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SEASONAL CHANGES OF WATER PHYSICOCHEMICAL PARAMETERS IN LAKE ROTCZE – A PRELIMINARY STUDY

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ABSTRACT

Aim of the study
The purpose of the study was to analyze selected physicochemical indicators of water in Lake Rotcze (Łęczyńsko-Włodawskie Lake District, Poland) during selected months of the year to determine possible seasonal changes.

Materials and methods
Water samples for analysis were taken four times, once in each season. Temperature, pH, ammonia (NH_3), nitrites (NO_2^-), nitrates (NO_3^-), phosphates (PO_4^{3-}), total hardness (GH), and carbonate hardness (KH) were measured in the collected water samples. Additionally, the floristic composition of vegetation in the littoral zone was determined.

Results and conclusions
The study of the seasonal variability of selected physical and chemical parameters of water in Lake Rotcze allows to form the following conclusions: in a shallow lake with intensely mixed waters, the water temperature varies seasonally as it is strongly dependent on air temperature, water pH remains stable throughout the year, and values of total hardness and carbonate hardness showed a decrease during the warm season.

Keywords: Lake Rotcze, water parameters, shallow lakes, Łęczyńsko-Włodawskie Lake District

INTRODUCTION

Although water is the most widespread substance on Earth, 97.5% of the water supply is salt water and only 2.5% is fresh water. In addition, 68.7% of fresh water is in the form of ice and permanent snow cover in Antarctica, the Arctic and mountainous regions. Another 30.06% of freshwater is groundwater. Lakes hold 0.26% of the world's freshwater resources. By comparison, marches and wetlands hold 0.03%, and rivers hold 0.006% of freshwater resources (Shiklomanov, 1993). Therefore, freshwater lakes are such an important part of the hydrological network collecting available water for humans, animals and plants. An accurate assessment of the global number and area of lakes is not possible. Several studies have been made estimat-

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ing these quantities. Studies published in the second half of the 20th century indicated that lakes and ponds represent 1.3–2.1% of Earth's land surface (Kalff, 2001; Downing et al., 2006). Reports show that the global lake area comprises 1522 great and large lakes, each with an area of more than 100 km^2 (the largest is the Caspian Sea 378.119 km^2). However, small lakes (>0.01 km^2) and even smaller waterbodies dominate in terms of numbers. Most of these small reservoirs are not even included in statistical studies (Kalff, 2001).

Analyzing the chemical parameters of surface waters, such as rivers and lakes, is crucial for understanding how these ecosystems function and for assessing their quality. These parameters provide valuable information about the processes taking place in the aquatic environment. Systematic testing enables the early detection of changes that could affect biodiversity, drinking water quality and water management.

Dynamic flow in watercourses causes rapid changes in chemical parameters. External factors (e.g., heavy rainfall, point and diffuse pollution, seasonal temperature fluctuations) can have a significant impact on short-term and point changes of the parameters. Anthropogenic factors, including agriculture, urbanization and industry, may affect surface water chemistry (Jakubiak and Bojarski, 2021; Lach et al., 2023). Natural processes such as water mixing, bank erosion, and the introduction of organic and inorganic material from the land can also impact the chemistry significantly (Meybeck, 2003; Vörösmarty et al., 2010). Lakes, unlike rivers, are more often characterized by relatively stable chemical conditions, although their variability also depends on the type of lake and its depth. However, shallow lakes are particularly vulnerable to external factors, such as nutrient inputs from agriculture or climate change. Their shallow depth intensifies water mixing processes, leading to the rapid spread of pollutants and changes in oxygen content (Kalff, 2001; Carpenter et al., 1998). Eutrophication often occurs in such reservoirs. This can result in intense algal growth and a reduced biodiversity. Poland's landscape is rich in shallow lakes, e.g. Lake Śniardwy, suffers intensified eutrophication processes due to human pressure (Lawniczak-Malińska et al., 2018). Due to their vulnerability to external factors and the many ecological functions they fulfil at local level, small lakes should be given special protection. Physiocenotic, biocenotic, hydrological, biogeochemical, microclimatic, landscape, as well as economic, scientific and educational are the most common functions carried by small water bodies (Borek, 2018; Jakubiak and Chmielowski, 2020).

Deep lakes, such as Morskie Oko, have a layered thermal structure of water that causes complex, vertical chemical gradients. The surface layer (epilimnion) is characterized by high oxygen content and intense sunlight, which promotes photosynthetic processes. In contrast, the deeper layer (hypolimnion) is often low in oxygen, especially during summer stagnation, leading to anaerobic conditions and the release of nutrients, such as phosphates, from the bottom sediments (Wetzel, 2001; Nürnberg, 1995). These processes are crucial to the functioning of deep-water ecosystems, and they require detailed monitoring to avoid long-term changes affecting water quality.

Monitoring of water chemical parameters in rivers and lakes is essential for protecting these ecosystems and ensuring their multifunctional use. The obtained data are used to create water management plans, assess pollution risks and carry out environmental protection tasks. For example, the European Water Framework Directive requires member states to maintain good ecological and chemical status of surface waters (Directive 2000/60/EC 2000; Meybeck, 2003). In the context of climate change and increasing human pressure, regular studies and analyses of water chemical parameters are crucial for the future of water resources. Also to ensure the continuity of the ecosystem services provided, the lake should be subjected to monitoring and possible protective efforts, if necessary. Some lakes are in need of maintenance, reclamation, renaturalization, restoration activities to prevent their disappearance (Jakubiak and Panek, 2017; Mazur et al., 2024).

Considering the fact that the diurnal and seasonal variability of parameters in small water bodies is a relatively rare topic of scientific work, the aim of this study was to identify potential seasonal changes. The physical and chemical parameters of the water of Lake Rotcze (temperature, pH, hardness, nitrate, nitrite, ammonia, phosphate concentrations) were analyzed during selected months of the year. This study is a continuation of our previous research (Bojarski et al., 2020) that examined changes occurring every six hours and involved water sampling and analysis in a single season.

STUDY AREA

The research was carried out in Lake Rotcze (Fig. 1). The lake is located in the central-eastern part of Poland in the Łęczyńsko-Włodawskie Lake District. The unique natural features of the lake district are shaped by shallow groundwater, areas of peat bogs, marshes and swamps. Due to low atmospheric precipitation supply (the average annual precipitation from 1991–2020 at the Włodawa station was 562.4 mm (IMGW, 2022) and little variation in terrain relief, there are water shortages in the lake district (Michalczyk et al., 2017). The shallow presence of poorly permeable silt and clay overlays that impede water infiltration into lower aquifers has resulted in the formation of numerous water reservoirs. The Łęczyńsko-Włodawskie Lake District has the total area of 1864 hectares of water reservoirs above 1 hectare (Wakuła and Łaszewski, 2022). The Lake District's hydrological network is constantly changing due to both natural and anthropogenic factors. Until the 20th century, the poorly developed river network influenced the natural, drainageless character of the area. The construction of the Wieprz–Krzna Canal and the expansion of the drainage system with hundreds of kilometers of drainage ditches had a sig-

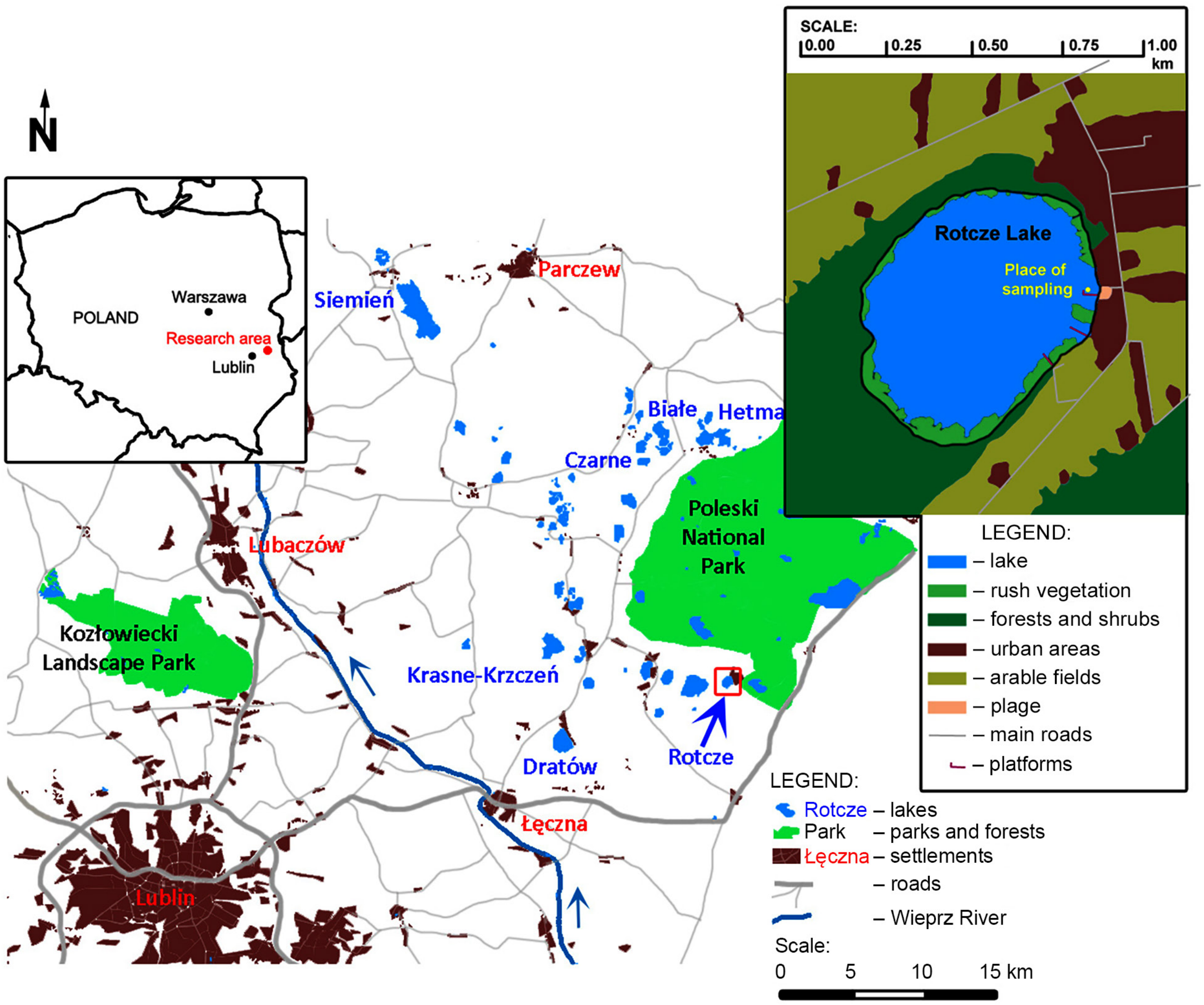

Fig. 1. Łęczyńsko-Włodawskie Lake District (source: Authors' own elaboration)

nificant impact on the environment. Improved rainwater and snowmelt runoff has lowered the groundwater table and reduced the area of wetlands. In the second half of the 20th century, the area of waters and wetlands decreased in the central and western parts of the Łęczyńsko-Włodawskie Lake District by more than 60% (Chmielewski et al., 2020).

The reservoir is located in the municipality of Urszulin, village Grabniak, on parcel No. 164 (51°22'27"N, 23°06'41"E). The lake is 170.5 m.a.s.l. The area surrounding the lake to the west is covered with mixed forest. From the north and south, the reservoir is surrounded by several dozen meters belts of bushes and shrubbery, behind which are arable fields and pastures. To the east, the reservoir is adjacent to residential and tourist developments of the Garbniak village. The developed area has a water supply and sewage system. There is also a guarded bathing area with a sandy beach by the lake, as well as a jetty and several small footbridges. Numerous natural and anthropogenic small bodies of water occur across the area surrounding Lake Rotcze, which is related to shallow groundwater table. The reservoir is also adjacent to larger lakes. There are Lake Sumin (located to the east) and Lake Uściwierz (located to the west) about 1 kilometer away. The Lake Rotcze catchment area is relatively small (473 832 m^2) (Ferencz et al., 2014). The surroundings of the lake consist of an elevated area in the north-east, which is managed, and a south-western area where wetlands and peat-bogs dominate. The lake has an outlet to the west. Waters from the lake and the adjacent wetlands are carried to the catchment area of Lake Uściwierz by a drainage ditch no more than 1m deep. As a result of the expansion of housing in Garbniak, the topography and drainage of the catchment area are undergoing some changes. Previously, there was also a drainage ditch supplying the lake with water from the eastern part of the catchment area. This ditch was backfilled with soil at the beginning of the 21th century (Ferencz and Dawidek 2012). The lake is located within the buffer zone of the Polesie Landscape Park, the Polesie Protected Landscape Area, and two Natura 2000 areas: Polesie (PLB060019, SPA) and Jeziora Uściwierskie (PLH060009, SAC). Within 1–2 km of the lake are the protected areas of the Poleski National Park, the Polesie Landscape Park, the Łęczyńskie Lake District Landscape Park, and two ecological sites (Ciesacin, Uściwierz).

The Lake Rotcze is polymictic (Szafran, 2003) reservoir with a surface area of 46.9 hectares. Since 1886, it has decreased by about 1.1 hectares (Wakuła and Łaszewski, 2022). Its length is 885 meters, and its width is 661 meters. The volume of the lake is about 882 dam^3 (Ferencz and Dawidek, 2012). The lakebed is flat and composed of sand and mud (Ferencz and Dawidek, 2012). The average depth is 1.9 meters and the maximum depth is 4.3 meters. The length of the shoreline is 2449 meters and development coefficient 1.06 (Bojarski et al., 2020).

Both vascular plants (see the Results section) and algae are present in the lake. Among the algae, chlorophytes (Chlorophyta) from the family Characeae (*Chara hispida* and *Chara fragilis*) were found (Nawrot and Mieczan, 2012). Research published in 2014 showed that dominant algal group in the phytoplankton are Dinophyceae (*Peridinium willei*, *Spirogyra* sp., *Mougeotia* sp.) and Cryptophyceae (*Chroomonas acuta*). Cyanobacteria were not observed (Ferencz et al., 2014). Information boards set up on the lakeshore and local anglers indicate that various fish species can be found in the Lake Rotcze, namely: northern pike (*Esox lucius*), *tench* (*Tinca tinca*), Prussian carp (*Carassius gibelio*), crucian carp (*Carassius carassius*), common carp (*Cyprinus carpio*), rutilus roach (*Rutilus rutilus*), common bream (*Abramis brama*), white bream (*Blicca bjoerkna*), wels catfish (*Silurus glanis*), brown bullhead (*Ameiurus nebulosus*), European perch (*Perca fluviatilis*), and common rudd (*Scardinius erythrophthalmus*). Other animals that can be observed include narrow-clawed crayfish (*Astacus leptodactylus*), wild duck (*Anas platyrhynchos*), and mute swan (*Cygnus olor*).

MATERIALS AND METHODS

Water samples for analysis were taken from a jetty located at the bathing area, 45 meters from the shore, on the beach side (Fig. 1). The location of the sampling point allows for water collection at a significant distance from the shore. Additionally, the location near the jetty made possible to reach the sampling point without mixing lake water. At the sampling site, the bottom was sandy, the water depth was about 80 cm.

Each time samples were taken from a depth of 60 cm. Immediately after sampling the water temperature was measured, and then other parameters (pH, ammonia (NH_3) concentration, nitrite (NO_2^-) concentration, nitrate (NO_3^-) concentration, phosphate (PO_4^{3-}) concentration, total hardness (GH), and carbonate hardness (KH)) were tested. Measurements of the above-mentioned chemical indicators were conducted by colorimetric method, using the reagent kits Aquatest produced by Zoolek company (Poland). All tests were performed with two replicates per test cycle. All tests were conducted according to the instructions provided by the producer. The accuracy of the used colorimetric methods is diversified depending on the tested parameter. The scale of the test and range also varies. For example, for Aquatest NO_2^- the scale for the results readout is: 0.00; 0.025; 0.05; 0.10; 0.20; 0.50; 0.75; 1.00; 1.50 [mg/l]. However, for Aquatest PO_4^{3-}, the scale is: 0.0; 0.25; 0.5; 1.0; 1.5; 2.0; 3.0; 5.0 [mg/l]. The Aquatest NH_3 allows to determine the total concentration of ammonia (NH_3) and ammonium ions (NH_4^+). The pH value of water must be additionally measured to determine the NH_3 level. The procedure provides checking the concentration of ammonia from the attached table of the relationship between the determined NH_3/NH_4^+ [mg/l] and the pH of the water. The two tests were used in the study to measure pH. The measurement ranges of the tests were: 4.5–9.0 and 6.0–8.0. The Aquatest pH (6.0–8.0) allows pH measurement with an accuracy of 0.2. Aquatest GH-KH allows measurement of total hardness and carbonate hardness in °n with an accuracy of 0.5 °n. Air temperature was measured at a distance of 20 m from the lake and 1 m above ground level. Water sampling was always carried out at the same time: 10:00 a.m. The choice of sampling day was related to weather conditions – typical for each season. Samples were not taken during rain or immediately after rainfall. Sampling was preceded by a minimum 48h period without rain. Thus, the study followed the previously proposed methodology of measurements (Bojarski et al., 2020).

To provide a comprehensive characterization of the water sampling site, an investigation of vascular plant species was also conducted. The species were named according to Mirek et al. (2020). Floristic inventories were carried out in September 2022 within the littoral zone of the lake, covering an area approximately 1 km in length (i.e., 0.5 km north and 0.5 km south of the sampling point) and 50 m in width (25 m west and 25 m east of the sampling point). Photographic documentation of the vegetation and flora within the defined area was also obtained.

RESULTS

The highest air and water temperatures were detected in August 2022 (25.4°C and 23.6°C), while the lowest were recorded in February 2022 (1.2°C and 2.8°C, respectively). The water temperature was higher than the air temperature in February 2022 and November 2022, while the opposite situation occurred in May 2022 and August 2022 (Table 1).

Some water chemical parameters differed in individual sampling months, while the other indicators showed no variability. The value of pH was 7.8 (in most cases) or 8.0 (in August 2022). Total hardness ranged from 6 °n (August 2022) to 10 °n (February and November 2022), while carbonate hardness from 4 °n (May 2022) to 7 °n (November 2022). The concentrations of nitrates, nitrites, ammonia, and phosphates were equal 0 mg/l in each research month (Table 1).

The floristic composition of vegetation in the littoral zone (including the epilittoral) in the vicinity of the sampling point was determined (Table 2). Shallow areas in the littoral zone are occupied by reed beds mainly composed of common reed (*Phragmites australis*) and narrowleaf cattail (*Typha angustifolia*) (Fig. 2). On the side of the water table, clusters of nymphaea (*Nuphar lutea*, *Nymphaea alba*) are often adjacent to the reed beds.

The littoral zone also includes communities of floating pondweed (*Potamogeton natans*) and Eurasian watermilfoil (*Myriophyllum spicatum*). In some places, water soldiers (*Stratiotes aloides*) were present in large quantities (Fig. 3). In the epilittoral zone, small patches of low peat bogs were observed with species such as bogbean (*Menyanthes trifoliata*), marsh cinquefoil (*Comarum palustre*), bog cranberry (*Oxycoccus palustris*), and marsh calla (*Calla palustris*). In the surroundings of the lake there are large areas of valuable *Molinia* meadows. Some species from meadows, e.g. purple moor grass (*Molinia* *caerulea*) or great burnet (*Sanguisorba officinalis*), have migrated to the epilittoral zone. Several alien species (e.g., *Padus serotina*, *Parthenocissus inserta*), spreading from allotment gardens located on the eastern shore of the lake, were observed in the epilittoral zone. Moreover, the alien aquatic species, *Nymphaea ×hybrida* (Fig. 4), was recorded in the littoral zone.

Table 1. Physicochemical parameters of water in Lake Rotcze determined during the research period (sampled every three months from February 2022 to November 2022)

	February 2022	May 2022	August 2022	November 2022
Air temperature [°C]	1.2 ± 0.00	18.8 ± 0.06	25.4 ± 0.12	5.7 ± 0.06
Water temperature [°C]	2.8 ± 0.00	16.0 ± 0.06	23.6 ± 0.00	9.9 ± 0.00
pH	7.8 ± 0.00	7.8 ± 0.00	8.0 ± 0.00	7.8 ± 0.00
Total hardness [°n]	10 ± 0.00	8 ± 0.00	6 ± 0.00	10 ± 0.00
Carbonate hardness [°n]	6 ± 0.00	4 ± 0.00	5 ± 0.00	7 ± 0.00
NO_3^- [mg/l]	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00
NO_2^- [mg/l]	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00
NH_3 [mg/l]	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00
PO_4^{3-} [mg/l]	0 ± 0.00	0 ± 0.00	0 ± 0.00	0 ± 0.00

Fig. 2. Lake Rotcze (source: photo by Authors)

Table 2. Species recorded in the littoral (including the epilittoral) of Lake Rotcze and its habitat groups. * – alien species to the Polish flora. The nomenclature of the species followed Mirek et al. (2020)

Habitat groups of species	Species
Aquatic	**Elodea canadensis*, *Hydrocharis morsus-ranae*, *Lemna minor*, *L. trisulca*, *Spirodela polyrhiza*, *Myriophyllum spicatum*, *M. verticillatum*, *Najas marina*, *Nuphar lutea*, *Nymphaea alba*, **N. ×hybrida*, *Polygonum amphibium*, *Potamogeton acutifolius*, *P. natans*, *P. perfoliatus*, *Ranunculus circinatus*, *Stratiotes aloides*, *Utricularia minor*, *Utricularia vulgaris*
Bulrush and marshy	*Alisma plantago-aquatica*, *Calla palustris*, *Carex gracilis*, *C. pseudocyperus*, *C. rostrata*, *Eleocharis palustris*, *Equisetum fluviatile*, *Galium palustre*, *Glyceria fluitans*, *Iris pseudacorus*, *Leersia oryzoides*, *Lysimachia thyrsiflora*, *Mentha ×verticillata*, *Oenanthe aquatica*, *Peucedanum palustre*, *Phragmites australis*, *Rorippa amphibia*, *Rumex hydrolapathum*, *Schoenoplectus lacustris*, *Scutellaria galericulata*, *Sium latifolium*, *Thelypteris palustris*, *Typha angustifolia*, *T. latifolia*, *Veronica beccabunga*
Waterside and muddy sites	*Bidens tripartita*, *Calystegia sepium*, *Cyperus fuscus*, *Epilobium hirsutum*, *Isolepis setacea*, *Juncus bufonius*, *Myosoton aquaticum*, *Rorippa palustris*
Peat-bog	*Carex lasiocarpa*, *Comarum palustre*, *Juncus articulatus*, *Menyanthes trifoliata*, *Oxycoccus palustris*
Meadow	*Geum rivale*, *Juncus effusus*, *Lysimachia nummularia*, *L. vulgaris*, *Lythrum salicaria*, *Molinia caerulea*, *Myosotis palustris*, *Ranunculus repens*, *Sanguisorba officinalis*
Forest and shrubs	*Alnus glutionosa*, *Betula pendula*, *B. pubescens*, *Calamagrostis canescens*, *Dryopteris carthusiana*, *Fraxinus excelsior*, *Frangula alnus*, *Lycopus europaeus*, *Padus avium*, *Populus tremula, Rubus caesius*, *R. plicatus*, *Salix cinerea*, *S. fragilis*, *Solanum dulcamara*, *Sorbus aucuparia*, *Viburnum opulus*
Synanthropic	**Impatiens parviflora*, **Padus serotina*, **Parthenocissus inserta*

Fig. 3. Lake Rotcze – water soldiers (*Stratiotes aloides*) (source: photo by Authors)

Fig. 4. Lake Rotcze – *Nymphaea ×hybrida* (source: photo by Authors)

DISCUSSION

The water temperature measurements indicate a significant dependence on air temperature. The water was observed to warm up to a temperature close to that of the air. In measurements taken in November and February, the water temperature was slightly higher. In the spring and summer periods, the opposite trend was observed. The rapid heating of the water during the day and cooling at night is due to the small capacity and shallow depth of the reservoir (Bojarski et al., 2020). Unified water temperature distribution is characteristic of shallow lakes related to a lack of stratification. Natural convective mixing occurs in such reservoirs during nighttime cooling (Herb and Stefan, 2004). During the day, the probability of stratification is reduced by increasing wind speed (Martinsen et al., 2019). The lack of dense forest in the vicinity of Lake Rotcze and the large proportion of free water surface, not overgrown with emergent vegetation, have a significant impact on the mixing of water during the day under the influence of higher wind speed. The small amount of submersed macrophytes also allows for increased mixing of water in the lake (Herb and Stefan, 2004). More complex seasonal dependencies of water temperature are observed in lakes with higher depths. In deep reservoirs, very limited mixing of water takes place between spring and autumn (Xu et al., 2022). Due to climate warming, an increase in water temperatures can be expected, especially in shallow reservoirs. Shortening length of the ice season is already being observed in Polish shallow lakes located further inland (Czernecki and Ptak, 2018). In the present study the pH test showed high stability of the results throughout the year. The results of the pH measurements were at the level of 7.8 (only in August it was visibly higher). The values obtained in the present study were similar to the results of previous measurements conducted on Lake Rotcze. The pH was 7.6 (Tarkowska-Kukuryk and Mieczan, 2017) and 7.4–8.5, and according to Bojarski et al. (2020) it depended on the time of day. Similar water pH values were recorded in neighboring lakes Uściwierz and Sumin, i.e. 8.2 and 7.9, respectively (Adamczuk et al., 2015). Intense mixing of water in shallow reservoirs causes uniformity of water parameters across the reservoir. Therefore, it may be assumed that in the whole reservoir that was studied in the current research the water has a slightly alkaline pH. In deep lakes, where intensive mixing occurs only during the winter time, the physical and chemical parameters of the water may vary considerably in different parts of the reservoir. In these reservoirs, along with the stratification of temperature and dissolved oxygen, pH is also stratified (Xu et al., 2022). Along with increased photosynthetic activity of aquatic vegetation, the pH of waters within plant communities increases. This can result in alkalization of the water throughout the reservoir (Pełechaty and Pronin, 2015). Therefore, it can be assumed that the increase of pH in August found in the current study may be a result of intensive photosynthesis. However, the influence of aquatic plants on the physicochemical parameters of water may be much broader. Aquatic plants use bicarbonates dissolved in water as a source of carbon dioxide, which leads to the precipitation of $CaCO_3$ in the form of carbonate encrustations on the surface of macrophytes, especially stoneworts (Charales). Calcium carbonate precipitation contributes to the decalcification of water (Pełechaty and Pronin, 2015). This phenomenon was found during a study of the development of a dense *Chara* community (dominated by *Chara tomentosa*) in Lake Jasne (Lubuskie voivodeship). Within each of the analyzed sites, the development of the *Chara* community was accompanied by a decrease in the concentration of calcium ions (Ca^{2+}) and a decrease in water hardness (Pełechaty et al., 2015). Therefore, it can be assumed that the reduction in water hardness observed in the present study during the warm period (spring and summer) was probably the result of increased photosynthetic activity.

In this study, none of the measurements show any seasonal variability of ammonia (NH_3), nitrite (NO_2^-), nitrate (NO_3^-), and phosphate (PO_4^{3-}) concentration. The results indicate a low biogenic load in the lake, and may suggest that the lake is oligotrophic. Although the results are similar to findings of our previous study (Bojarski et al., 2020), it should be emphasized that this conclusion is preliminary and it needs confirmation in further research; especially there is need for more detailed hydrochemical tests and analysis of phytoplankton abundance. It can be hypothesized that nitrogen metabolites excreted by water animals have been probably effectively absorbed by aquatic plants found in the lake. The results obtained during the summer period suggest that residential and tourist facilities located near the lake have a minor impact on water quality. Moreover, the existence of a sewage network in Garbniak undoubtedly has a positive effect on the condition of the lake's waters. The construction of a collective sewage network less than 10 years ago was carried out as part of pro-environmental projects of Urszulin municipality. Wastewater is discharged to the municipal treatment plant in Urszulin. The anthropogenic impact is evident in the species composition of the riparian vegetation. Species originating from adjacent allotment gardens were observed in both the aquatic zone and the epilittoral. It is believed that *Nymphaea ×hybrida* was intentionally introduced into the lake. Considering the invasive potential of hybrid species within the genus *Nymphaea*, the abundance and spread of the species within the lake should be carefully monitored.

The results obtained in the this study should be considered preliminary as they were obtained using simple colorimetric tests dedicated to aquarists (except for water and air temperature), which are not routinely used in scientific research. Moreover, water samples were taken from only one location, and it is not known whether they were representative of the entire lake. Therefore, expanding our findings by collecting water samples for analysis from different sites (and different depths) of the Lake Rotcze should be taken into account in future research. This is also indicated by the results of our previous study (Bojarski et al., 2020), which demonstrated that some of the tested parameters differed depending on the site of water sampling. An added value of the conducted study is the floristic inventory of the sampling area.

CONCLUSIONS

The study of the seasonal variability of selected physical and chemical parameters of water in Lake Rotcze allows us to form the following conclusions:

- in shallow lakes with intensely mixed waters, water temperature varies seasonally as it is strongly dependent on air temperature,
- water pH remains stable throughout the year,
- values of total hardness and carbonate hardness demonstrated a decrease during the warm season,
- during the whole year the waters of the lake show low trophy.

The study did not detect any variability of ammonia, nitrite, nitrate, phosphate concentrations in the water of Lake Rotcze, since analysis of all the taken samples showed zero values. Drawing broader conclusions regarding the seasonal variability of water parameters in shallow reservoirs requires the continuation and expansion of research. Therefore, a broader study of the seasonal variability of the parameters in small bodies of water is already in progress. These studies are being conducted on reservoirs in the Łęczyńsko-Włodawskie Lake District and the Upper Vistula Valley. More water reservoirs of different origins and uses (including fish ponds) are included in the study. Both water and bottom sediment parameters are being investigated. The research is being carried out with more precise methods and equipment.

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SEZONOWE ZMIANY PARAMETRÓW FIZYKOCHEMICZNYCH WODY W JEZIORZE ROTCZE – WSTĘPNE BADANIA

ABSTRAKT

Cel pracy
Celem niniejszej pracy była analiza wybranych wskaźników fizykochemicznych wody w jeziorze Rotcze (Pojezierze Łęczyńsko-Włodawskie, Polska) w wybranych miesiącach roku zmierzająca do określenia możliwych zmian sezonowych.

Materiał i metody
Próbki wody do analizy pobrano cztery razy, raz w każdym sezonie. W pobranych próbkach wody zmierzono temperaturę, pH, amoniak (NH_3), azotyny (NO_2^-), azotany (NO_3^-), fosforany (PO_4^{3-}), twardość całkowitą (GH) i twardość węglanową (KH). Ponadto określono skład florystyczny roślinności w strefie litoralnej.

Wyniki i wnioski
Badanie sezonowej zmienności wybranych parametrów fizycznych i chemicznych wody w jeziorze Rotcze pozwala na sformułowanie następujących wniosków: w płytkim jeziorze o intensywnie mieszanych wodach temperatura wody zmienia się sezonowo, ponieważ jest silnie zależna od temperatury powietrza, pH wody pozostaje stabilne przez cały rok, a wartości twardości całkowitej i węglanowej wykazują spadek w sezonie ciepłym.

Słowa kluczowe: Pojezierze Łęczyńsko-Włodawskie, jezioro Rotcze, parametry jakości wody, jeziora płytkie