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TEMPERATURE DIVERSIFICATION OF THE SURFACE LAYER OF WATER IN THE KARST LAKES IN THE STASZÓW REGION (NIDZIAŃSKA BASIN)

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Abstarct: The north-eastern part of Nidziańska Basin, near Staszów, boasts a large grouping of small but relatively deep lakes of karst origin. In 2010, 26 of them underwent regular measurements of the temperature of their surface layer of water. The results show that although the basins are situated close to each other and the area has similar characteristics, the temperature differs significantly. The thermal differences reach 11.6ºC. The warmest lakes appear to be Lake Łajba, Duży Staw, Lakes Torfowe I and Torfowe II. However, the coldest surface water is in lakes Piąty Staw, a small unnamed lake located near Lake Ciemne and an unnamed lake sandwiched between Lake Szyja and Lake Jasne.
The fact that the temperature of the water goes up results directly from solar radiation, which was the strongest in the case of Lake Łajba, located in an open area. However, the coldest basins were located in the central parts of the lakes of the floating peat islands. Those biogenic islands are perfect "insulators", protecting the water from thermal radiation. Moreover, the lakes which are fed with soligenous water supplies, tend to have a lower temperature.

Keywords: karst lakes, surface layer of water, temperature, Nidziańska Basin, Poland

INTRODUCTION

In the belt of Polish uplands, the lakes of the area bigger than 1 hectare are not frequent (Choiński 1995). However, there are places where the accumulation of natural basins is bigger. Jaśkowski and Sołtysik (2000; 2001; 2003), drew attention to one of such groupings in Świętokrzyskie Region. The lakes in this area became the subject of interest and research of Biernat (2001), Biernat and Gwiazda (2003), as well as Biernat i Sobieszczański (2003), Choiński and Zieliński (2020).

Apart from the previously mentioned area, there is also a lake accumulation in Połaniecka Basin, especially in the north-eastern part of it, near Staszów. Moreover, the lakes may be found near Jarząbki, Szarbków, Sędziejowice, Bogucice, Busko-Zdrój and many more places. Frequently, the basins are used for farming purposes and turned into ponds. The lakes located in Nidziańska Basin became the subjects of study for Zieliński (2007a; 2007b; 2008; 2013), Zieliński and Łoziński

(2007a; 2007b), Stachura et al. 2018. The study concerned, apart from others, the morphometric characteristics of the lakes. They also covered the issues of the water property (Zieliński 2010a). However, Zieliński and Ziętek (2010) focused on defining the thickness of lake sedimnets, and Zieliński (2010b), Zieliński et al. (2020) characterized the properties of the sediments. The research showed a significant property diversity of the objects, which consequently induced further scientific challenges. Unfortunately, the knowledge about the lakes of Świętokrzyskie Region still seems to be unsatisfactory and insufficient. Therefore, it is necessary to continue and advance the observations.

Among them, determination of the thermal conditions of lake water has a crucial meaning since temperature is considered as one of the basic parameters that have great impact on the functioning of a water ecosystem, e.g.: Lange 1993; Skowron 2001; 2011; Choiński 2007; Sobolewski et.al. 2014; Ptak and Nowak 2016.

Study area and methods

Nidziańska Basin, in terms of its physio-geographical characteristics, is situated in the southern part of Małopolska Upland (Solon et al. 2018). However, the north-eastern part of it, which is the subject of the study, is known as Połaniecka Basin.

In terms of administrative characteristics, the area is situated in the southern part of Świętokrzyskie Voivodship, in the Staszów County. Near Staszów, there is a large accumulation of small lakes of karst origin (Fig. 1).

Generally, most of the lakes analysed are located in the catchment of the River Czarna Staszowska. Only some of the objects, situated in the eastern part of the area analysed, near Lake Jasne, are already situated in the the catchment of the River Kacanka, which is the right-bank tributary of the Koprzywianka.

In 2010, 26 lakes were chosen for observation and undergone 9 measurement sessions. The research was the continuation of the observations started in 2008 (Zieliński 2010a). Temperature of the surface layer of water was measured at all points, for one day. Measurements were taken in the shortest time period possible. For measurement purposes, days with the most stable weather were chosen.

The research was carried out from March to November (of monthly frequency). The measurements were made from the banks, in the previously defined, permanent locations. The temperature was measured by the U-10 meter, produced by the Japanese company Horiba. The measurements were made with the accuracy of 0.1°C. Only in the case of Duży Staw, the measurements were made from the pier, several metres from the bank. Additionally, the thermal property of the water was measured at the depth of 1 m.

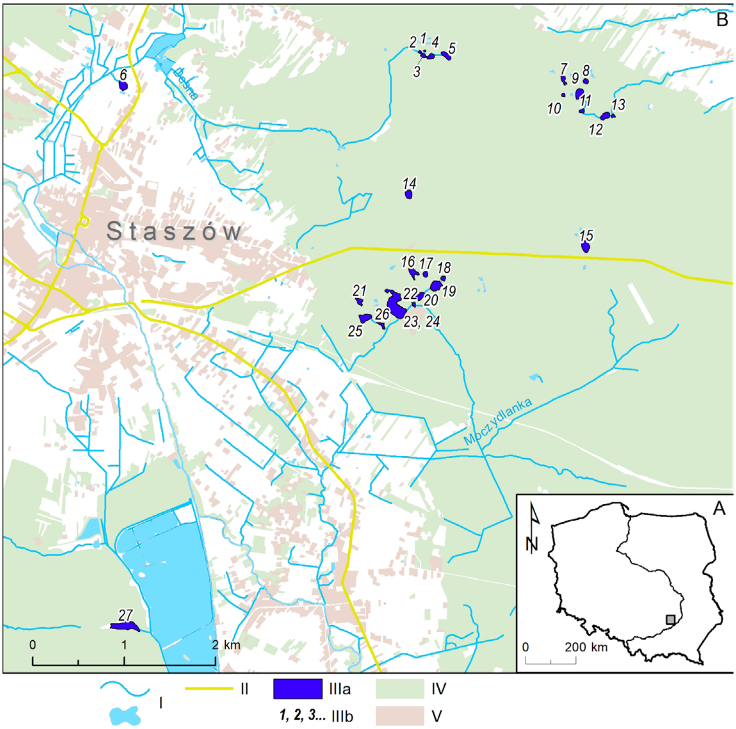

Fig. 1. Location of the study area on the background of the contour map of Poland (A). The location of the researched lakes near Staszów (B)

I – lakes and watercourses, II – roads, III a. – analyzed lakes, III b – locations of specific lakes: 1 – the lake to N of the of Lake Torfowe III, 2 – Lake Torfowe IV, 3 – Lake Torfowe III, 4 – Lake Torfowe II, 5 – Lake Torfowe I, 6 – Lake Łajba, 7 – Lake Szyja, 8 – Lake Mai, 9 – Lake Jasne, 10 – the lake between Lake Szyja and Lake Jasne, 11 – the lake to S of Lake Jasne, 12 – Lake Ciemne, 13 – the lake near Lake Ciemne, 14 – Lake Odrodzone, 15 – Lake Przeciwpożarowe, 16 – Lake Kacze, 17 – Lake Bez Nazwy, 18 – Lake Piąty Staw, 19 – Lake Czwarty Staw, 20 – Lake Trzeci Staw, 21 – Lake Przedpole, 22 – Lake Drugi Staw, 23 – Lake Duży Staw, 24 – Lake Duży Staw (1 m), 25 – Lake Donica, 26 – Lake Rozlane, 27 – Lake Dziki Staw, IV – forests, V – buildings and structures.

RESULTS AND DISCUSSIONS

The results of the temperature measurements of the water surface layer show a significant thermal diversity of the objects. It is worth emphasizing that the basins analysed are at the similar heights. The highest, at 217 m above sea level, are Lake Torfowe I and a unnamed lake situated to the north of the grouping of so called Lakes Torfowe. The lowest is Lake Dziki Staw (180.3 m) and Lake Łajba (191 m). The difference in the location of the lakes in terms of the metres of sea level, is not of significant importance in this case. Moreover, the basins are situated close to each other. The outermost basins are 6 km apart from each other, so it may be presumed that the climatic conditions in the region are similar. It is also worth emphasizing that the lakes are located in the area similar in terms of forestation. The only exception is Lake Łajba, which, as the only one, is situated at the open area, with no forests.

Apparently, the temperature of the water surface layer in the lakes is influenced by their characteristic features of morphometric properties, e.g. the area, the maximum and average depth and volume of water, etc. However, it was observed that the basins of similar properties are different. The results of the research show that Lakes Łajba, Duży Staw and Torfowe I and Torfowe II (Fig. 2) have the warmest surface layer of the water.

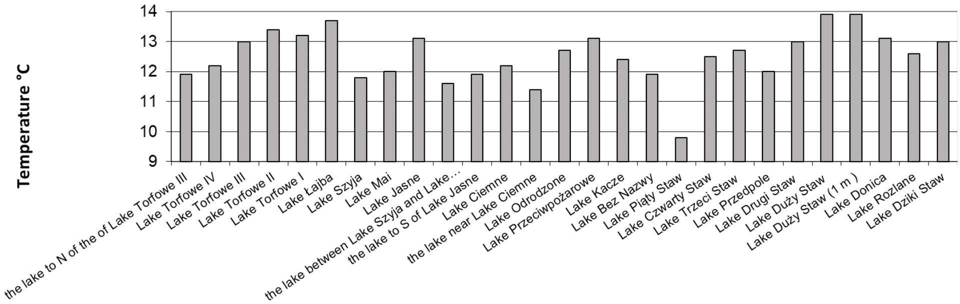

Fig. 2. Average temperature of surface waters of lakes from 9 measurement series

The high temperature of the surface layer in Lake Łajba is, without any doubt, influenced by the open area, with no forestation, which as a consequence creates favourable conditions for heating the water by direct solar radiation. The highest temperature – 28.1°C (Fig. 3) was taken in Lake Łajba on 10.07.2010. The average temperature at that time in the basins was 24.1°C, the lowest temperature (Lake Piąty Staw) was 16.5°C. Earlier, on 13.06, the same temperature – 28.1°C was observed in the smaller and shallower forest lake called Przeciwpożarowe. The average temperature in the basins was at that time also 24.1°C, and the coldest lake (Lake Piąty Staw, as before) 17°C. The usually lower temperature values of water in the Piąty Staw lake result from the groundwater tributaries flowing to this basin. Most certainly, this influences the thermal conditions of the surface layer.

Lake Przeciwpożarowe is 3 m deep, however, Lake Łajba 4.3 m deep. Lake Łajba is additionally much bigger – app. 0.8 ha.

Lake Łajba had also much higher temperature than other lakes, e.g in June 2008 and September 2009 (Zieliński 2010a).

The next group of the warmest lakes is Lake Torfowe I. It is only 0.5 ha big and its depth is 5.3 m. The depth of Lake Torfowe III, however, is 5.1 m maximum.

What is more, Lake Duży Staw is the biggest of all the lakes described. It is 3.63 ha big. It obtains less energy from the direct thermal radiation, much smaller than Lake Łajba. However, the amount of the energy it receives, is much greater than the amount received by any other remaining forest lakes. Lake Duży Staw is 7.8 m deep and therefore, is much deeper than Lake Łajba. The water capacity of Lake Duży Staw is 134 000 m^3, which means that it is 9.6 times bigger that the water capacity of Lake Łajba, which is 14 000 m^3. Consequently, Lake Duży Staw heats up much longer but it cools much slower. It is influenced by the volume of the heated surface of the water, as well as by the forest surrounding the lake, which moderates rapid air temperature drops. For this reason, on 29th of August 2010 it was observed that Lake Duży Staw was the warmest lake among all the lakes measured, with the water temperature of 20.5°C (Fig. 3). Moreover, the water temperature in the lake on the depth of 1 m was at that time 0.1°C higher than the surface water temperature. The average water temperature in the basins was at that time 17.4°C, and the water temperature in the coldest lake (Lake Piąty Staw) was 14.3°C.

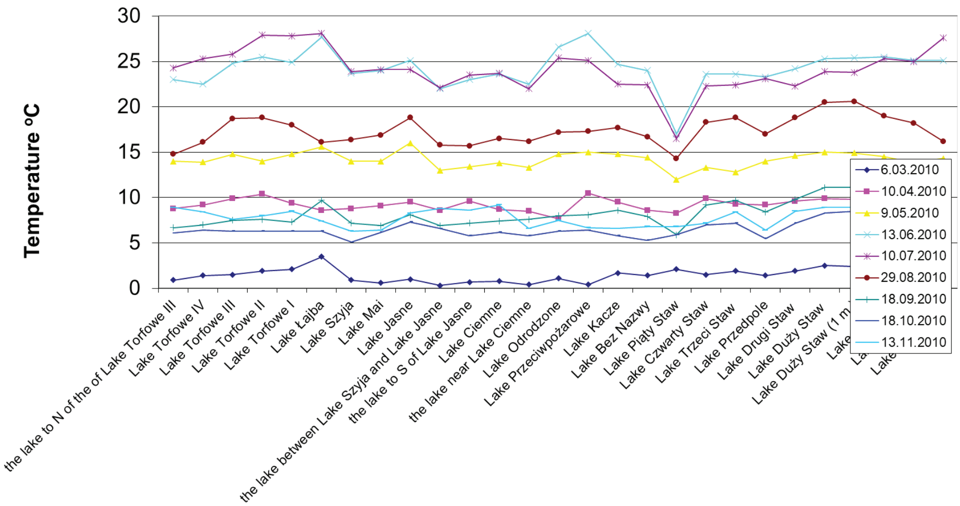

Fig. 3. The temperature of the surface water in the lakes in (research series)

The results of the research show explicitly that the drop of the surface water temperature in Lake Duży Staw was much lower than in other lakes. For example, in Lake Łajba, the drop of the water temperature between the measurements of 10.07 and 29.08 was 12°C, while in Lake Duży Staw in the same period of time the difference was of only 3.4°C. Such a big water temperature drop in Lake Łajba was influenced by its location in the open area. Wind blows have much easier access to the water surface and therefore, carry the heat off the lake.

The coldest surface water was in Lake Piąty Staw, the unnamed lake situated near Lake Ciemne and the unnamed lake situated between Lake Szyja and Lake Jasne (Fig. 2). They are small lakes, up to 25 ares, with a regular, oval shape. However, they are of relatively big, several-metre depths. Moreover, it is worth pointing out, that on the coldest of those lakes, Lake Piąty Staw and the unnamed lake situated between Lake Szyja and Lake Jasne, in their central parts, floating peat islands can be observed (Fig. 4). They are perfect water "insulators" against the direct thermal radiation. In spring, when there is no sheet of ice on the lake, it was also observed that the ice was still lying on the peat islands in the form of ice lens. Similar ice lens were noticed in the same period of time in some other places of the region analysed, e.g. at peatlands.

Fig. 4. Floating and moving peat island on Lake Donica (fot. A. Zieliński, 30.05.2010)

It is worth mentioning, that the most significant thermal differences of the lakes' surface water were recorded in the summer period of time: 10th July (11.6°C) and 13th June (11.1°C).

Interestingly, the lakes which were the subject of the research in November, had the temperature higher than in October. However, it should be emphasized that the average air temperature in 2010 in November was higher than in October.

Moreover, the divergence of the thermal conditions of surface waters show how differently the sheet of ice disappears. Its melting is also different within the same lake. Such a phenomenon may be observed on Lake Donica, which is situated in a deep karst sink-hole, with steep sides. Frequently, the northern part of the lake surrounded by the side exposed to the south lacks the sheet of ice, while the southern side, permanently shaded, is still covered by a thick ice layer. It is also interesting to compare the water surface temperature in Lake Donica and Lake Duży Staw. Sometimes, the water temperature in Lake Duży Staw rises to10^{o}C, while Lake Donica, only 200 m away, is covered by a thick ice layer. What is more, when the sheet of ice vanishes from the surface of the lakes, some other deep, shaded places may be found. The thickness of the ice layer may reach between ten and twenty centimetres. Such an instance could be observed e.g. on 20th March 2010 in one of the karst sink-holes in the region of so called "Wilcze Doły", near Staszów. The thickness of the ice in the place described was at that time 12 cm. The depression with deep and steep sides made the bottom of the sink-hole shaded for a long time. Additionally, the trees surrounding the depression made air circulation and hot air inflow difficult. The observations prove that in the case of the lakes analysed, the thermo conditions may be modified by the factors connected with exposure, regardless of the characteristics of the lake basin. Topoclimatic conditions have a clear and significant influence on the water temperature. Because of the fact that the lakes are small and the surrounding area is peculiar, it is quite easy to define the influence of the soligenous water supplies on the thermal conditions of its waters. The soligenous water supplies in winter make the water temperature naturally higher, while in summer it may lower it.

CONCLUSIONS

Karst lakes may be an interesting subject of study

The results of the research indicate that in the close area of similar landform and sea level as well as comparable flora, the local lake ecosystems may appear with significantly diversified topoclimatic conditions. Topoclimate may also have a great influence on the temperature of surface water in the individual basins as well as one particular basin. Moreover, floating peat islands have basic impact on thermal conditions of the water surface layer. Their influence grows bigger with their size and the percentage share of its size compared to the acreage of the whole lake. Floating islands are perfect "insulators" of thermal energy flow and exchange between water and atmosphere.

As a result of the lakes being situated in deep sink-holes and releases with steep sides, a significant influence of soligenous water supplies on some of the basins is observed, which in winter makes the water temperature in the lake naturally higher, while in summer it may lower it.

REFERENCES

Biernat T., 2001: *The project of limnological research in the Świętokrzyskie Region and its initial results*, [in:] T Ciupa, E. Kupczyk (red.), *The impact of the area usage and anthropogenic* *environmental transformations into elements of water circulation in the river catchment*. Wyd. Instytutu Geografii Akademii Świętokrzyskiej, Kielce, 17–19 (in Polish).

Biernat T., Gwiazda P., 2003: *Morphometric parameters of Lake Ruda near Ruda Zajączkowska*, [in:] *VII Polish Limnological Conference; Natural and Anthropological Transformations of Lakes, Jodłowy Dwór near Święty Krzyż, 9–11th October 2003*. Kielce, 105–116 (in Polish).

Biernat T., Sobieszczański K., 2003: *Nature-landscape conditions and morphometric parameters of Lake Elżbieta near Michala Góra*, [in:] *VII Polish Limnological Conference; Natural and Anthropological Transformations of Lakes, Jodłowy Dwór near Świętym Krzyżem, 9–11th October 2003*. Kielce, 93–101 (in Polish).

Choiński A., 2007: *Limnologia fizyczna Polski*. Wydawnictwo Naukowe UAM, Poznań, 547.

Choiński A., 1995: *The Catalogue of the Lakes in Poland*. Part. 3: *Lake District Wielkopolska-Kujawskie and lakes south of a line within the Baltic glaciation*. Wyd. Nauk. UAM, Poznań, 1–149 (in Polish).

Choiński A., Zieliński A., 2020: *Characteristics of selected lakes with aeolian and karst genesis in the Świętokrzyski Region*, Limnol. Rev., 20, 2, 59–64. DOI:10.2478/limre-2020-0007.

Jaśkowski B., Sołtysik R., 2003: *The origin and age of the lakes of the Świętokrzyski Lake Distict*. Limnological Review, Volume 3/2003, Kielce, 101–106.

Jaśkowski B., Sołtysik R., 2001: *The Lakes of the Świętokrzyski Lake Distict as an imoprtant element of hydrographic network in comparison with the transformations of the natural environment including anthropopressure factor*, [in:] T. Ciupa, E. Kupczyk (eds.), *The impact of the area usage and anthropogenic environmental transformations into elements of water circulation in the river catchment*. Wyd. Instytutu Geografii Akademii Świętokrzyskiej. Kielce, 46–1949 (in Polish).

Jaśkowski B., Sołtysik R., 2000: *The origin and age of the lakes of the Świętokrzyski Lake Distict and nature-landscape qualities of its hydro-peat-dune elements*, [in]: *Problems of protecting and usage of rural areas of great natural qualities*. Wyd. UMCS, Lublin, 137–142 (in Polish).

Lange W., 1993: *Fizyczne właściwości wód jeziornych*, [in:] W. Lange (ed.), *Metody badań fizycznolimnologicznych*. Wyd. Uniwersytetu Gdańskiego, Gdańsk, 67–108.

Ptak M., Nowak B., 2016: *Warunki termiczno-tlenowe Jeziora Białego Włodawskiego w półroczu letnim (2012–2015), Thermal-oxygen conditions in Lake Białe Włodawskie in the summer half year (2012–2015)*. Annales Universitatis Mariae Curie-Sklodowska, sectio B, Vol. 71, z. 1, 61–71.

Skowron R., 2011: *Zróżnicowanie i zmienność wybranych elementów reżimu termicznego w jeziorach na Niżu Polskim (The differentiation and the changeability of chosen of elements the thermal regime of water in lakes on Polish Lowland)*. Wydawnictwo Uniwersytetu M. Kopernika, Toruń, 345.

Skowron R., 2001: *Surface water thermal seasons in polish lakes, their distribution and spatial differentation*, [in:] W. Marszelewski and R. Skowron (eds.), *Limnological Review*. Toruń, 1, 251–263.

Sobolewski W., Borowiak D., Borowiak M., Skowron R., 2014: *Baza danych jezior Polski i jej wykorzystanie w badaniach limnologicznych*. "Picador" Komunikacja Graficzna s.c., Lublin, 198.

Solon J., Borzyszkowski J., Bidłasik M., Richling A., Badora K., Balon J., Brzezińska-Wójcik T., Chabudziński Ł., Dobrowolski R., Grzegorczyk I., Jodłowski M., Kistowski M., Kot R., Krąż P., Lechnio J., Macias A., Majchrowska A., Malinowska E., Migoń P., Myga-Piątek U., Nita J., Papińska E., Rodzik J., Strzyż M., Terpiłowski Sł., Ziaja W., 2018:

Physico-geographical mesoregions of Poland: Verification and adjustment of boundaries on the basis of contemporary spatial data. Geographia Polonica, Volume 91, Issue 2, 143–170.

Stachura M., Wieczorek D., Zieliński A., 2018: *An attempt at a typology of karst lakes in the Połaniec Basin (Małopolska Upland, Poland)*. Bulletin of Geography. Physical Geography Series, No. 15, 63–74.

Zieliński A., 2007a: *Environmental transformation on the example of the little lakes karst in the Staszów region*, [in:] E. Smolska, P. Szwarczewski (red.), *Human activity records in the natural environment*, t. 4. *VI Warsztaty Terenowe, Sejny-Suwałki 14–16 czerwca 2007 r.*, 157–159 (in Polish).

Zieliński A., 2007b: *Natural pecularities lakes karst in the Staszów region*, [in:] M. Strzyż, A. Świercz (red.), *Regional Studiem – Chosen Problems, Geography in the Regional Studies*. Vol. 3. Instytut Geografii AŚ w Kielcach, Oddział Kielecki PTG, Kielce, 259–262 (in Polish).

Zieliński A., 2008: *Morphometric characteristics of the karst Jasne lake and the little unnamed lake in the area of the Golejowskie Forest near Staszów*, [in:] *Contemporary reasearch problems of Polish geographical studies – physical geography*. Geographical Records nr 37. PAN IG i PZ, PTG, Warszawa, 56–61 (in Polish).

Zieliński A., 2010a: *Preliminary studies of the physico-chemical properties of lake waters in Golejowskie Forests (Połaniecka Basin)*, [in:] T. Ciupa, R. Suligowski (red.), *Water in the geographical research*. Instytut Geografii Uniwersytet Jana Kochanowskiego, Kielce, 253–259 (in Polish).

Zieliński A., 2010b: *Preliminary studies of organogenic sediments in the selected little lakes and peatland in Golejowskie Forests near Staszów*, [in:] M. Ludwikowska-Kędzia, A. Zieliński, I*nterdisciplinary research – the past, presence, future of natural sciences, 15–16.04.2010. Golejów near Staszów*. Instytut Geografii UJK w Kielcach. Kielce, 163–164 (in Polish).

Zieliński A., 2013, *Rozwój jezior krasowych w Niecce Połanieckiej (Development of karst lakes in Połaniec Basin)*. Wyd. UJK, Kielce, 186 (in Polish).

Zieliński A., Choiński A., Machula S., Ławniczak A., Strzelczak A., 2020: *Chemistry of bottom sediments from selected karst lakes in the vicinity of Staszów (Nida Basin)*. Limnol. Rev. 20, 2: 81–87. DOI 10.2478/limre-2020-0009.

Zieliński A., Łoziński Ł., 2007a: *Morphometric characteristics of the little lakes "Kacze" and "Bez Nazwy" in the Staszów area*, [in:] A. Zieliński (red.), *The transformation of the geographical environment in the south east part of the Holy Cross region*, t. 7. Instytut Geografii AŚ w Kielcach, Oddział Kielecki PTG, Kielce, 113–121 (in Polish).

Zieliński A., Łoziński Ł., 2007b: *Morphometric parameters of lakes karst "Donica", "Przedpole" and "Rozlany Staw" in the Staszów area*, [in:] A. Zieliński (red.), *The transformation of the geographical environment in the south east part of the Holy Cross region*. Instytut Geografii AŚ w Kielcach, Oddział Kielecki PTG, Kielce, 101–112 (in Polish).

Zieliński A., Ziętek J., 2010: *Reconnaissance ground-penetrating radar research near Lake Duży Staw in Golejowskie Forests near Staszów*, [in:] M. Ludwikowska-Kędzia, A. Zieliński, *Interdisciplinary research – the past, presence, future of natural sciences*, 15–16.04. 2010. Golejów near Staszów. Instytut Geografii UJK w Kielcach. Kielce: 157–162 (in Polish).