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The spatial variation of oxygen condition in carp pond located in nature reserve „Stawy Milickie”

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Abstract

The paper presents the results of research on the spatial variation of oxygen condition in a carp pond. The analysis of dissolved oxygen was carried out in the summer in 29 measuring points. In the analysed months the differences were determined between dissolved oxygen concentration in the strip of rushes and the part of the pond free from macrophytes. In the strip of rushes, the average concentration of dissolved oxygen was between 4.69–6.49 mg $O_2 \cdot dm^{-3}$. In the part of pond located near the strip of rushes the oxygen concentration was between 6.23–7.91 mg $O_2 \cdot dm^{-3}$ and in open water concentration of dissolved oxygen was in range 7.60–9.09 mg $O_2 \cdot dm^{-3}$. It was found that the biggest differences in oxygen concentration occur between the strip of rushes and the open water column: 40% in June, 26% in July, 28% in August, 38% in September, respectively. In the south-western part of the pond, covered with macrophytes and shaded by trees, the worst oxygen conditions were observed – below the optimum level for carps, sometimes reaching lethal values. The best oxygen conditions, noted in July and August, were in the central and northern part of the pond including the fishery and feeding point. In order to improve the oxygen conditions in macrophytes zone it is recommended to remove the rushes periodically and to remember to leave the part of emergent plants that are necessary for breeding and living avifauna. The scope and timing of the removal of plants has to be consulted and co-ordinated with the Regional Conservator of Nature.

Key words: *aquatic macrophytes, carp pond, dissolved oxygen, milickie ponds, nature reserve, rushes*

INTRODUCTION

The level of concentration of dissolved oxygen in water reservoirs is seldom stable; it is rather prone to significant fluctuations, both in the seasonal and daily perspective. This is influenced by a series of biotic and abiotic factors. The sources of oxygen in the water of a pond ecosystem are: the inflow of fresh water, diffusion from the atmosphere and photosynthesis (which accounts for as much as 80% of the oxygen income in the pond). The concentration depends on numerous factors, including temperature, solar radiation, the clarity of water, the content of nutrients, shading of the water surface by plants, the development of phytoplancton [BRYSIEWICZ *et al.* 2012; JAWECKI 2011; JAWECKI, KRZEMIŃSKA 2008; JAWECKI *et al.* 2008; SADOWSKI *et al.* 1999]. On the other hand, the oxygen is mainly used for the breathing of water organisms and oxygen-related decomposition of organic remains (dead plants and plankton, undigested feed, organic fertilisers) [DANIELEWSKI 1970; DOJLIDO 1987; KAJAK 2001]. Moreover, oxygen is consumed in the chemical reactions of oxidation of iron and manganese [DOJLIDO 1995].

Spatial differentiation of the oxygen conditions is also observed within the ponds. It depends, among

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others, on the depth (large variability and usually good oxygenation of surface layers, lower variability and worse oxygenation of layers close to the bottom [BRYSIEWICZ 2012; JAWECKI 2008; JAWECKI; DRABIŃSKI 2003; JAWECKI *et al.* 2005; WESOŁOWSKI, VENNINGEN 1982]); the availability of sunlight (necessary for photosynthesis), temperature (intensification of the physiological processes of phytoplanctone is observed along with the increase in temperature [JAWECKI *et al.* 2008; JAWECKI, KRZEMIŃSKA 2008; VENNINGEN 1982]); the presence of water flora (in the strip of macrophytes the content of oxygen can be only half the value noted in open water and even 90% lower if it is shaded by trees) [JAWECKI 2006; JAWECKI *et al.* 2010]); the population and feeding of fish (in the feeding areas the concentration of oxygen can fall even by 50% after the feed is dispensed [ZAKĘŚ 2001]; the quality of inflowing water (fresh water is richer in oxygen) [GUZIUR 1997; KARPIŃSKI 1995].

It should be noted that carp is quite resistant to the fluctuations and deficits of oxygen in water. Thus, when analysing the oxygen conditions it is important to take into account its oxygen demand. Different authors specify different levels, resulting from the changes in water temperature during research, the condition and age of the fish and the method of conducting the analysis. 5 mg O_2 dm^{-3} is considered as the bottom limit of the oxygen optimum for carp. The range 1.7–5.0 mg O_2 dm^{-3} (saturation 40–50%) is considered as critical value, although the decrease in water oxygen content to the level of 2–3 mg $O_2 \cdot dm^{-3}$ is believed to cause anxiety in fish. Values between 0.6–1.7 mg $O_2 \cdot dm^{-3}$ (water oxygen saturation lower than 20%) are considered as lethal content, leading to death, although carp can survive for some time in water where the concentration of oxygen falls into the range of 0.3–0.5 mg $O_2 \cdot dm^{-3}$ [BIENIARZ *et al.* 2003; DANIELEWSKI 1970; GUZIUR 1997; JAROSZEWICZ-SMYK 2011; ŁYSAK *et al.* 1995; MOHANTY *et al.* 2004; WOŹNIEWSKI 1987; 1992].

MATERIAL AND METHODS

The object of the test was the pond "Staś Górny" (Stawno complex), located in the nature reserve "Stawy Milickie" (Milickie Ponds) in the Lower Silesian Voivodeship, situated in the area of the natural landscape park Dolina Baryczy (Valley of Barycza). Field analyses were conducted in summer (June–September) 2007, in the fish fry pond "Staś Górny", designed for low-intensity breeding of carp. The reservoir has an area of 13.41 ha, out of which an area of approx. 3 ha was overgrown with rushes (common reed and lesser bulrush). The average depth of the pond was 0.9 m (maximum depth of approx. 1.6 m) [JAWECKI *et al.* 2008; 2010].

The measurements were taken in 29 points (Fig. 1) that were divided into three groups: 12 points in the strip of rushes (SZ), at the distance of 1 m into the rushes, from the side of the pond, 11 points in the proximity of rushes (P), located 1 m from the border of rushes, 6 points in the open water (T), situated in characteristic parts of the pond: the centre of the pond, the fishery, the feeding point, the point at the outlet box, between islands, between the dike and the island (Fig. 1). Individual measurement points of the SZ and P groups, located at 2m distance from each other, were grouped in pairs for the purposes of calculation of the percentage difference in the oxygen concentration values between the strip of rushes and the strip adjacent to the rushes (I: points No. 1 and 2; II: points No. 3 and 4; III: points No. 5 and 4; IV: points No. 6 and 7; V: points No. 9 and 10; VI: points No. 11 and 12; VII: points No. 14 and 15; VIII: points No. 16 and 17; IX points No. 18 and 19; X: points No. 21 and 22; XI: points No. 24 and 25; XII: points No. 26 and 27).

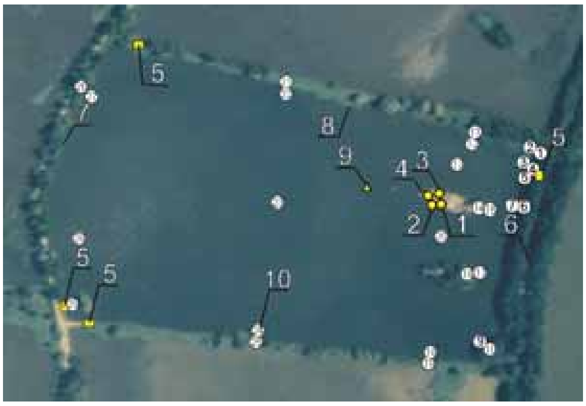

Fig. 1. Staś Górny pond: *1* – meteorological cage, *2* – heliograph, *3* – Hellman rain-gauge, *4* – automatic weather station, *5* – outlet boxes (monks), *6* – water supply ditch, *7* – trees and shrubbery, *8* – aquatic macrophytes, *9* – water temperature measurement point, *10* – dissolved oxygen measurement points; source: own elaboration

Measurements were taken at the depth of 0.2 m with use of a multi-functional meter Multi 340i with an oxygen probe CellOx 325, manufactured by WTW (measurement scope 0.0–19.19 mg $O_2 \cdot dm^{-3}$ or 0.0–90 mg $O_2 \cdot dm^{-3}$ accuracy ±0.5%), which also measured the temperature of water (with the accuracy to 0.1°C). Observations were conducted in the morning, between 9–11 a.m. The measurements of meteorological factors were carried out with use of the automatic measurement station manufactured by Campell SCI, equipped, among others, with the detectors of: air temperature (HMP45C – by Vaisala), precipitation (pluviometer by Young), and anemometer by Young, model 05103.

The percentage scale of changes in oxygen concentration in water between: the zone of the pond adjacent to the rushes and the strip of rushes (*SZ.P*), the open water and the zone adjacent to the rushes (*P.Tsr*), the open water and the strip of rushes (*SZ.Tsr*) was calculated from the equation:

$$SZ.P = \left(1 - \frac{SZ_i}{P_i}\right)100\%$$

$$P.Tsr = \left(1 - \frac{P_i}{Tsr}\right)100\%$$

$$SZ.T = \left(1 - \frac{SZ_i}{Tsr}\right)100\%$$

where:

- $SZ.P$ – is the percentage value of changes in oxygen concentration between the zone of water adjacent to the rushes and the concentration of oxygen in the water of the strip of rushes;
- $P.Tsr$ – is the percentage value of changes in oxygen concentration between the open water and the zone of water adjacent to the rushes;
- $SZ.T$ – is the percentage value of changes in oxygen concentration between the open water and the oxygen concentration in the water in the strip of rushes;
- SZ_i – concentration of oxygen in the strip of rushes, in subsequent measurement points;
- Tsr – arithmetic mean of the oxygen concentration in open water;
- P_i – concentration of oxygen in the zone adjacent to the rushes, in subsequent measurement points.

The mean values of oxygen concentration in specific groups of points and on specific days were calculated as an arithmetic mean, for which the calculus of errors was conducted. The random error of individual measurements was determined and then compared to systematic error [KUBIACZYK 2013]. No situations occurred in which the systematic errors would equal random errors and in which systematic errors would prevail over random errors [JAROSZEWICZ-SMYK 2011].

RESULTS

In the subsequent days of observation the average daily air temperature ranged from 16.2°C to 21.3°C, whereas the temperature noted during measurements fell into the range from 15.8 to 19.7°C (Tab. 1). The momentary wind velocity at the moment of observations ranged from 0.78 to 3.0 m s^{-1} (Tab. 1), and the water temperature fell into the range from 14.7 to 25.4°C (Tab. 1) [JAWECKI *et al.* 2010; JAROSZEWICZ--SMYK 2011].

The oxygen conditions noted in the pond Staś Górny in most instances met the oxygen demand of the carp. However, values below the optimum range for carp, i.e. 5 mg $O_2 \cdot dm^{-3}$ were noted quite often. In June, the least beneficial conditions were observed in the south-eastern part of the pond, along the western dike and near one of the islands. (Fig. 2.), where concentrations lower than 5 mg $O_2 \cdot dm^{-3}$ were noted, and in point 1 concentration of 0.68 mg $O_2 \cdot dm^{-3}$ was noted, which is lower than the lethal value 1.7 mg $O_2 \cdot dm^{-3}$. In the subsequent months, the zone with oxygen concentration below optimum decreased significantly. In July (Fig. 2.) it encompassed only the south-eastern corner of the pond, although it was smaller than in June. In July the oxygen conditions were beneficial, as in September (Fig. 2.). The oxygen concentration in the water slightly deteriorated in August. The zone with the critical values of oxygen concentration, apart from the south-eastern corner of the pond, also appeared at the western dike. (Fig. 2). The central and northern parts of the pond (the fishery) were characterised by good oxygen conditions for carp breeding for the whole duration of the research period.

Table 1. Characteristic of dissolved oxygen concentration and meteorological factors in Staś Górny pond

Factor			Date			
			22.06.2007 VI	18.07.2007 VII	04.08.2007 VIII	17.09.2007 IX
Dissolved oxygen concentration, mg O_2 dm^{-3}	rushes (SZ)	mean	4.69±0.74	6.45±0.34	6.49±0.60	5.63±0.45
		max.	7.25	7.76	7.89	7.40
		min.	0.68	3.59	2.76	2.66
	pond, nearby rushes (P)	mean	6.23±1.28	7.24±0.54	7.91±0.88	6.95±0.86
		max.	8.48	8.90	9.12	8.29
		min.	0.82	4.07	3.32	3.06
	open water (T)	mean	7.60±0.02	8.71±0.27	8.95±0.06	9.09±0.04
		max.	8.21	9.42	9.34	9.78
		min.	7.04	7.74	8.58	8.43
Air temperature, °C	daily mean		17.8	21.3	16.2	17.3
	during measurement time		15.8	19.7	17.2	18.7
Wind speed, $m \cdot s^{-1}$	during measurement time		2.5	1.6	3.0	0.78
Water temperature, C	during measurement time		20.5	25.4	19.2	14.7

Source: JAWECKI i in. [2010], JAROSZEWICZ-SMYK [2011].

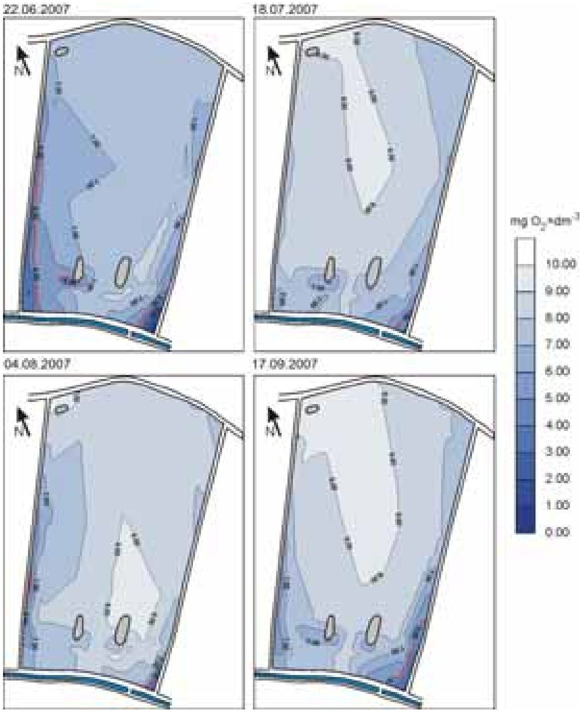

Fig. 2. Spatial differentiation of the dissolved oxygen concentration in the pond "Staś Górny"; source: own elaboration

In the strip of rushes, the mean concentration of dissolved oxygen in specific months fell into the range from 4.69 (VI) – 6.49 (VIII) mg $O_2 \cdot dm^{-3}$ (Tab. 1). The lowest oxygen concentration in specific months was measured on point 1, and it was, respectively, 0.68 mg $O_2 \cdot dm^{-3}$ (VI), 3.59 mg $O_2 \cdot dm^{-3}$ (VII), 2.76 mg $O_2 \cdot dm^{-3}$ (VIII), 2.66 mg $O_2 \cdot dm^{-3}$ (IX). The highest oxygen concentration values in the strip of rushes in specific months were noted on points No. 2 – 7.25 mg $O_2 \cdot dm^{-3}$ (VI); No. 25 – 7.76 mg $O_2 \cdot dm^{-3}$ (VII); No. 3 – 7.89 mg $O_2 \cdot dm^{-3}$ (VIII); No. 21 – 7.40 mg $O_2 \cdot dm^{-3}$ (IX).

The mean oxygen concentration of the zone of water adjacent to the rushes fell into the range from 6.23 mg $O_2 \cdot dm^{-3}$ (VI) to 7.91 mg $O_2 \cdot dm^{-3}$ (VIII), on the average 7.08 mg $O_2 \cdot dm^{-3}$ (Tab. 1). The lowest oxygen concentration among the points in the zone adjacent to rushes was noted in point 2, respectively 0.82 mg $O_2 \cdot dm^{-3}$ (VI); 4.07 mg $O_2 \cdot dm^{-3}$ (VII); 3.32 mg $O_2 \cdot dm^{-3}$ (VIII); 3.06 mg $O_2 \cdot dm^{-3}$ (IX). The highest values in specific months in the zone adjacent to rushes were noted in points: No. 15 – 8.48 mg $O_2 \cdot dm^{-3}$ (VI); No. 18. – 8.90 mg $O_2 \cdot dm^{-3}$ (VII); No. 15. – 9.12 mg $O_2 \cdot dm^{-3}$ (VIII); and No. 24. – 8.29 mg $O_2 \cdot dm^{-3}$ (IX).

Points located in the open water zone were characterised by the highest oxygen concentration values in each month. The mean values from subsequent months fell into the range from 7.60 mg $O_2 \cdot dm^{-3}$ (VI) to 9.09 mg $O_2 \cdot dm^{-3}$ (IX), on the average 8.59 mg $O_2 \cdot dm^{-3}$ (Tab. 1). The highest oxygen concentration was measured in point No. 29 – 9.78 59 mg $O_2 \cdot dm^{-3}$ (IX), and the lowest in point No. 23 – 7.04 mg $O_2 \cdot dm^{-3}$ (VI).

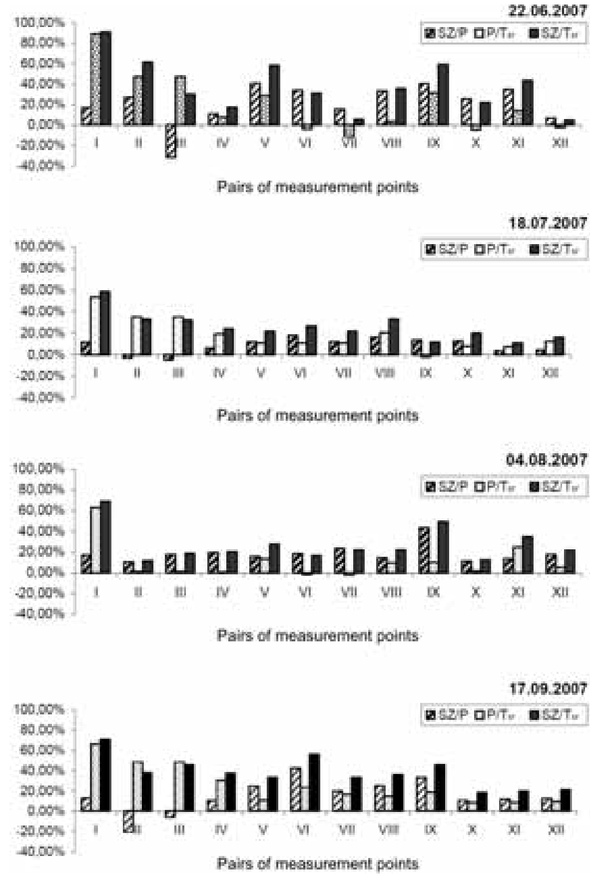

Fig. 3. Variability of dissolved oxygen concentration in "Staś Górny" pond; source: JAROSZEWICZ-SMYK [2011]

In June, the average difference in oxygen concentration between points in the rushes group (*SZ*) and the points in the zone adjacent to rushes (*P*) was on the level of 21%, and between open water (*Tsr*) and points adjacent to rushes (*P*) on the level of approx. 20.5%. The highest variability was observed in points located in the open water and rushes, where the mean percentage difference reached nearly 40% (Fig. 3). In July, the mean differences in oxygen concentration were lower. The difference between the points in rushes (SZ) and points in the zone adjacent to rushes (P) was about 9%, and between P points and T points 19% on the average. The variability between the points in rushes and open water was also on the average level of approx. 26% (Fig. 3). In August, the mean differences in oxygen concentration between the points in rushes (SZ) and the points in the zone adjacent to rushes (P) were approx. 19%, and between the points adjacent to rushes and points located in open water (T) – 11% (Fig. 3). In August, the mean difference in oxygen concentration between points in rushes (SZ) and points adjacent to rushes (P) was 15%, while the difference between rushes (SZ) and open water (T) – 38%, between open water (T) and points adjacent to rushes – 26% (Fig. 3). The conducted research shows that the highest differences in oxygen concentration occurred between the strip of rushes and open water: in June approx. 40%, in July 26%, in August 28% and in September approx. 38% (Fig. 3).

CONCLUSIONS

The conducted research allows to formulate the following conclusions:

1. The general evaluation of the oxygen conditions in the pond Staś Górny, occurring in summer of 2007 was positive, as for the majority of the research period the conditions observed in the major part of the pond were above the bottom limit of the oxygen optimum for carp (5 mg $O_2 \cdot dm^{-3}$).

2. The accumulation of a zone of macrophytes and of trees overgrowing the dikes on the pond (which supply significant amounts of organic matter that is hard to decompose to the pond) in the south-eastern part of the pond contributed to a significant deterioration of the oxygen conditions, which reached lethal values.

3. Rush type flora contributed to the deterioration of oxygen conditions on the average by 32%, whereas the most disadvantageous oxygen conditions were noted in June and September, in particular in the strip of rushes shaded by trees.

4. The most beneficial oxygen conditions were observed in July and August in the central and northern parts of the pond, encompassing the feeding point and the fishery, which is particularly important for the correct performance of maintenance operations (such as supplementary feeding and control fishing).

5. Due to the strict regulations that are binding in the area of the natural reserve "Milickie Ponds", the application of intense maintenance operations in order to oxygenate the water (in particular noise-emitting equipment) on the pond "Staś Górny" is limited, and it seems unnecessary, due to the good oxygenation of water observed for a majority of the research period on a major part of the pond surface.

6. In order to improve the aerobic conditions in macrophytes zone it is recommended to remove the rushes periodically and to remember to leave the part of emergent plants that are necessary for breeding and living avifauna. The scope and timing of the removal of plants have to be consulted and coordinated with the Regional Conservator of Nature.

7. The conducted research showed the importance of selection of the measurement point for the evaluation of the oxygen conditions. This is particularly important in fish ponds with rich rush flora and dikes overgrown by trees and bushes.

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Przestrzenne zróżnicowanie warunków tlenowych w stawie karpiowym położonym w rezerwacie przyrody „Stawy Milickie"

STRESZCZENIE

Słowa kluczowe: *makrofity, rezerwat przyrody, staw karpiowy, stawy milickie, szuwary, tlen rozpuszczony*

W pracy przedstawiono wyniki badań przestrzennego zróżnicowania warunków tlenowych w stawie karpiowym, narybkowo-kroczkowym. Badania tlenu rozpuszczonego w wodzie przeprowadzono w lecie w 29 punktach. W badanych miesiącach określono różnice między stężeniem tlenu rozpuszczonego w pasie szuwarów a częścią stawu wolną od makrofitów. W pasie szuwarów średnie stężenie tlenu rozpuszczonego kształtowało się w przedziale 4,69–6,49 mg $O_2 \cdot dm^{-3}$. W części stawu położonej przy pasie szuwarów mieściło się w granicach 6,23–7,91 mg $O_2 \cdot dm^{-3}$, a w otwartej toni wodnej w zakresie 7,60–9,09 mg $O_2 \cdot dm^{-3}$. Stwierdzono, że największe różnice zawartości tlenu występują pomiędzy pasem szuwarów a otwartą tonią, średnio: 40% w czerwcu, 26% w lipcu, 28% sierpniu, 38% we wrześniu. W południowo-zachodniej części stawu, porośniętej przez makrofity i zacienionej przez drzewa, odnotowywano najgorsze warunki tlenowe, poniżej poziomu optimum tlenowego dla karpi, czasami osiągające wartości letalne. Najlepsze warunki tlenowe, odnotowane w lipcu i sierpniu, występowały w centralnej i północnej części stawu, obejmującej punkt karmienia i łowisko. W celu poprawy warunków tlenowych w pasie makrofitów można okresowo częściowo wykaszać szuwary, pamiętając o pozostawieniu części pasa roślinności wynurzonej niezbędnej dla rozrodu i bytowania ornitofauny. Zakres i termin planowanego koszenia należy konsultować z ornitologami i uzgadniać z regionalnym konserwatorem przyrody.