.02	9.30	9.23
5	Charzykowskie	5.76	12.43	17.32	19.46	19.34	15.74	11.29	9.64
6	Raduńskie Górne	5.15	10.59	15.60	17.82	17.84	14.65	10.33	8.88
7	Gopło	8.07	14.46	19.01	20.65	20.23	16.66	12.12	10.85
8	Jeziorak	7.72	14.77	19.27	20.82	20.52	16.09	10.56	10.14
9	Mikołajskie	4.95	12.12	17.60	19.81	20.08	16.49	11.80	9.69
10	Nidzkie	6.85	14.10	18.58	20.45	20.20	16.04	10.62	9.78
11	Hańcza	3.52	9.47	16.77	19.21	19.04	14.66	9.52	8.56
12	Studzieniczne	5.61	13.52	18.37	20.28	20.04	15.86	10.54	9.66

small lakes not covered by stationary temperature measurements, the surface water temperature may exceed 31–32°C (Skowron 2011).

Generally, in lakes in the Polish Lowlands, a clear decrease in the surface water temperature is observed towards the north and north-east (Skowron 2011; Koźmiński and Michalska 2016).

The surface water temperature in lakes located in the Polish Lowlands in the summer months (June–August) in the period 1961–2020 is clearly differentiated. For all lakes, this temperature has a positive trend, and the highest values were in August (Lake Nidzkie 0.059 °C·year^{-1}) and July (Lake Jeziorak 0.050 °C·year^{-1}) (Table 6). They are close to the values given by other authors for lakes located in Western Europe (Dokulil 2013) and lakes in North-Eastern Europe (Karetnikov and Naumenko 2008).

A clear differentiation of individual ranges of surface water temperature in lakes and their duration occurs within individual lake districts. Dates of the beginning of the period with a temperature of 15°C and 18°C, the earliest occurred in lakes in the Wielkopolskie Lake District. The period with the temperature above 18 and 20°C was also varied, with an average of 68 and 35 days, respectively. The temperature above 25°C in the surface layer occurred sporadically, and the warmest was in 1994 and 2010, when it occurred on lakes Sławskie, Gopło, Jeziorak and Studzieniczne for over 20 days. However, it should be remembered that the average values of surface water temperature for lakes located in individual lake districts are significantly different, both between individual lakes and between years.

In the vast majority of lakes, with the exception of polymictic water bodies, during the thermal summer (Jun–Aug) there is thermal stratification of water with epi-, meta- and hypolimnion. In Polish lakes during the summer thermal stagnation, the most clearly developed thermal systems occur on average from mid-July to mid-August. The degree of development of individual thermal layers depends on depth, surface area and the possibility of dynamic wind impact on the water mass of the lake. The thickness of individual layers and their thermal gradients are clearly differentiated and correspond to the parameters characterizing the lake basin (Skowron 1991, 2009b, 2022). On their basis, it is possible to determine the thermal type – an important feature differentiating the lakes from one another. In the group of 652 lakes analyzed, the most numerous are the shallowest (warmest) lakes with epi- and meta-epithermic features, which constitute as much as 54.1%. The least numerous are the deepest lakes classified as hypothermic lakes – 1.1% (Table 7).

Table 6. Average monthly and annual trend of surface water temperatures (°C·year^{1}) in selected lakes in the 60-year period 1961–2020

Lake	Month				Year
	VI	VII	VIII	IX	
Lubie	**0.046**	**0.045**	**0.048**	**0.034**	**0.038**
Sławskie	**0.031**	**0.042**	**0.048**	**0.030**	**0.032**
Gardno	**0.015**	**0.039**	**0.027**	**0.021**	**0.022**
Łebsko	**0.020**	**0.044**	**0.037**	**0.029**	**0.028**
Charzykowskie	**0.028**	**0.038**	**0.041**	**0.028**	**0.031**
Raduńskie Górne	**0.031**	**0.038**	**0.038**	0.018	**0.031**
Gopło	0.025	0.018	**0.036**	0.011	**0.028**
Jeziorak	0.027	**0.050**	**0.058**	**0.049**	**0.032**
Mikołajskie	0.020	**0.035**	**0.045**	**0.026**	**0.027**
Nidzkie	**0.026**	**0.041**	**0.059**	**0.039**	**0.032**
Hańcza	**0.038**	0.024	**0.038**	0.054	**0.015**
Studzieniczne	0.027	**0.040**	**0.047**	0.024	**0.025**

Source: (based on IMiGW PIB data)
(statistical significance < 0.01 is given in bold)

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For most people bathing in lakes, the surface water temperature (as of 7:00 a.m.) is only of general importance. The time when the optimum water temperature occurs is of great importance. For this purpose, the author conducted research on the daily course of water and air temperature in various points of the lake (including in the bathing area). For this purpose, in the years 1971–2015, experimental measurements were made on 19 lakes located in various parts of the Polish Lowland (Skowron and Piasecki 2016). However, it should be remembered that experimental research can only be used to learn in detail about selected processes shaping the thermal regime and to detail their course, and they should therefore be treated as a necessary supplement (Skowron 2011, 2020, 2022).

According to the analysis of the daily course of water temperature in the surface layers in various lowland lakes in Poland, the maximum was recorded on average between 14:00–17:00 (13:00–16:00 GMT), while the minimum was most often observed between 6:00 and 7:00 a.m. (5–6 a.m. GMT). Daily changes in the vertical distribution of water temperature are clearly visible down to a depth of 2.5–3.5 m and are noticeable down to a depth of 5.5–7 m (Skowron and Piasecki 2016).

It is assumed that the beginning of the potential bathing season (water temperature above 18 °C) in Poland starts between May 31 and June 25 and ends between August 26 and September 15 (Lijewski et al. 2008).

The average dates of the beginning of the bathing season (>18°C) on lakes located in the Polish Lowlands fall between May 16 and June 4 (Table 8). The earliest were recorded in the following lakes: Sławskie (May 15), Jeziorak (May 16) and Śniardwy (May 17). On the other hand, they occurred latest in the deep lakes: Raduńskie Górne, Drawsko and Hańcza (June 4). In the remaining lakes, the date of passing through the surface water temperature of 15 °C was usually between 20 and 25 May.

The bathing season covers only a part of the annual thermal cycle, including mainly the phase of summer water heating and summer cooling, separated by the date of occurrence of maximum surface water temperatures. Since the bathing season in lakes in Poland usually lasts from the end of May to mid-September, the analysis of water temperature in lakes was carried out from May to October (Koźmiński and Michalska 2016; www.eea.europa.eu).

The average dates of occurrence of the temperature of 18°C in the surface layer are between June 2 and 3 (Lakes Gopło and Sławskie) and June 26 (Lake Raduńskie Górne). In turn, the final dates of occurrence of this temperature occur on average between the end of August and the middle of the second decade of September, with extreme values between the beginning of the third decade of August and the beginning of the third decade of September (Table 7).

Table 7. Quantitative assessment of thermal types of lakes in individual regions in Poland (percentage in brackets) (after Skowron 2009a)

Lakeland	Number of lakes studied	Epithermal type	Metaepithermal type	Metathermic type	Hypometathermic type	Hypother-mictype
Pomoranian	230	43 (18.7)	91 (39.6)	53 (23.0)	38 (16.5)	5 (2.2)
Mazurian	159	50 (31.4)	49 (30.8)	40 (25.2)	19 (11.9)	1 (0.7)
Wielkopolsko-Kujawskie	152	50 (32.9)	55 (36.2)	33 (21.7)	13 (8.6)	1 (0.7)
Total	541	143 (27.7)	195 (35.5)	126 (23.3)	70 (12.3)	7 (1.1)

The calculations showed that the occurrence of dates of the bathing season (temperature above 18 °C) in the analyzed 60-year period (1961–2020) was characterized by significant variation, which is confirmed by the values of the standard deviation

(11.6–12.3). The initial dates in all lakes showed a negative trend (average: 0.23–0.28 days·year^{-1}), i.e. they appeared earlier and earlier, while the end dates showed a positive trend (average: 0.15–0.19 days·year^{-1}). This distribution confirms the average duration of this season, which ranges from 45 days (Lake Gardno to 93 days (Lake Sławskie).

The variability of the length of the bathing season characterizes the calculated trend for the period 1961-2020. For all lakes it is positive, it ranged from 0.32 day·year^{-1} in the case of Lake Gopło to 0.78 day·year^{-1} in Lake Lubie (Table 9). In turn, the period of occurrence of the ice cover shortened, which is clearly indicated by a negative trend of 0.43–0.82 day·year^{-1}.

The Chief Sanitary Inspectorate in Poland states that the bathing beach is designated by a resolution of the commune council; a separated and marked fragment of surface water used by a large number of bathers. An official organized bathing beach must be equipped with full infrastructure necessary for those on vacation, i.e.: appropriate markings, designated areas for swimming adults and children, piers, showers, changing rooms, toilets, adaptation for the disabled, swimming equipment rental, small gastronomy and protection by qualified lifeguards. Otherwise, such a place becomes unattractive or simply illegal. Apart from the above-mentioned features, the attractiveness of recreational places is also determined by: the natural values of the place, the exposure of the shore zone of the bathing beach, as well as the physical and chemical characteristics of the water (mainly transparency and water temperature). In addition, most lakes in Poland are characterized by an advanced degree of trophy, which may limit their use for recreation and leisure (Młynarczyk and Borkowski 2015). The exact location of the bathing areas and basic updated information about them can be found on the website of the Chief Sanitary and Epidemiological Inspectorate http://sk.gis.gov.pl.

In the information space there is a "Bathing service", which provides up-to-date information on the quality of water at all designated bathing areas in Poland, also providing basic information about the location, available infrastructure, as well as current information. The need for such information transfer is evidenced by the fact that the website was visited by over 800,000 users.

In 2020 out of 602 active bathing areas, the vast majority were organized on lakes. At that time, the authorities of the State Sanitary Inspection issued almost 3,000 assessments, of which only 95 bathing sites were temporarily prohibited from use, mainly

Table 8. Dates of surface water temperature 18°C in spring and autumn in lakes in the Polish Lowlands, 1961–2020

Lake	Temperature 18°C – spring			Temperature 18°C – autumn			Number of days with temperature above 18°C
	First dates	Average date	Latest dates	First dates	Average date	Latest dates	
Lubie	16-05	19-06	30-07	25-07	29-08	20-09	65
Sławskie	05-05	03-06	23-07	23-08	10-09	29-09	93
Gardno	07-05	09-06	20-07	20-07	23-08	16-09	45
Łebsko	10-05	23-06	08-08	02-07	21-08	18-09	49
Charzykowskie	10-05	17-06	08-08	06-07	30-08	25-09	64
Raduńskie Górne	26-05	26-06	16-08	03-07	23.08	14-09	47
Gopło	09-05	02-06	19-07	28-07	06-09	28-09	88
Jeziorak	30-04	05-06	14-08	04-08	03-09	26-09	85
Mikołajskie	11-05	14-06	14-08	01-08	04-09	25-09	71
Nidzkie	11-05	10-06	06-09	02-07	03-09	25-09	81
Hańcza	28-05	24-06	16-08	23-06	24-08	17-09	58
Studzieniczne	02-05	06-06	19-07	29-07	02-09	24-09	78

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Table 9. Course of trends in the duration of the bathing season and the period with ice cover on the lakes of the Polish Lowland, 1961–2020

Lake	Bathing season (day·year^{-1})	Period with ice cover (day·year^{-1})
Lubie	**0.78**	-0.43
Sławskie	**0.63**	**-0.61**
Gardno	**0.38**	**-0.67**
Łebsko	**0.59**	**-0.82**
Charzykowskie	0.75	-0.46
Raduńskie Górne	**0.55**	**-0.66**
Gopło	0.32	**-0.80**
Jeziorak	**0.77**	**-0.66**
Mikołajskie	**0.45**	**-0.68**
Nidzkie	**0.54**	**-0.56**
Hańcza	**0.46**	-0.44
Studzieniczne	**0.40**	**-0.67**

(statistical significance < 0.02)

due to the excessive extent of cyanobacteria blooms. At the end of the bathing season in 2020, the authorities of the State Sanitary Inspection, based on four bathing seasons with full data documentation, separated bathing sites with excellent, good, sufficient and insufficient water quality, of which there were 201 in total. Unfortunately, for as many as 401 bathing sites (66.6% total) this was impossible due to the insufficient amount of necessary data.

In 2020, 602 bathing sites operated under the supervision of the State Sanitary Inspection, of which 436 were inland bathing sites and 166 were marine, and 189 places were used occasionally for bathing (Table 8). The most inland bathing areas were located in Wielkopolskie (86), Pomorskie (51) and Kujawsko-Pomorskie (35) voivodeships, while the fewest were in Podkarpackie (7) and Małopolskie (10) voivodeships.

Ice phenomena on lakes are the result of negative air temperatures and cooling of the surface layer of water. Information on the nature and course of ice phenomena is of great importance to winter sports enthusiasts and ice fishing anglers.

As shown in Table 11, the average dates of the appearance of the ice cover in the Polish Lowland were usually recorded between December 24 and 30 and occurred about 8–10 days later than the dates of the first ice phenomena. On the other hand, the average final dates of the ice cover occurrence were recorded between 10 and 12 March, with it disappearing by far the latest in the eastern part

Table 10. Number of bathing areas in Poland supervised by the State Sanitary Inspection, 2011–2020 (data based on: http://sk.gis.gov.pl)

Type of water	Number of bathing areas									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coastal and transitional waters	89	87	82	84	82	88	97	146	163	166
Inland waters	131	134	122	117	115	113	108	337	443	436
Total	**220**	**221**	**204**	**201**	**197**	**201**	**205**	**483**	**606**	**602**

of the Masurian Lake District. The duration of the ice cover was on average about 66 days and was 14 days shorter on the lakes located west of the Vistula than east of the Vistula. It was also noticed that, on the lakes located east of the Vistula river, there are numerous breaks in the course of the ice cover, much less often than on the lakes of the Pomeranian and Wielkopolsko-Kujawskie Lake Districts. This is confirmed by the ice cover stability index, which was about 40–55% for lakes located west of the Vistula, and over 96% for lakes located in the Suwałki Lake District (Marszelewski and Skowron 2006). Both the duration of the cover and its thickness clearly correspond to the North Atlantic Oscillation (NAO) index (Wrzesiński et al. 2015).

The maximum thickness of the ice cover on lakes in Poland occurred on average at the transition of January to February and amounted to ~25 cm, while on lakes located east of the Vistula it exceeded 30 cm. This diversity was confirmed by synchronous studies of its thickness carried out at the transition of January to February 2004 on 33 lakes located in northern Germany, Poland and south-eastern Lithuania. For the safety of people enjoying the pleasure of winter sports (skating, ice-boating competitions), as well as popular ice fishing, lakes located east of the Vistula, and especially east of the Olsztyńskie and Brodnickie Lake Districts, are definitely safer compared to other regions.

It is generally accepted for fresh, black and transparent ice that the safe thickness of the ice cover should be: for a dog – at least 5 cm, for a single person – at least 10 cm, for three people standing next to each other – at least 15 cm, for a car passenger car (small) – at least 20 cm, and for an off-road van – at least 30 cm. In the case of ice fishing, holes with a diameter of no greater than 20 cm, and the distance between holes should be at least 1 m, while ice anglers should keep a distance of at least 10 m between themselves

Conclusions

The greatest intensification of tourist traffic in Poland, which falls in June–August is especially noted on the Baltic coast and lake districts (Lijewski et al. 2008).

Table 11. Average values of ice characteristics in lakes in Poland, 1961–2020

No	Lake	Beginning of		End of		Duration of days		Maximum thickness of ice cover (cm)	Mean proportional part of ice phenomena in longterm period (%)
		ice phenomena	ice cover	ice cover	ice phenomena	ice phenomena	ice cover		
1	Lubie	07-01	11-01	09-03	08-03	57.7	54.8	22.8	87.3
2	Sławskie	13-12	26-12	3-03	5-03	67.1	55.1	20.9	75.9
3	Gardno	10-12	19-12	28-02	09-03	69.4	55.2	20.7	74.3
4	Łebsko	14-12	24-12	28-02	07-03	65.7	52.1	21.7	73.5
5	Charzykowskie	29-12	5-01	12-03	18-03	69.8	60.2	23.8	79.3
6	Raduńskie Górne	30-12	09-01	16-03	27-03	73.3	58.4	23.1	73.3
7	Gopło	14-12	21-12	28-02	9-03	74.1	59.0	19.7	74.5
8	Jeziorak	06-12	16-12	15-03	19-03	93.0	80.9	27.1	85.3
9	Mikołajskie	18-12	1-01	16-03	30-03	93.4	69.6	31.1	71.0
10	Nidzkie	8-12	20-12	19-03	29-03	102.5	84.9	29.0	81.4
11	Hańcza	27-12	04-01	19-03	28-03	89.5	71.4	28.6	77.1
12	Studzieniczne	15-12	22-12	28-03	1-04	103.8	93.2	34.2	89.0

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Among all the days in the bathing season (from April to October), in the multi-year period 1971–2020, comfortable days (18.1–23.0°C) were the most common; on average, from 59 to 96 days, followed by moderately hot days (23.1–25.0°C) – from 30 to 48 days. In summer, a large share of comfortable days in the total number of days creates good conditions for recreation and tourism in all Lake Districts (Pomeranian, Masurian and Wielkopolsko-Kujawskie) (from 40 to 44%) and on the coast (from 45 to 50%). The share of very hot days (>30.0 °C), burdensome for the human body, is 6–8% in the central-western part of the country, and 2–3% in the coastal zone. In the warm half-year, hot days (25.1–30.0°C) most often occur from June 26 to August 25, and very hot days (>30.0°C) from July 15 to August 20 (Koźmiński and Michalska 2011a, b; Skowron 2018, 2022).

The most optimal conditions for swimming in Polish lakes appear on average from mid-July to mid-August. At this time, the warmest waters occur in epithermic and meta-epithermic lakes, in which the volume of the littoral zone (up to 2.5 m deep) is the largest (on average 50–60% of the lake volume). At the same time, these lakes are characterized by the lowest water transparency in the summer, within the range of 0.8–1.6 m (for 118 lakes).

Research and calculations have shown that the bathing season in lakes in Poland comes earlier and ends later and later, which results in its lengthening with an average trend of 0.55 days·year^{-1}. In turn, the period with the occurrence of ice cover is getting shorter with a negative trend of 0.63 days·year^{-1}.

The summer temperature of lake waters, especially in the surface layers, is mainly determined by the air temperature of the spring and summer months, the length of the thermal summer and the morphometric parameters of the lake (Skowron 2022). After the depth of the lake, the next most important indicators are lake basin compactness and shaping of the coastal zone. In turn, the course, duration and thickness of ice cover are determined by the air temperature in December–March, which is determined by the North Atlantic Oscillation (NAO) (Wrzesiński et al. 2015).

The rapidly growing number of bathing areas on lakes in Poland (in 2021 there were already 657 of them) poses great challenges to the services appointed to control water quality. It should be remembered that over 66% of bathing sites do not have full documentation in this regard. One of the reasons that hinder faster adaptation of bathing areas on lakes is the overly slow pace of adapting the infrastructure to modern requirements and the process of systematic overgrowing of lakes.

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