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PRIMARY PRODUCTIVITY OF PHYTOPLANKTON IN PELAGIC ZONE OF LAKE KRASNE IN ŁĘCZNA-WŁODAWA LAKELAND AFTER DISCONNECTING WATER SUPPLY FROM WIEPRZ-KRZNA CANAL

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Summary. In the summer seasons of 2004–2005, the primary productivity of phytoplankton was surveyed in the pelagic zone of Lake Krasne that had been a part of the Wieprz-Krzna Canal melioration system for over 30 years, and has been disconnected since 2000. Earlier, the lake was classified in the mesotrophic type. The gross primary production was measured by means of the oxygen method, while chlorophyll *a* concentration with the alcoholic method. Values of phytoplankton primary production and chlorophyll concentration in the waters were high, and values of the TSI_{SD} and $TSI_{Chl\ a}$ coefficients indicated a fertile character of the lake water. Disconnection of the lake from the melioration system caused gradual improvement of water quality as compared to previous periods.

Key words: lakes, primary production, chlorophyll *a* concentration, phytoplankton, TSI_{SD}, $TSI_{Chl\ a}$, assimilation number, eutrophication

INTRODUCTION

Lake Krasne situated in the Łęczna-Włodawa Lakeland occupies an area of 75.9 ha, while its volume is 8180 thousand m^3, and depth 33 m. Its volume to coastline length ratio is 2.31, whereas the Ohle index -3,54 [Harasimiuk *et al.* 1998]. It is a dimyctic lake with great susceptibility to contamination. Its waters were classified in the 3rd purity class in 2000. Such a status of mesotrophy (or vendace-type for fishermen) with very good water quality parameters resulted from its incorporation in the Wieprz-Krzna Canal system in the 70's of the 20th century. Finally, in 2000, the water supply to Lake Krasne was blocked. Since then, natural factors and surface runoff from the catchment, along with recreational centres around the lake, have had a major impacts on water fertility.

Investigations of phytoplankton productivity within the pelagic zone, carried out in 2004–2005, aimed at determining the trophy type of the waters just several years after lake Krasne disconnection from the Wieprz-Krzna Canal waters supply.

MATERIALS AND METHODS

The study was performed in the pelagic zone of Lake Krasne in the summer seasons of 2003–2005. The sampling points were located within inlakes at 0.5, 2.5, and 5.0 m depths. The numbers of water samples (n) were 12 in 2004 and 10 in 2005. The water samples with phytoplankton, collected using a Patalas bucket, were exposed at their sampling sites. The exposure times were always the same, lasting from 10 a.m. till 2 p.m. The method of „light" and „dark" vessels, of 175 ml in capacity, was used for direct measurements of gross primary production [Vollenweider 1969], which was based on Winkler's titrimetric method for measuring the concentration of oxygen in water separated due to photosynthesis [Hermanowicz *et. al*. 1976]. Values of primary production were expressed in volume units (mg O_2 dm^{-3} h^{-1}), while for comparisons and to make it possible to calculate the assimilation number, they were converted to mg C under 1 m^2 surface area in a water column per 1 hour (mg C m^{-2} h^{-1}) [Strickland 1960].

In order to determine the primary productivity, the indirect method consisting in chlorophyll *a* concentration measurements in phytoplankton was applied at the same time and at the same sampling points. Therefore, water samples of 1 dm^3 volume were filtered through Whatman GF/C filter papers. Then, filters along with the sediment was homogenised and flooded with hot ethanol. The chlorophyll *a* concentration was measured using spectrocolorimeter „Specol" at wavelengths of 665 and 750 nm [Nusch 1980]. Results were expressed in mg dm^{-3} and converted to 1 m^2 surface area in water column (mg m^2). Each series of productivity measurements was made in three replications. Mean values, standard deviations for particular points (0–5 m) and for the two-year experimental period were calculated. Water chemical analyses for particular sampling points were performed twice by the Chemical Laboratory of Main Mining Institute in Lublin. Values of assimilation number (gross primary production/chlorophyll *a* concentration ratio) and Carlson's coefficients were calculated on the basis of water visibility (TSI_{SD}) and chlorophyll *a* content ($TSI_{Chl\ a}$).

RESULTS AND DISCUSSION

Prior to incorporation into the Wieprz-Krzna Canal melioration system, Lake Krasne was a mesotrophic and vendace-type one. In 1967–1968, the amount of total phosphorus was recorded at the level of 0.015 in surface layers and 0.05 mg dm^{-3} at the bottom, while contents of Ca, Mg, K, Fe ions qualified its waters to the 1st purity class [Radwan *et al.* 1971]. Wieprz-Krzna Canal waters, abundant in biogens, caused its sudden degradation. All physicochemical parameters indicated advanced eutrophication, and sometimes hypertrophy. In 2000, complete oxygen disappearance and hydrogen sulphide presence was recorded starting from 7 m depth, while oxygen was absent even in the epilimnion in the 90's of the 20th century [Girsztowtt 2002]. As a result of numerous interventions in 2000, supplies of fertile waters to the lake were disconnected, hence beginning the self-purification process. Four years later, the water quality was apparently better. Chemical analyses made in 2004–2005 confirmed its good quality. Water visibility was not high enough, ranging from 1.94 to 2.2 m. Oxygen concentration decreased along with depth to the average value of 3.99 mg O_2 dm^{-3}, but its level above 1 mg O_2 dm^{-3} was reported in the benthic zone (Tab. 1). A majority of analysed parameters [Decree... 2004], i.e. electrolytic conductivity, water pH, ammonia, nitrites, chlorides, sulphates, and phosphates indicated the 1st purity class, except for COD_M (2nd class) and nitrates (3rd class) (Tab. 1). A survey made by WIOŚ [Report... 2008] in Lublin revealed that water visibility increased from 1.8 m in 2000 to 3.5 m in 2004, and decreased to 2.3 m in 2008. Quantity of total nitrogen oscillated from 1.48 in 2000 to 1.02 mg N dm^{-3} in 2004. Wojciechowska and Solis [2009] achieved similar results, classifying that lake in the mesotrophic type.

The gross primary production measured during the experiment reached its highest value in the epilimnion in 2004 (0.67 mg O_2 dm^{-3} h^{-1}), with decrease along with depth (0.11 per 5 m in 2005). Mean value for the 0–5 m water profile was 40.5, while average for both experimental years – 0.60 mg O_2 dm^{-3} h^{-1} (Tab. 2). Most of the production results were lower in 2005 than in 2004. When converted to the surface unit, it was characterised by high values – 104.52 mg C m^{-2}·h^{-1} in 2004, higher than those achieved for the mesotrophic littoral of lake Piaseczno (55.05 mg C m^{-2} h^{-1} in 1989) [Czernaś 2001]. This could result from high nitrate concentrations, from 0.15 mg dm^{-3} at 2.5 m depth to 0.20 at 5 m depth. According to Wetzel [1983], lakes with production values of 250–1000 mg C· m^{-2}·day^{-1} are considered as mesotrophic, whereas above 1000 as eutrophic. Taking this into considerations, Lake Krasne shows a eutrophic character.

Similarly, chlorophyll *a* concentrations were quite high, ranging from 12.21 mg dm^{-3} at 2.5 m depth in 2005 to 16.56 at 0.5 m depth in 2004 (Tab. 2). Average value for the 0–5 m water profile amounted to 16.25 mg dm^{-3} in 2004 and 13.65 in 2005, whereas mean value for both experimental years was 14.95 mg dm^{-3} (Tab. 2). The surplus of chlorophyll *a* concentration results were higher in 2005 than in 2004. However, when converted to the surface area unit, it was characterised by high values: from 10.13 mg m^{-2} in 2005 to 12.42 in 2004; its concen-

Table 1. Values of selected physicochemical parameters of pelagic zone water in Lake Krasne in 2004–2005*

Parameter	Unit	Depth in m		
		0.5	2.5	5
Conductivity	μS cm^{-1}	246	245	252
Color	mgPt dm^{-3}	natural	natural	natural
pH		7.75	7.68	7.25
Oxygen	O_2 dm^{-3}	7.43	4.67	3.99
Dry residua	mg dm^{-3}	176.5	172	200.5
Turbidity	NTU	0.68	0.6	3.35
COD_{Mn}	μgO_2 dm^{-3}	6	6.1	6
Ca	Ca^{2+} mg dm^{-3}	43.69	43.29	51.7
Mg	Mg^{2+} mg dm^{-3}	8.51	8.27	8.27
Na	Na^{+} mg dm^{-3}	8.05	8.05	8.8
K	K^{+} mg dm^{-3}	1.95	1.95	2.045
NH_4-N	NH_4^{+} mg dm^{-3}	0.11	0.08	0.087
NO_2-N	NO_2^{-} mg dm^{-3}	< 0.01	< 0.01	0.07
NO_3-N	NO_3^{-} mg dm^{-3}	0.16	0.15	0.2
Cl	Cl^{-} mg dm^{-3}	16.3	16.3	16.3
SO_4	SO_4^{2-} mg dm^{-3}	23.45	21.6	27.98
PO_4-P	PO_4^{3-} mg dm^{-3}	0.05	0.01	0.01

* Chemical analyses were carried out in Chemical Laboratory of Main Mining Institute in Lublin.

Table 2. Values of phytoplankton primary production in summer in pelagic zone of Lake Krasne in 2004–2005

	Year	Depth / Unit	0.5 m	2.5m	5.0 m	Mean	n	Stand. dev.
Primary production	2004	mg O_2 $dm^{-3}h^{-1}$ mg C $m^{-2}h^{-1}$	0.67 104.52	0.58 452.40	0.16 249.60	0.47 268.84	12 12	0.27
	2005	mg O_2 $dm^{-3}h^{-1}$ mg C $m^{-2}h^{-1}$	0.53 82.68	0.38 296.40	0.11 171.60	0.34 183.56	10 10	0.21
	mean two-years old	mg O_2 $dm^{-3}h^{-1}$ mg C $m^{-2}h^{-1}$	0.60 93.60	0.48 374.40	0.14 210.60	0.41 226.20	11 11	
Chlorophyll *a*	2004	mg dm^{-3} mg m^{-2}	16.56 12.42	15.63 39.08	16.55 82.75	16.25 44.75	12 12	2.92
	2005	mg dm^{-3} mg m^{-2}	13.50 10.13	12.21 30.53	15.25 76.25	13.65 38.97	10 10	2.15
	mean two-years old	mg dm^{-3} mg m^{-2}	15.03 11.27	13.92 34.80	15.90 79.50	14.95 414.86	11 11	
TSI	2004	TSI_{SD} $TSI_{Chl\,a}$				50.04 57.90		
	2005	TSI_{SD} $TSI_{Chl\,a}$				49.47 56.20		
Ass. numb.	2004 2005 mean two-years old	Pr.p./chl Pr.p./chl Pr.p./chl				6.01 4.71 5.36		

tration was over twice as high as that reported for the mesotrophic littoral of Lake Piaseczno (6.18 mg m^{-2} in 1987) [Czernaś and Serafin 2007].

Wojciechowska and Solis [2009] reported abundant presence of algae from *Chlorophyta* phylum in spring seasons of 2006–2007, while *Cyanophyceae* phylum, with such species as *Limnothrix redekei*, *Planktolyngbya limnetica*, and *Psudoanabena limnetica*, dominated in the summer. In the summer, chlorophyll *a* concentration reached the level of 23.2 in the metalimnion, while only 9.5 mg dm^{-3} in the epilimnion. Relatively low water visibility values (about 2 m) confirm great share of phytoplankton in water profile up to 5 m depth. Measurements performed by WIOŚ [2008] revealed that chlorophyll *a* content changed from 11.5 mg dm^{-3} in 2000 to 8.60 in 2004. It is characteristic that its high value (20.1 mg dm^{-3}) was again recorded in 2008. On the basis of chlorophyll *a* concentration, Wetzel [1983] divided lakes into mesotrophic with 2–15 mg m^{-2} vs. eutrophic with 15–500. In view of that, and on the basis of the two-year mean value (41.48 mg m^{-2}), Lake Krasne should also be considered as eutrophic or between eutrophic and mesotrophic.

The lake's trophy level can be determined on the basis of calculated coefficients such as assimilation number and Carlson's trophy indices. Ichimura [1978] defined that assimilation number (gross primary production in mg C m^{-2} h^{-1}/chlorophyll *a* content in mg m^{-2} ratio) within 0.1–1 range indicates oligotrophy, 1–2 mesotrophy, while above 2 eutrophy. All assimilation number values in Lake Krasne were, high reaching up to 4.71 in 2005 and 6.01 in 2004 at mean value for both experimental years of 5.36 (Tab. 2). However, the lower level of assimilation number in 2005 should be kept in mind. Indices of trophy status for water visibility and chlorophyll *a* concentrations were calculated with the help of Carlson's formula [1977]. Calculated values of TSI_{SD} were 50.04 in 2004 and 49.47 in 2005; $TSI_{Chl\ a}$ amounted to 57.9 and 56.2, respectively. All above indices were greater than 55, which, according to Carlson, indicated the eutrophic character of the lake (Tab. 2).

Summarising, it should be stated that connecting deep lakes with stabilised self-regulating mechanisms to melioration systems or converting them into retention reservoirs results in disturbance of these processes, and in consequence degradation of lake ecosystem.

CONCLUSIONS

1. The analyses of selected physicochemical parameters carried out in 2004–2005 qualify the water of Lake Krasne to the 1st purity class, except for COD_M and nitrate concentration.

2. On the basis of phytoplankton productivity, assimilation number, and Carlton's coefficients (TSI_{SD} and $TSI_{Chl\ a}$), Lake Krasne should be classified as eutrophic or between eutrophic and mesotrophic type.

3. The disconnection of the lake from the melioration system contributed to slow, gradual improvement of water quality.

REFERENCES

Carlson R.E., 1977. A trophic state index for lakes. Limnol. Oceanogr. 22, 361–369.

Czernaś K., 2001. Productivity of the psammic algal communities in the near-shore zone of mesotrophic Lake Piaseczno (Easter Poland). Water Qual. Res. J. Canada, 36, 3, 537–564.

Czernaś K., Serafin A., 2007. Changes in phytoplankton productivity in the pelagic zone of the mesotrophic Piaseczno Lake in 1987–1989 and 2001–2003. Oceanol. Hydrobiol. Stud. V, XXXVI, 210–212.

Decree of Ministry of Environment from 2004. Dz. U. No 32, on classification for presenting the status of surface and underground waters.

Harasimiuk M., Michalczyk Z., Turczyński M., 1998. Jeziora Łęczyńsko-Włodawskie. UMCS Lublin, pp. 176.

Hermanowicz W., Dojlido W., Dożańska W. Koziorowski B., Zerbe J., 1999. Physicochemical determination of water and sewage. Arkady. Warszawa, pp. 556.

Girsztowtt, 2002. Aqueous-legal statement for Lake Krasne. Polish Angling Association, Lublin.

Ichimura S., 1968. Phytoplankton photosynthesis. Algae, man and the environment. Syracuse.

Kajak Z., 2001. Hydrobiology – Limnology. Ecosystems of Inland Waters. PWN, Warszawa.

Nusch AE., 1980. Comparison of different methods for chlorophyll and phaeopigment determination. Arch. Hydrobiol. Beih. Ergebn. Limnol. 14, 14–36.

Radwan S., Podgórski W., Kowalczyk Cz., 1971. A contribution to the hydrochemistry of the Łęczna and Włodawa Lake District. Part. I. Mineral relations. Annales UMCS, sec. C, v. XXVI, 13, 155–168.

Report on Environment Status. WIOŚ Lublin, 2008.

Serafin A., Czernaś K., 2003. Seasonal changes in primary production and chlorophyll concentration of algae in pelagial and shore zone of mesotrophic Lake Piaseczno in 2001–2002. Acta Agrophisica, 1(3), 521–527.

Stricland J.D.H., 1960. Measuring the production of marine phytoplankton. Bull. Fish. Res. Bard Canada, 125, 1–182.

Vollenweider RA., 1969. A manual on methods for measuring primary production in aquatic environments. Oxford–Edinburgh, Blackwell (IBP Handbook No. 12).

Wetzel R.G., 1983. Limnology. Mc Graw-Hill Book Company Inc. pp. 538.

Wojciechowska W., Solis M., 2009. Pro- and eucaryotic algae at lakes of Łęczyńsko-Włodawskie District. KUL, Lublin.

PRODUKTYWNOŚĆ PIERWOTNA FITOPLANKTONU W PELAGIALU JEZIORA KRASNE NA POJEZIERZU ŁĘCZYŃSKO-WŁODAWSKIM, PO ODŁĄCZENIU DOPŁYWU WÓD Z KANAŁU WIEPRZ-KRZNA

Streszczenie. W latach 2004–2005, w okresie lata badano produktywność pierwotną fitoplanktonu strefy pelagialu Jeziora Krasne, które przez ponad 30 lat włączone było w system Kanału Wieprz–Krzna, a od roku 2000 zostało od niego odcięte. Wcześniej jezioro było zaliczane do typu mezotroficznego. Produkcję pierwotną brutto mierzono metodą tlenową, a koncentrację chlorofilu *a* oznaczano metodą alkoholową. Wartości produkcji pierwotnej fitoplanktonu i stężenia chlorofilu *a* w wodzie były wysokie, wartości współczynnika TSI_{SD} i $TSI_{Chl\ a}$ wskazywały na żyzny charakter wody tego jeziora. Jednocześnie notowano systematyczną poprawę jakości wody w porównaniu z rokiem poprzednim.

Słowa kluczowe: jeziora, produkcja pierwotna, chlorofil *a*, fitoplankton, TSI_{SD}, $TSI_{Chl\ a}$, liczba asymilacyjna, eutrofizacja