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ORIGINAL PAPER

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SEASONAL VARIABILITY OF SELECTED PHYSICAL AND CHEMICAL PROPERTIES OF SURFACE WATERS IN THE WIELKOPOLSKI NATIONAL PARK BASED ON LAKES BUDZYŃSKIE AND KOCIOŁEK

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ABSTRACT

Surface waters of the Wielkopolski National Park constitute one of the most important elements of the natural environment in that areal. Progressing degradation processes and hence eutrophication of lakes require specific actions in order to monitor waters and implement methods for their protection. The examination of the variability of physicochemical parameters of water is a key element of water monitoring and facilitates determination of its ecological status. The study in question analyzed selected water parameters recorded during measurements carried out on Lakes Budzyńskie and Kociołek. The results of these measurements showed that the status of the lakes under study was stable.

Keywords: surface waters, physicochemical parameters of water, lake eutrophication, Wielkopolski National Park

INTRODUCTION

Water protection in Poland is regulated by legal acts and ordinances. The latest document regarding water protection is the water law act of July 20, 2017 (Act…, 2017), which came into force on January 1, 2018. The Act regulates the principles of water management, in particular the formation and protection of water resources, water use and management of water resources. Article 10 of the aforementioned Act refers to management of water resources serving the needs of the population and the national economy, as well as protection of waters and the environment related to these resources, in particular protection of water resources against pollution and improper or excessive exploitation, as well as maintaining or improving the status of water and water-dependent ecosystems. Activities related to both passive and active water protection are based primarily on the "Water quality monitoring" scheme operating under the State Environmental Monitoring (www.srodowiskoabc.cba.pl, 2015). Regulations related to the discharge of wastewater into waters are particularly important, because the problem of wastewater management poses the greatest threat to water quality.

The assessment of quality of surface waters by determining their ecological status is a new approach, which is in line with the provisions of the Water Framework

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Directive. The Directive no. 2000/60/EC, commonly referred to as the Water Framework Directive, establishes an objective for the European Union countries to achieve "good status" of surface waters in the member states, which should be implemented primarily by preventing the deterioration of water status (Główny Inspektorat…, n.d.).

Monitoring is a fundamental element of water protection, which plays a warning and preventive role and serves to anticipate threats. Surface water quality assessment in Poland is carried out on the basis of surface water monitoring. The act of July 18, 2001 – Water law (as amended) defines the competence and scope of surface water examination (Ustawa…, 2001). The study and assessment of surface water quality as part of the State Environmental Monitoring including examination of surface water quality in terms of physicochemical, chemical and biological properties fall within the competence of the Provincial Inspector of Environmental Protection.

PURPOSE AND SCOPE OF THE STUDY

The purpose of this work was to recognize the quantitative variability and time variability in selected physical and chemical parameters of surface waters. Identification of potential threats to aquatic ecosystems resulting from adverse changes in the studied parameters in the lakes over the analyzed period could help in determining the directions of protective measures in relation to these ecosystems, but also in forecasting potential threats.

The research objects were selected based on the differences in the structure of lake basins and the degree of overgrowing, as well as characteristics of the basins of both water bodies. Their degree of terrestrialization indicates that processes occurring in them could significantly differ, while the obtained results obtained would facilitate their assessment.

DESCRIPTION OF THE RESEARCH AREA

The Wielkopolski National Park is located less than 20 kilometers from Poznań. Due to its geomorphological diversity, it is a great natural and cultural resource. The area of the park with a buffer zone amounts to almost 15,000 hectares, where 18 strict protection areas were established. The total area of protected areas amounts to 260 ha.

The physical and geographical location of the Wielkopolski National Park (WNP) consistent with the universal international classification presented in the decimal classification system (Kondracki, 2000) classifies WNP to Western Europe (1-924). According to the nature and forest regionalization (Zielony and Kliczkowska, 2012), the Wielkopolski National Park is located in the Wielkopolsko-Pomorska Region (III), the Mesoregion of the Opalenicko-Wrzesińska Plain (III.24). In terms of the geobotanical regionalization of Poland (Matuszkiewicz, 2008), WNP is located in the following geobotanical units: European Deciduous and Mixed Forests.

Today's relief of the terrain in the Wielkopolski National Park is the result of the ice field activity during three consecutive glaciations: the Kraków, Central Poland and the last Baltic glaciations.

The Park has a moderate climate resulting from its location on the border between the influence of oceanic and continental climate. There are smaller than Polish the average temperature amplitudes are smaller than the national averages for Poland. Springs and summers are warm and early, while winters are mild with impermanent snow cover or what is more common nowadays its lack. According to climate regionalization, the area of the Wielkopolski National Park belongs to the southwestern part of the (XV) climatic region of Central and Greater Poland (Woś, 1993). The Wielkopolski National Park is located in the area with the lowest annual rainfall in Poland (500–550 mm). June, July and August are the wettest months (Wojewódzki Inspektorat…, n.d.). The unit outflow volume amounts to about 1 $l \cdot s^{-1} \cdot km^{-2}$ for mainly forest areas of WNP and is three times lower than the average for the Wielkopolska Province (Miler and Krysztofiak, 2003).

Four glacial troughs formed during the last glaciation are essentially the hydrological network of the Wielkopolski National Park. The retreating glacier also left small kettles, which are now small ponds, in which water is present all year round. The surface water network includes the Warta River and the two smaller rivers: the Samica Stęszewska flowing through the trough of the glacial gutter and the Wirenka, also called the Wirynka. The lakes of the park are part of a system of glacial gutters, which formed relatively parallel, crossing the area of the park from the north -west to the southeast.

The park area is dominated by forest habitats. The habitats occupy over 50% of forest ecosystems. The predominant habitats are those corresponding to hornbeam-oak forests with an admixture of small-leaved lime and European white elm and field elm. Scots pine is the main species in the park in terms of area coverage, which share among the tree species is almost 70%.

The current assessment of the ecological state of the WNP lakes and the National Park buffer zone based on morphometric, biological, physicochemical and hydromorphological parameters as well as the macrophyte monitoring classifies the lakes of the park in 66.6% as moderate (including Lakes Kociołek and Budzyńskie), 26.6% as bad and 6.6% as poor (Plan ochrony..., 2013).

SELECTION AND LOCATION OF RESEARCH STATIONS

Two ribbon lakes located in the south-eastern part of the park within the Osowa Góra Protective District were selected for the study. Both lakes lie in the same Górecko-Budzyńska tunnel valley (Fig. 1).

Lake Budzyńskie with an area of 13.5 ha (Fig. 2) has the status of a Strict Protection Area. In terms of trophic type, it was classified as a eutrophic lake rich in organic matter and nutrient-rich substances. At present it is an endorheic reservoir. The construction of the drainage ditch of the lake to the Mosiński Canal had a significant impact on the shallowing of the lake. Now, the culvert under voivodship road no. 431 is partially filled in and obstructed. A strong process of shallowing and overgrowing is observed in the lake, resulting from its glacial trough nature and shallow depth, especially in the northwestern part. In principle, the lake has two stream pools, the south-eastern one with the greatest depth of the lake amounting to 3.4 m and the north-western, longitudinal one, relatively narrow and definitely shallower with a maximum depth of 1.5 m. During the vegetation period the northern stream pool is covered with patches of overwater vegetation. Due to the intensive process of overgrowing of the lake a clear zonation of the vegetation is noticeable. Common reed (*Phragmites australis*) and lesser bulrush (*Typha angustifolia*) enter from the shore, while on the lake surface, especially in its northern part, European white water lily (*Nymphaea alba*) and yellow water lily (*Nuphar lutea*) are found. The bottom of the lake, especially in the northern part, is overgrown with numerous patches of chara. On the water surface during flowering, greater bladderwort (*Utricularia vulgaris*), a carnivorous plant being a cosmopolitan species, can be seen.

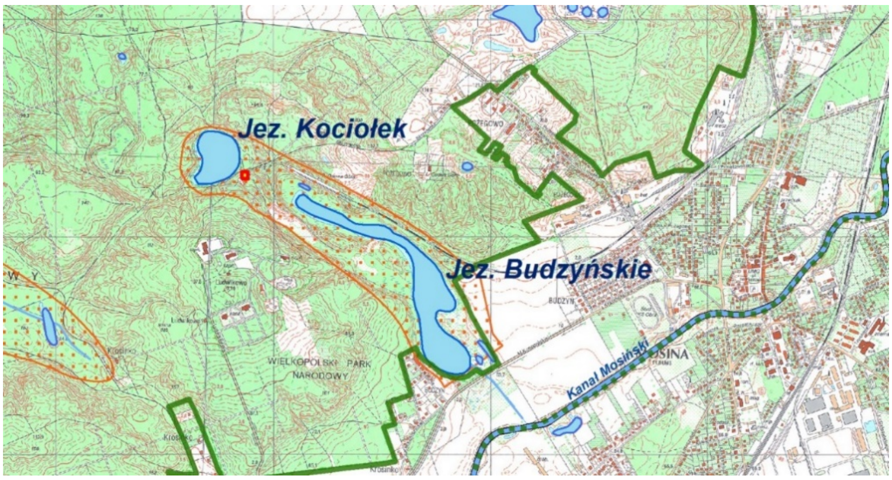

Fig. 1. Location of Lakes Budzyńskie and Kociołek
Source: Plan ochrony… (2013) and the authors' own elaboration.
Rys. 1. Położenie Jeziora Budzyńskiego i jeziora Kociołek
Źródło: Plan ochrony… (2013) i opracowanie własne.

Fig. 2. Lake Budzyńskie (photo D. Węclewski)
Rys. 2. Jezioro Budzyńskie (fot. D. Węclewski)

Fig. 3. Run-off from the voivodeship road no. 430 towards Lake Budzyńskie (photo D. Węclewski)
Rys. 3. Spływ z jezdni drogi wojewódzkiej nr 430 w kierunku Jeziora Budzyńskiego (fot. D. Węclewski)

The catchment of Lake Budzyńskie is for the most part (88%) a forest catchment. The urbanized areas located at the south-western shore account for 3% and arable lands for 9% of the total catchment area.

The housing developments along the shore pose a real threat to the lake ecosystem. In the coming years, in accordance with the Spatial Development Plan devised for the land located at the south-eastern shore of the lake, a residential housing estate with amenities will be erected. This will significantly change the nature of the lake catchment and contribute to greater anthropopressure on the water body.

The voivodship road running at the southern shore poses a real threat to the lake ecosystem in the form of road pollution or exhaust fumes emission (Fig. 3). The lack of settlement tanks causes the free penetration of harmful substances that flow from the roads and penetrate into the lake basin through the soil. Another factor negatively affecting the condition of the lake is the fact that for over 100 years sewage was discharged into the lake from the nearby sanatorium and later the hospital in Ludwikowo. It was not until 2015 that the sewage system was put in place in the Wielkopolska Centre for Pulmonology and Thoracic Surgery at the Ludwikowo hospital and sewage discharge from the local sewage treatment plant ceased.

Lake Kociołek (Fig. 4) is a small forest lake with an area of 4.2 ha and a maximum depth of 7.4 m. Similarly as Lake Budzyńskie, it is covered by strict protection. Due to the relatively small surface area, steep slopes and being sheltered by forest-covered hills, the water surface is subject to limited influence of heat radiation and winds. The low variability of thermal parameters at a relatively big depth and the small surface of the lake results in the lake being meromictic (Dojlido, 1997). There are hiking trails along its shores.

The Lake Kociołek catchment has been almost entirely (around 98% of the area) forested for several decades. The remaining part consists of arable and urbanized areas. This makes the catchment less susceptible to transportation of potential pollutants into the water body (Ławniczak et al., 2016).

Fig. 4. Lake Kociołek (photo D. Węclewski)
Rys. 4. Jezioro Kociołek (fot. D. Węclewski)

Fig. 5. Water treatment plant at Lake Kociołek (photo D. Węclewski)
Rys. 5. Stacja uzdatniania wody nad jeziorem Kociołek (fot. D. Węclewski)

The deterioration in water quality in the lake observed over time has significantly been affected by the discharge of rinse water from the water treatment station located at the south-eastern shore of the lake for a number of years (Fig. 5). Drilled wells located there, which are a water intake for the hospital in Ludwikowo, are characterized by high iron content. Water quality in Lake Kociołek in the period from 1974 to 2012 analyzed in this study in relation to the development of the WNP conservation plan, deteriorated from the mesotrophic to the eutrophic state (Ławniczak et al., 2016).

RESEARCH METHODOLOGY

As part of the study, selected physical and chemical parameters were recorded. Prior to the measurements the course of transects was established on each of the lakes, along which measuring points were established. The location of the transects resulted from the analysis of bathymetric plans of the lakes in question (Figs. 6, 7). They were identified considering depth differentiation of these lakes and their shape. The measurements were taken at monthly intervals at a constant depth of 1 m below the water surface at five measuring points on each of the lakes in the hydrological year 2017. The aim of the adopted research methodology consisting in measuring selected parameters at a depth of 1 m from the water table was to monitor changes in the epilimnion layer in real time. In January 2017, when there was a thick ice cover, holes were made in the ice in order to take measurements. In February 2017 due to unfavorable conditions on the lakes (thin ice layer) the measurement could not be conducted.

Measurements were made using the YSI Professional Plus multi-parameter meter. The following parameters were recorded on site: pressure (mm Hg), temperature (°C), electrical conductivity (μS/cm), oxygen saturation (%), dissolved oxygen content (mg/L), total dissolved solids (TDS) in water (g/L), water pH (units) and salinity (ppt). The YSI meter has a built-in barometer operating in the range of 375–825 mm Hg. The dissolved oxygen content was measured using a galvanic or polarographic sensor (in this case the galvanic one) that read data in the range of 0–50 mg/dm^3. Water conductivity was recorded with the use of a 4-electrode conductivity probe in the range

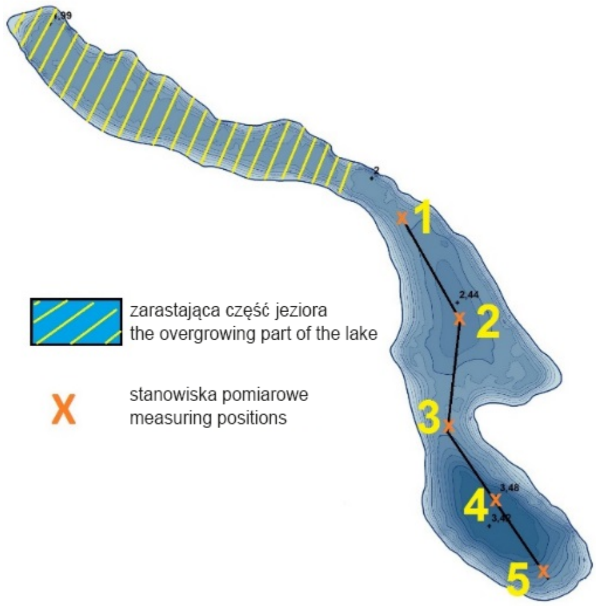

Fig. 6. Measuring points along the transect on Lake Budzyńskie
Source: authors' study based on Brodzińska et al. (2010)
Rys. 6. Stanowiska pomiarowe wzdłuż transektu na Jeziorze Budzyńskim
Źródło: opracowanie własne na podstawie Brodzińska i in. (2010)

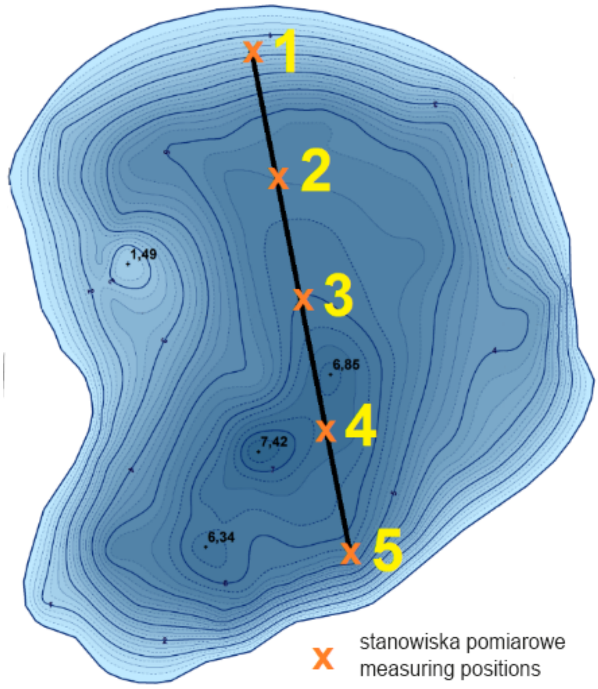

Fig. 7. Measuring points along the transect on Lake Kociołek
Source: authors' study based on Brodzińska et al. (2010)
Rys. 7. Stanowiska pomiarowe wzdłuż transektu na jeziorze Kociołek
Źródło: opracowanie własne na podstawie Brodzińska i in. (2010)

of 0 to 200 mS/cm. Salinity was measured in the range of 0–70 ppt. The pH of water was measured by means of a glass combined electrode operating in the range of 0–14 pH. The TDS level was obtained by automatically calculating conductivity and temperature (OMC ENVAG, n.d.). After measurements were made, all the data obtained during the measurements were read in order to prepare measuring cards.

Along with the above-mentioned analyses meteorological parameters were also measured. Air temperature was read during measurement days based on the instantaneous readout from an outdoor thermometer located at the headquarters of the Osowa Góra Protective District. Precipitation was recorded at the Adam Mickiewicz University station in Jeziory using the Hellmann rain gauge and was made available from the database of the Adam Mickiewicz University Ecological Station in Jeziory.

RESEARCH RESULTS AND METEOROLOGICAL BACKGROUND

During the research period, the highest monthly precipitation amounting to 133.9 mm was recorded in July 2017, while the lowest precipitation level was noted in January 2017. At the same time, the highest number of days with precipitation was recorded in November and December 2016 amounting to 14 rainy days in each of those months. Only 5 rainy days were recorded in April 2017.

The highest precipitation intensity was noted in summer, while relatively low precipitation was recorded in winter and spring (Fig. 8).

According to the Kaczorowska scale, the hydrological year 2017 was classified as a moist year (Gąsiorek and Musiał, 2011).

In agreement with the thermal classification of H. Lorenc according to meteorological data (IMGW PIB, 2018) the year 2017 was a warm year in the Greater Poland Lakeland.

The analysis of the tested parameters at individual measuring points for days of mearurements showed that some of them (pressure, salinity, TDS) were stable, while the other ones (temperature, pH, dissolved oxygen, oxygen saturation, conductivity) showed no significant fluctuations. The analysis presented in the table below (1) shows multiple recordings of extreme values for measured parameters broken down into individual points. The greatest extremes on Lake Kociołek were found at points 1 and 5. The analysis of the positions on Lake Budzyńskie was similar. The results indicate that the extremes occurred at the points located in the closest vicinity of the shore.

Figures 9–16 show the results of measurements carried out on site regarding physical and chemical parameters.

ANALYSIS OF RESULTS

Fluctuations in water conductivity in Lake Kociołek in the studied period amounted to 10%. During the study, there were two clear increases in this parameter – in January, when the lake was covered with ice and in June, when the highest conductivity level of 293.9 µS/cm was noted.

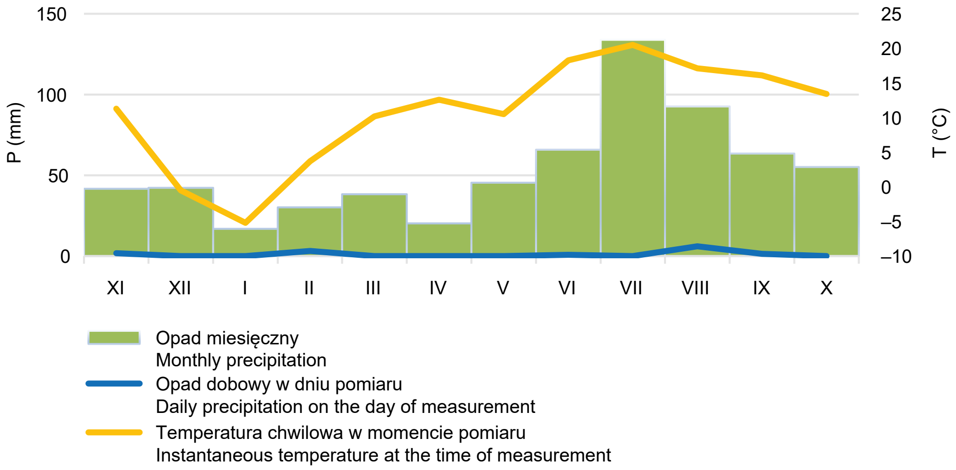

Fig. 8. Meteorological characteristics of the measurement days: instantaneous temperature – authors' readouts, monthly precipitation – data from the database of the Adam Mickiewicz University Ecological Station in Jeziory
Rys. 8. Charakterystyka meteorologiczna dni pomiarowych: chwilowa temperatura – odczyty własne, sumy miesięczne opadów – dane z bazy danych Stacji Ekologicznej UAM w Jeziorach

Table 1. The analysis of measuring points in terms of extreme values of selected physicochemical parameters of water
Tabela 1. Analiza stanowisk pomiarowych na pod kątem skrajności wyników wybranych parametrów fizykochemicznych wody

Parameter	Measuring points on Lake Kociołek Punkty pomiarowe na jeziorze Kociołek					Measuring points on Lake Budzyńskie Punkty pomiarowe na Jeziorze Budzyńskim				
	1	2	3	4	5	1	2	3	4	5
Temperature Temperatura	↓ x 7				↑ x 5	↓ x 7				↑ x 6
pH	↓ x 5				↑ x 6	↓ x 11				↑ x 8
Conductivity Przewodność właściwa	↓ x 5	↑ x 4			↓ x 5; ↑ x 4	↑ x 6			↓ x 4	
Dissolved oxygen Zawartość tlenu rozpuszczonego			↓ x 5		↑ x 4	↑ x 6				↓ x 5
Oxygen saturation Nasycenie wody tlenem			↓ x 5		↑ x 5	↑ x 6				↓ x 5

↑ – the highest result, ↓ – the lowest result, x – multiple of the readout.
Source: authors' study.
↑ – najwyższy wynik, ↓ – najniższy wynik, x – liczba wystąpień.
Źródło: opracowanie własne.

In the case of Lake Budzyńskie water conductivity was relatively high compared to Lake Kociołek, and its fluctuations in the analyzed period exceeded 23%. In Lake Budzyńskie the high level of conductivity was maintained in the winter-spring period, reaching the maximum value amounting to 562 µS/cm on January 18, 2017, while in the summer the value of this parameter decreased to the lowest value during the period

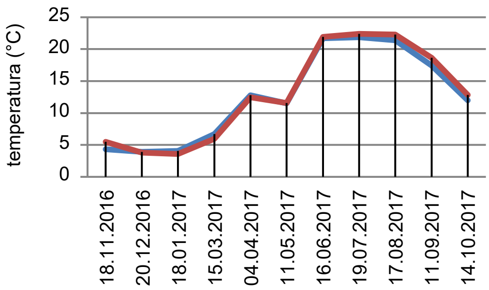

Fig. 9. Water temperature at a depth of 1 m
Rys. 9. Temperatura wody na głębokości 1 m

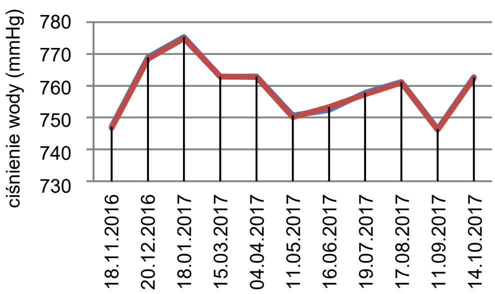

Fig. 10. Water pressure at a depth of 1 m
Rys. 10. Ciśnienie wody na głębokości 1 m

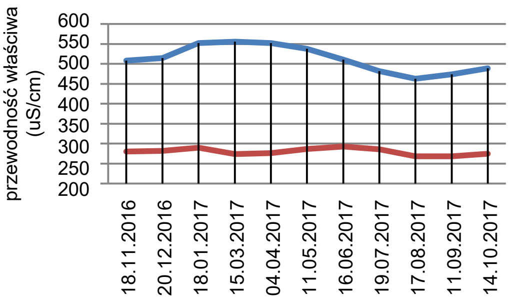

Fig. 11. Specific conductivity of water at a depth of 1 m
Rys. 11. Przewodność właściwa wody na głębokości 1 m

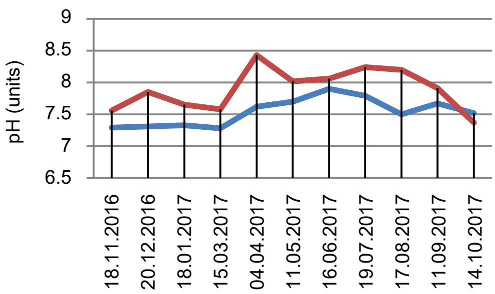

Fig. 12. pH of water at a depth of 1 m
Rys. 12. pH wody na głębokości 1 m

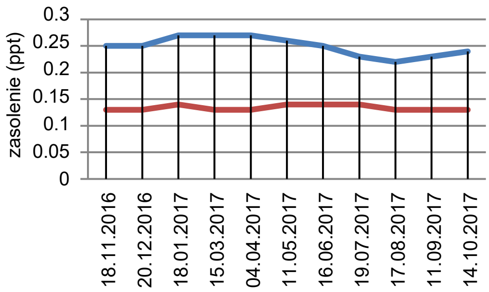

Fig. 13. Water salinity at a depth of 1 m
Rys. 13. Zasolenie wody na głębokości 1 m

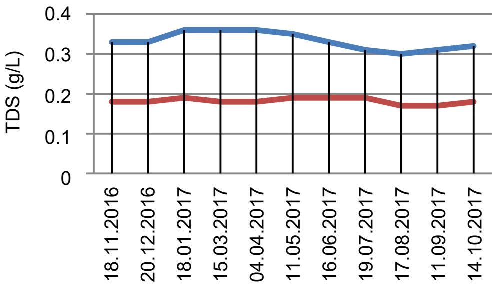

Fig. 14. Total dissolved solids (TDS) content in water at a depth of 1 m
Rys. 14. Całkowita zawartość substancji rozpuszczonych (TDS) w wodzie na głębokości 1 m

under study amounting to 455.10 µS/cm on January 18, 2017.

Fluctuations in water temperature for both water bodies were similar during the examined period; however, attention should be paid to differences occurring during both spring circulation and summer stagnation. The impact of the lake location and the associated susceptibility to wind were noticeable. As a result, the average temperature of Lake Kociołek as a water body surrounded by forests and hills differed compared to

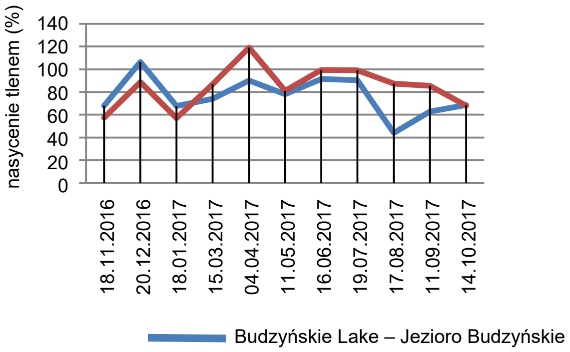

Fig. 15. Water saturation with oxygen at the depth of 1 m
Rys. 15. Nasycenie wody tlenem na głębokości 1 m

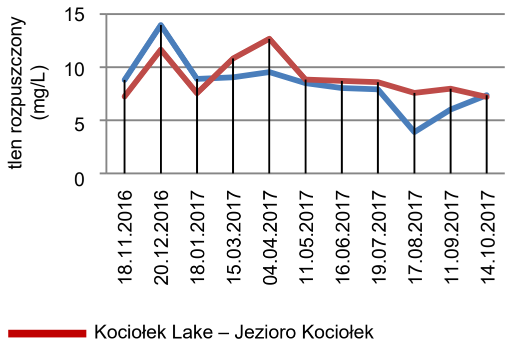

Fig. 16. Oxygen content dissolved in water at a depth of 1 m
Rys. 16. Zawartość tlenu rozpuszczonego w wodzie na głębokości 1 m

the temperature readout on Lake Budzyńskie. On the days of measurement it was higher by about 1°C. The highest water temperatures were recorded during the summer stagnation on July 19, 2017 and amounted to 22.6°C for Lake Kociołek and 22.3°C for Lake Budzyńskie. The lowest temperatures were noted during the winter stagnation on January 18, 2017 during the presence of ice cover, where the temperature recorded at a depth of 1 meter was 3.4°C for Lake Budzyńskie and 3.5°C for Lake Kociołek.

The results of water pressure were closely related to atmospheric conditions and reflected conditions prevailing in the given period.

In Lake Kociołek the pH level fell on average into the range of 7.37 and 8.43 pH, which means that this water body constitutes transition water from slightly alkaline to alkaline one. The highest pH value for Lake Kociołek was recorded on April 4, 2017 and it amounted to 8.63, while the lowest value was noted on October 14, 2017 at 7.34.

In Lake Budzyńskie the average pH level ranged between 7.28 and 7.79 pH, which means that this water body qualifies as transition water between neutral and slightly alkaline one. At the same time, the maximum increase in the pH level amounting to 8.13 was recorded on June 16, 2017 in the examined period, whereas the lowest result of pH = 6.97 on November 18, 2016.

With regard to salinity and total dissolved solids content in water as related parameters, their variability in the studied lakes was almost identical within the same water body. However, large differences between these two lakes need to be stressed. The level of salinity in Lake Kociołek fell on average into the range of 0.13–0.14 ppt, whereas in Lake Budzyńskie the level was much higher and ranged from 0.23 to 0.27 ppt. Fluctuations in salinity and total dissolved solids content in water of Lake Kociołek were minor, whereas in Lake Budzyńskie there were periodic increases during the spring circulation and drops in the values of these parameters during summer stagnation.

The level of oxygen saturation was referred to the course of changes in dissolved oxygen content. The distribution of dissolved oxygen content and the degree of water saturation with oxygen in lakes corresponded to changes in water temperature and reflected thermal changes in the water bodies during the period under study. Individual spikes of dissolved oxygen content probably resulted from photosynthesis processes in the water bodies and were associated with the degree of insolation in the studied lakes and the degree of wind influence on the surface water layers.

CONCLUSIONS

Potential threats resulting from exceeding the permissible parameters can be detected through systematic monitoring. Due to the fact that the studied lakes are characterized by a relatively small area and they are not subject to continuous monitoring resulting from the Ordinance of the Ministry of the Environment of November 15, 2011, there is a growing need to implement a program to monitor changes occurring in them.

The analysis of all physicochemical parameters measured during this study showed that seasonal variability is a consequence of natural processes occurring in the water bodies. Increases and decreases in water pressure and temperature were closely related to current weather conditions. The results of electrical conductivity of water and the associated salinity and total dissolved solids (TDS) showed that Lake Budzyńskie was more polluted than Lake Kociołek. This is probably due to the long-term supply of the lake with sewage from nearby Ludwikowo and the general characteristics of the catchment. At the same time, the status of Lake Kociołek despite the favorable character of the catchment, mainly composed of mixed forests (98% forest cover) also showed increased values of these parameters. This is probably a consequence of the long-term discharge of filtration rinses of water intake for the hospital in Ludwików. Fluctuations in pH as well as the content and degree of oxygen saturation were within the ranges resulting from the natural processes taking place in the lakes. This confirmed relative stability of both lakes. All tested water parameters showed similar values both at the beginning of the examined period and during the last measurements.

Considering the analyzed parameters, it should be assumed that the status of the studied lakes is stable and there is no need to specify the necessary conservation tasks. In the case of Lake Kociołek it is essential to stop the discharge of filtration rinses from the water treatment plant for the hospital in Ludwików. For Lake Budzyńskie it is necessary to modernize voivodship road No. 431 in the part adjacent to the southern shore of the lake in order to stop water draining from the motorway to the lake. In view of the urban development of the town of Mosina in the immediate vicinity of Lake Budzyńskie a zone covered with woody and shrubby vegetation needs to be established, which would play a protective role for the lake ecosystem.

Pursuant to the provisions in force, it is not possible to classify qualitatively the analyzed lakes on the basis of physicochemical parameters tested, but they should be treated as supporting parameters allowing for a partial assessment of the water status.

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SEZONOWA ZMIENNOŚĆ WYBRANYCH WŁAŚCIWOŚCI FIZYKOCHEMICZNYCH WÓD POWIERZCHNIOWYCH WIELKOPOLSKIEGO PARKU NARODOWEGO NA PRZYKŁADZIE JEZIOR BUDZYŃSKIEGO I KOCIOŁEK

ABSTRAKT

Wstęp. Wody powierzchniowe Wielkopolskiego Parku Narodowego są jednym z najważniejszych elementów środowiska przyrodniczego tego obszaru. Postępujące procesy degradacji, a w konsekwencji eutrofizacji jezior stwarzają konieczność podejmowania określonych działań mających na celu monitorowanie wód i wdrażanie metod ich ochrony. Badanie zmienności parametrów fizykochemicznych wody jest istotnym elementem monitoringu wód i określania ich stanu ekologicznego.
Cel. W pracy poddano analizie wybrane parametry wód zebrane podczas pomiarów wykonywanych na Jeziorze Budzyńskim i jeziorze Kociołek w celu określenia potrzeby wskazania niezbędnych zadań ochronnych o charakterze ratowniczym.
Zakres analiz. Praca obejmuje pomiary parametrów fizykochemicznych, które wykonano w roku hydrologicznym 2017. Na każdym z jezior w cyklach miesięcznych przeprowadzano pomiary w pięciu punktach leżących w linii wyznaczonego transektu. Podczas pomiarów oznaczano osiem parametrów charakteryzujących właściwości fizyczne i chemiczne wody, tj. temperaturę, ciśnienie, zasolenie, nasycenie tlenem, zawartość tlenu rozpuszczonego, przewodność właściwą, całkowitą zawartość substancji rozpuszczonych oraz pH.
Wnioski. Wyniki pomiarów pozwalają stwierdzić, że stan badanych jezior jest stabilny.

Słowa kluczowe: wody powierzchniowe, parametry fizykochemiczne wody, eutrofizacja jezior, Wielkopolski Park Narodowy