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VARIATIONS IN THE N:P RATIO IN THE SOLINA RESERVOIR ECOSYSTEM DURING 1999–2000

The results of investigations carried out within the area of the Solina reservoir and its drainage basin during the period of 1999–2000 are presented. On the basis of analytic measurments of the total nitrogen and the total phosphorus concentrations in the reservoir and its tributaries the N:P ratio was evaluated. It was found that phosphorus could be considered the factor that limited eutrophication process in almost all period being investigated. Only in September and October, nitrogen was the limiting factor. The values of N:P ratio decreased from 60:1 in 1990 to 40:1 in 2000.

1. INTRODUCTION

The loading of surface waters with biogenic compounds is mainly dependent on the type of drainage basin, soil, plant cover and intensity of land use. Hydrological and meteorological conditions, especially in mountainous countries with relatively substantial superficial run-off, are also of a great importance (KAJAK [6], ARBUCKLE and DOWNING [1]). The nitrogen and phosphorus compounds that flow into rivers and lakes, both in mineral form and as an organic matter, undergo decomposition, enriching the waters with nutrients. Eutrophication means an initial moderate increase of biological production, but after exceeding a certain limit it leads to many undesirable effects. This is clearly exemplified by the influence of phosphate content on an excessive growth of phytoplankton (algal blooms) and blue-green algae, whose decomposition is associated with the production of toxic compounds (KAJAK [6], GUILFORD and HECKY [5], NALEWAJKO [8]).

Carbon is the most important element in biological production. However, under natural conditions it occurs in such excess (DOJLIDO [2], GARCIA-RUIZ et al. [3]) that in the assessment of water productivity and its limitation by given element, the N:P ratio has been adopted. The most suitable proportion between nitrogen and phospho-

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rus lies in the range from 16:1 to 20:1 (DOJLIDO [2]). If the N:P ratio is less than 20:1, nitrogen determines the eutrophication process, and if this ratio is higher than 50:1, phosphorus determines the process. Between these values, both elements are uniformly exhausted. However, interpretation this phenomenon is not univocal (GOPHEN [4], ARBUCKLE and DOWNING [1]). Monitoring of both nitrogen and phosphorus concentrations in the reservoir is necessary and important for a proper reservoir management (STARMACH et al. [11], TOMASZEK and CZERWIENIEC [12]).

2. AREA OF INVESTIGATION

The Solina reservoir (figure 1) came into existence in 1968 as a result of damming up the San River water by a concrete dam. The reservoir is the biggest dam water basin in Poland in terms of volume (502 mln m^3) and also the deepest one (max 60 m, on average 22 m). The basin occupies the area of 22 km^2. A variable coastline is its typical feature, and its length along the San River midstream reaches 21.4 km. Natural water-courses, i.e. rivers and streams, are the basin tributaries. All of them are mountainous rivers with large slope and erosive character. The tributaries as typical mountainous streams have sudden freshet after heavy rains. Under those circumstances all pollutants and soil material in the area of drainage basin are intensively washed out. The tributaries differ in their lengths, areas of percolation and mean flows.

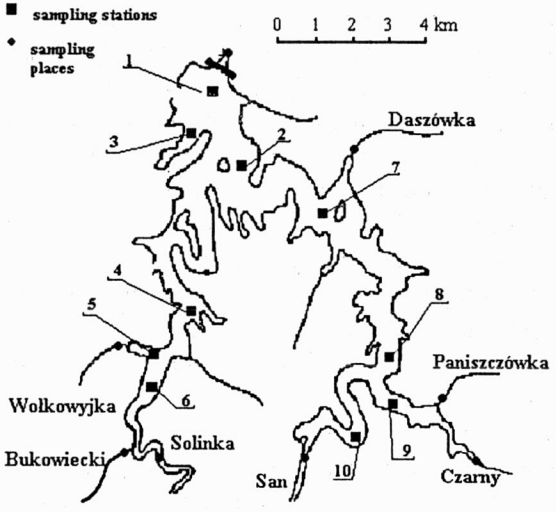

Fig. 1. The Solina reservoir. Points of water sampling

Overall drainage basin occupies the area of 1174,5 km^2. It is dominated by forests, meadows and pastures. Area used as arable land is very small. The drainage basin is

poorly populated. Buildings are mainly found in valleys near the river and stream estuaries. There are no industrial plants. Most of the resorts have recreational character with leisure centers and bungalows.

3. METHODS

The contents of nitrogen and phosphorus compounds were determined from March 1999 to November 2000 in seven points localized in the estuaries of seven tributaries, ten points localized in the reservoir and one at the basin outflow from the reservoir (figure 1). Samples were being collected 1–2 times per month.

4. RESULTS AND DISCUSSION

All results obtained are collected in table 1 and table 2. The lowest value of N:P ratio in all tributaries of the Solina reservoir ranged from 34:1 to even 5:1 both during summer and autumn periods, on an average it reached 19:1. We assumed that this time nitrogen was the factor limiting eutrophication. During other seasons of both years the ratio was relatively high and we had to claim that the progress of eutrophication in spring was closely associated with the limiting phosphorus content. Figure 2 shows seasonal variation of the N:P ratio in the San River, which supplies the reservoir with about 60% of total nitrogen and phosphorus and for this reason has decisive impact on water purity and the values of the N:P ratio in all tributaries.

Table 1

N:P ratio measured in the tributaries of the reservoir and at its outflow

Date	The San	The Solinka	The Czarny	The Panisz-czówka	The Wołko-wyjka	The Daszów-ka	The Buko-wiecki	Mean inlet	Outlet
1	2	3	4	5	6	7	8	9	10
29 March 1999	11	73	19	32	13	18	57	32	29
26 April 1999	38	31	55	28	11	31	43	34	33
18 May 1999	26	152	48	60	32	8	44	53	34
10 June 1999	28	6	54	36	12	13	41	27	126
01 July 1999	51	56	66	47	27	79	39	52	44
20 July 1999	60	57	84	62	43	77	42	61	20
09 August 1999	59	13	48	48	20	35	63	41	24
19 September 1999	18	22	21	19	10	10	59	23	6
28 October 1999	31	21	21	25	18	12	23	22	28
19 November 1999	31	21	57	27	57	22	32	35	28

1	2	3	4	5	6	7	8	9	10
10 December 1999	21	69	68	38	30	13	19	37	85
14 January 2000	24	96	55	44	40	16	22	42	48
11 February 2000	43	63	62	40	53	27	26	45	37
17 March 2000	47	66	77	58	83	182	65	83	39
21 April 2000	64	34	38	129	13	44	36	51	19
18 May 2000	126	40	82	63	75	199	43	90	139
26 May 2000	88	58	68	95	75	75	47	72	55
07 June 2000	35	48	82	112	6	47	19	50	55
28 June 2000	42	46	69	52	75	164	59	72	37
15 July 2000	24	17	35	28	12	14	13	20	20
28 July 2000	30	22	27	32	18	31	19	26	22
16 August 2000	10	14	10	24	9	34	9	16	11
19 August 2000	18	16	33	31	11	25	12	21	16
17 September 2000	13	5	30	24	8	13	8	14	9
18 October 2000	31	19	21	27	18	12	10	20	17
06 November 2000	21	69	68	42	30	14	22	38	13
Mean	36	45	48	46	26	40	33	41	35
Max	126	152	84	129	83	199	65	90	139
Min	10	5	10	19	6	8	8	14	6
SD	25.8	35.7	23.8	28.4	21.7	52.9	18.3	22.8	31.2

Table 2

N:P ratio measured in superficial water of the Solina reservoir

No. of sampling points	1	2	3	4	5	6	7	8	9	10	Mean
20 July 1999	39	38	31	41	44	52	67	50	67	56	49
09 August 1999	32	35	24	42	21	15	32	42	40	51	33
16 July 2000	45	24	33	48	12	16	56	52	43	13	33
18 August 2000	35	15	9	21	11	14	24	22	20	18	19
17 September 2000	23	17	24	17	12	13	10	24	12	11	16
18 October 2000	21	11	24	14	18	6	18	33	25	25	20
06 November 2000	14	11	9	21	23	28	12	22	29	16	18
Mean	30	22	22	29	20	21	31	35	34	27	20
Max	45	38	33	48	44	52	67	52	67	56	44
Min	14	11	9	14	11	6	10	22	12	11	11
SD	11	11	10	14	12	15	22	13	18	19	12

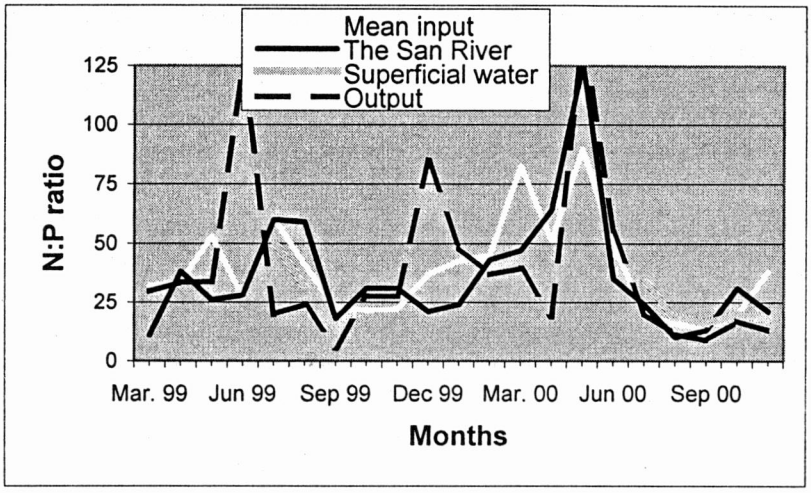

Fig. 2. Seasonal variations of N:P ratio

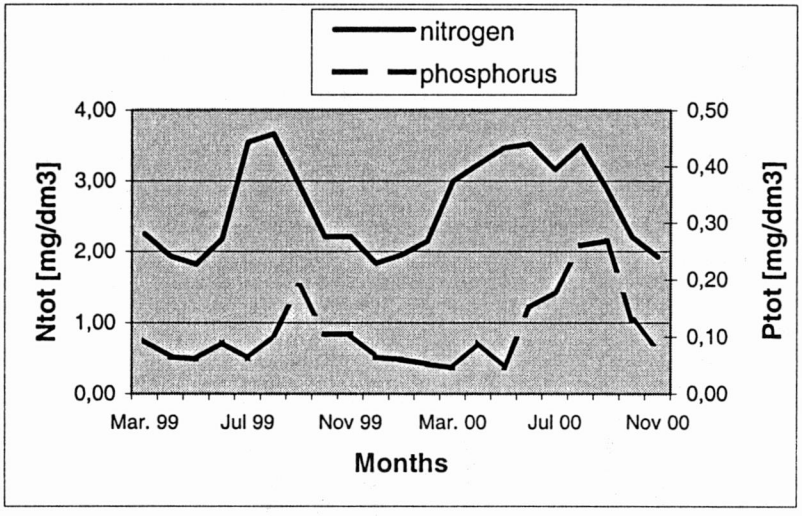

Fig. 3. Seasonal variations of total nitrogen and total phosphorus concentrations in the tributaries of the Solina reservoir

The diagram shows also that variations of the average N:P ratio for all tributaries are similar to variations of the N:P ratio for the greatest tributary mentioned. From March 1999 to May 2000 the N:P ratio determined for the outflow from the reservoir varied in inverse proportion to this ratio in the tributaries (figure 2). The increase in the N:P ratio in the tributaries was being accompanied with the decrease in the N:P ratio in the reservoir outlet. From the spring 2000 the trends observed were similar both in the outlet and in

tributaries. The results obtained from the analysis of the samples of surface water of the reservoir confirm that N_{tot} and P_{tot} concentrations and hence the N:P ratio are similar to these measured at the outflow (figure 2). This allows the statement that nitrogen content is the factor responsible for eutrophication process during late summer and autumn.

Figure 3 shows the differences between total concentrations of nitrogen and phosphorus in particular months of the experimental period. In the water of the reservoir tributaries, the increase in the total phosphorus concentration, even above 0.2 mg P/dm^3, was being observed from June to October both in 1999 and 2000. Intensive food growing in the drainage area and the height of the tourist season seem to explain this phenomenon. Total nitrogen concentrations (N_{tot}) followed this pattern, but their increase was registered two or three months earlier. Maximum N_{tot} concentrations exceeded 3.5 mg/dm^3 and were recorded in summertime of both years. During September and October when nitrogen content was the determining factor, phosphorus concentrations were still the highest, whereas nitrogen concentrations rapidly decreased.

Table 3

Comparison of mean loads (10^3 kg/year) of nutrients during both 1989–1990 (PŁUŻAŃSKI et al. [10])] and 1999–2000 periods

Nutrient	Year	The San	The Solinka	The Czarny	The Paniszczówka	The Wołkowyjka	The Daszówka	The Bukowiecki	Sum	Cs*
N_{total}	1989–90	1526.6	793.7	236.5	50.7	76.4	84.1	44.41	2812.36	2.84
	1999–00	1771.4	584.6	269.8	41.8	92.3	42.8	5.4	2808.17	2.45
P_{total}	1989–90	23.64	12.17	3.23	0.64	2.33	2.66	1.26	45.93	0.05
	1999–00	66.57	25.13	6.58	1.04	15.82	2.09	0.08	117.32	0.14

*Concetrations on surface of the reservoir area.

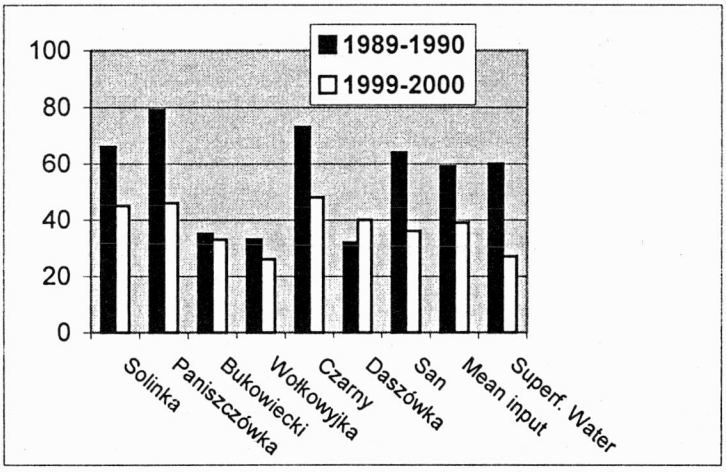

Fig. 4. Comparison of the N:P ratios from 1999–2000 to 1989–1990 periods

The results described were compared to the results of similar investigations conducted in 1989–1990 (table 3). The earlier investigations revealed that in this period, the phosphorus concentrations were being maintained on limiting level in all points analyzed. Our observations showed that the N:P ratio in almost all tributaries and also in the reservoir decreased significantly during last ten years (figure 4). The average N:P ratio for all tributaries, which was about 60:1 in 1990, was reduced approaching 40:1, while this ratio measured in reservoir was reduced more considerably, i.e. from 60:1 to 27:1.

The growth of algae was determined in such a dramatic way by nitrogen concentration, because a significant increase in phosphorus concentrations took place (table 3). Whereas the nitrogen loadings were maintained on a steady level of 2800 t/year, phosphorus loadings increased twice from 46 t/year to 117 t/year in the same period.

5. SUMMARY

1. Phosphorus content was the factor limiting eutrophication process in the Solina reservoir ecosystem during almost all the year. However, in autumn months, the nitrogen was the limiting factor.

2. The increase in the N:P ratios in tributaries was accompanied with the decrease in the N:P ratio in the reservoir outlet. An efficient nitrogen retention in the reservoir was responsible for this phenomenon.

3. The lowest values of the N:P ratio were registered in the Bukowiecki and the Wołkowyjka tributaries, whose water proved to be relatively highly polluted (PŁUŻAŃSKI [9], KOSZELNIK et al. [7]).

4. Comparison of the current results to similar data obtained ten years ago allows the conclusion that the N:P ratio in almost all tributaries and in the reservoir has considerably decreased during these years.

REFERENCES

[1] ARBUCKLE K.E., DOWNING J.A., *The influence of watershed land use on lake N:P in a predominantly agricultural ladscape*, Limnology and Oceanography, 2001, 46(4).

[2] DOJLIDO J.R., *Chemia wód powierzchniowych*, Wydawnictwo Ekonomia i Środowisko, 1995.

[3] GARCIA-RUIZ R., LUCENA J., NIELL F.X., *Seasonal and vertical variations in the C:P ratio in an Eutrophic P limited Reservoir* (*La Concepción, South Spain*), Intrnat. Rev. Hydrobiol., 1998, 83.

[4] GOPHEN M., *Prediction of N_2-fixing cyanobacteria blooms in lake Kinnert (Israel) based on N and P balance,* Verh. Internat. Verein. Limnol., 2000, 27(3).

[5] GUILDFORD S.J., HECKY R.E., *Total nitrogen, total phosphorus, and nutrient limitation in lakes and oceans: Is there a common relationship?* Limnology and Oceanography, 2000, 45(6).

[6] KAJAK Z., *Hydrobiologia – Limnologia. Ekosystemy wód śródlądowych*, PWN, Warszawa, 1998.

[7] KOSZELNIK P., TOMASZEK J., *Zasilanie solińskiego zbiornika zaporowego związkami biogennymi – bilans masowy*, Konferencja Rzeszowsko–Lwowsko–Koszycka, Rzeszów, 2000.

[8] NALEWAJKO Cz., MURPHY T.P., *Effects of temperature, and availability of nitrogen and phosphorus on the abundance of Anabaena and Microcystis in Lake Biwa, Japan: an experimental approach*, Limnology, 2001, 2.

[9] PŁUŻAŃSKI A., *Nutrients load in small mountain watersheds of Solina reservoir*, Ekologia Polska, 1990, 38.

[10] PŁUŻAŃSKI A., PÓŁTORAK T., TOMASZEK J., GRANOPS M., ŻUREK R., DUMNICKA E., *Charakterystyka limnologiczna zbiorników kaskady górnego Sanu. Funkcjonowanie ekosystemów wodnych, ich ochrona i rekultywacja. Ekologia zbiorników zaporowych i rzek*, Materiały CPBP 04.10, SGGW, AR, Warszawa, 1990.

[11] STARMACH K., WRÓBEL S., PASTERNAK L., *Hydrobiologia – Limnologia*, PWN, Warszawa, 1970.

[12] TOMASZEK J.A., CZERWIENIEC E., *Sedimentation, sediment oxygen demand and eutrophication in Rzeszów man-made lake*, International Review of Hydrobiology, 1998, 83, 261–268.

ZMIANY STOSUNKU N:P W EKOSYSTEMIE ZBIORNIKA SOLIŃSKIEGO

Przedstawiono wyniki prac prowadzonych w zlewni zbiornika Solińskiego w latach 1999–2000. Określono stężenia azotu i fosforu ogólnego w zbiorniku i w jego dopływach, a następnie wyznaczono stosunek N:P. Przez większą część analizowanego okresu czynnikiem limitującym eutrofizację był fosfor. Wyjątkiem były miesiące jesienne, wrzesień i październik, kiedy tym czynnikiem stawał się azot. Zaobserwowano, że w ciągu ostatnich 10. lat wartości stosunku N:P zmalały od około 60:1 w 1990 r. do około 40:1 w 2000 r.

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