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PHYTOSOCIOLOGICAL AND ECOLOGICAL ANALYSIS OF LOWER SECTION OF THE KWACZA RIVER BEFORE RESTORATION (SLUPIA RIVER BASIN)

ANALIZA FITOSOCJOLOGICZNO-EKOLOGICZNA DOLNEGO ODCINKA RZEKI KWACZY PRZED RENATURYZACJĄ (DORZECZE SŁUPI)

Abstract: The 2.5 km long section of the Kwacza River (tributary of the Slupia River) was investigated in 2007 in terms of hydrochemistry and phytosociology. The aim was to assess the quality of river waters as well as to identify vegetation composition before the planned restoration of the river. Hydrochemical research was conducted four-times (spring, summer, autumn and winter) at the beginning and at the end of the studied river section. Additionally, hydrochemical measurements were performed in the Slupia River above the outlet of Kwacza in order to compare the results. Vegetation was studied according to the Braun-Banquet method and the results were presented in the form of phytosociological table.

The performed chemical analyses indicated that the river along its whole length had unclassified waters and the parameter which caused that situation was phosphorus content. Mineral forms of nitrogen over the vegetation period accumulated considerably due to biosorption in plants. The analysis of 174 phytosociological records revealed the presence of 15 phytocoenoses of *Potametea* and *Phragmitetea* classes, including seldom observed in Pomerania plant communities of *Ranunculion fluitantis* (*Callitricho-Batrachion*) alliance. The dominant position in the riverbed of *Sagittario-Sparganietum emersi* plant society as well as the dynamic development of *Elodeetum canadensis* were the result of water contamination which could further lead to elimination of valuable *Callitricho-Batrachion* plant communities of *Ranunculion fluitantis* alliance. The planned renaturization works should be conducted carefully due to the presence of legally protected plant species and natural habitats. First the water and sewage management should be regulated in the whole Kwacza drainage area.

Keywords: vegetation, river macrophytes, water hydrochemistry, renaturization, Kwacza River, tributary of Slupia River

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A river valley is a specific type of complex ecosystem with spatial continuity but also variability in transverse and longitudinal sections. Its structure is very rich, with considerable biological diversity [1, 2].

Phytosociological and ecological research of small Pomeranian rivers has been fragmentary so far, therefore their results can not be the basis of ecological state assessment according to the Water Framework Directive 2000/60/EC [3]. The investigations were focused on selected plant species, for example *Callitriche* sp. [4] or species of alliance *Ranunculion fluitantis* (= *Callitricho-Batrachion*) [5]. There is a lack of complex research on the ecology of river phytocoenoses in terms of their species composition, structure, distribution and dynamics.

The Slupia River with its tributaries is one of the main Pomeranian rivers, valuable from the natural point of view due to the presence of salmonid fish spawning grounds [6]. Therefore, the discussed area has been included in the European ecological network called Nature 2000 [7]. However, at the same time, it is a highly anthropogenically transformed river, particularly in its middle watercourse, which destabilizes the functioning of riparian ecosystems [8]. The Kwacza River, one of the largest tributaries of Slupia, was highly transformed at the beginning of the XX century. The applied regulation works mostly consisted in riverbed straightening and the application of weirs [8]. The water and sewage management in the discussed river basin has not been regulated so far. Transformations the riverbed as well as water contamination have caused changes in habitat conditions of river hydrobionts.

Therefore, the restoration works have been carried out since 2007 in the lower Kwacza River section. They constitute the part of research project "Protection of Atlantic salmon and migratory trout spawning grounds in the Slupia river basin", managed by the Slupia River Basin Landscape Park and financed by EkoFundusz. Restoration of the river consisted in the application of various deregulation solutions, which effects has been monitored. The biomonitoring includes various, interdisciplinary environmental analyses [9].

The aim of this study was to reveal macrophyte structure and its dependence on hydrochemical conditions in the outlet section of the Kwacza River, before restoration.

Material and methods

Study area

The Kwacza River is a left-sided tributary of the middle Slupia River and drains the area of 85 km^2. Its length is equal to 21 km. According to the physico-geographical division of Poland [10] Kwacza is located in the mesoregion Rownina Slupska (313.43) being a part of macroregion Pobrzeze Koszalinskie (313.4).

The hydrological regime of Kwacza is characterized by ground, rain and snow supply. Mean water flow is 0.97 $m^3 \cdot s^{-1}$. Unitary outflows from the drainage area are rather high compared with other rivers of the region and amount to 13 $dm^3 \cdot s^{-1} \cdot km^{-2}$. Water supply of the Kwacza River measured as annual outflow is equal to 34.89 mln m^3 with more than half (54 %) occurring in winter [11].

The Kwacza hydrographic network consists in small watercourses, often highly transformed by hydrotechnical works, particularly in the outlet section. Almost the whole river basin is meliorated. Riparian areas has been considerably drained and now are used as grassland [12]. The present structure of use of the river basin is predominated by arable areas, particularly in the upper and middle parts of the discussed basin [8].

The research included vegetation and hydrochemical analyses of Kwacza waters. 10 sampling profiles K1–K10 (Fig. 1) were located at the 2.5 km long outlet section of the Kwacza River, at sites the restoration works were planned [9]. In this study was used the results of hydrological research conducted within the framework of Kwacza restoration project [11]. Hydrochemical carting was performed 4 times (spring, summer, autumn and winter) in 2007 at 10 profiles located along the water course (Fig. 1). At each profile samples were taken from 3 sampling sites – by both river banks and in the middle of riverbed. In this study we only compared site K1 (beginning of the studied section) with K10 (end of the studied section). Additionally, hydrochemical analyses of Slupia waters above the outlet of Kwacza were performed (Table 1). The following physicochemical parameters were measured every three months using multi-parameter water quality sonde YSI 6600: water temperature, electrolytic conductivity (SEC), reaction (pH), redox potential (Eh), dissolved oxygen concentration, oxygen saturation, turbidity, chlorophyll content, dry residue, salinity as well as NH_4-N, NO_3-N and Cl concentrations. At the same time water samples were taken for the purpose of laboratory analyses, in which PO_4, total phosphorus, Ca, Na, K and Mg contents were determined using the appropriate methodology [13]. Water quality classification into 5 grades was performed according to the Decree of the Minister of Environment from the

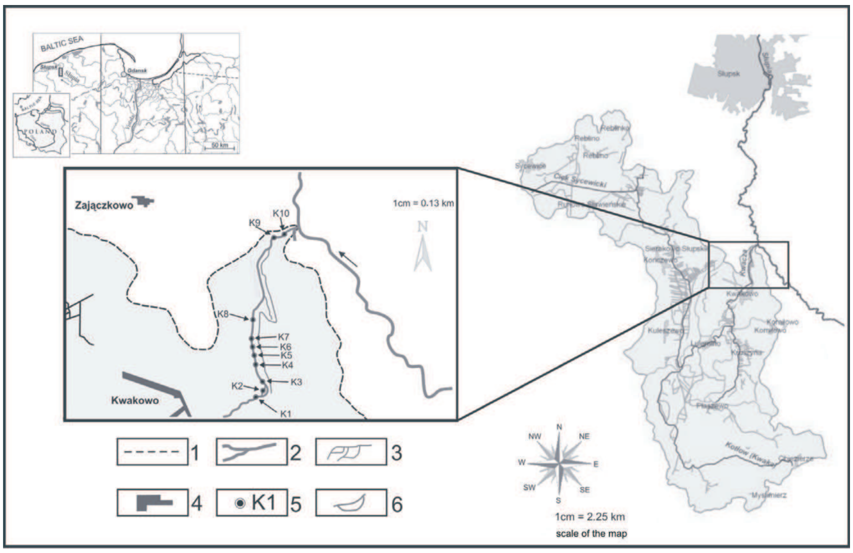

Fig. 1. The Kwacza River Basin and location of the research object: 1 – range of the river basin, 2 – rivers, 3 – melioration ditches, 4 – town/village, 5 – research sites – profiles, 6 – new riverbed sections

Table 1

Physico-chemical parameters of the Kwacza waters (sampling site K1 and K10) against the background of physicochemical characteristics of the Slupia River; ±SD – standard deviation; CV – coefficient of variability; II, III, IV, V denoted in superscript – classes of waters quality according to the Decree of the Minister of Environment [11, 14]

Parameter	Kwacza K 1					Kwacza K 10					Slupia (142 km)				
	Average	Max	Min.	±SD	CV	Average	Max	Min.	±SD	CV	Average	Max	Min.	±SD	CV
Water temperature [°C]	10.06	16.26	3.27	4.78	47	10.04	16.43	3.15	4.82	48	9.36	17.02	2.76	5.67	61
Electrolytic conductivity [$mS \cdot cm^{-1}$]	0.37	0.39	0.35	0.01	3	0.37	0.39	0.36	0.01	3	0.35	0.37	0.34	0.01	3
Reaction [pH]	7.72	8.03	7.45	0.21	3	7.73	8.29	7.34	0.28	4	7.72	8.08	7.05	0.35	5
Eh [mV]	153	210	66	46	30	154	198	125	31	20	157	212	82	53	34
Turbidity [NTU]	6.20	20.96	1.63	6.77	109	5.64	17.42	1.78	5.50	98	4.34	10.80	1.78	3.35	77
Chlorophyll [$\mu g \cdot dm^{-3}$]	8.34	13.47	3.85	2.98	36	7.88	13.95	4.01	3.16	40	7.73	19.89	3.51	6.19	80
Dissolved oxygen [$mg \cdot dm^{-3}$]	8.25	12.15	3.29	3.22	39	8.91	13.84	3.13	3.95	44	7.98	13.16	2.04	4.13	52
Oxygen saturation [%]	74.0	113.6	28.4	30.3	40.9	80.5	133.2	27.0	38.1	47.3	70.2	101.6	17.3	36.1	51.3
COD_{Cr} [$mg \cdot dm^{-3}$]	23.04^{III}	43.60	12.80	10.10	44	23.74^{III}	44.40	13.60	10.61	45	14.42^{II}	17.20	12.00	2.23	15
Dry residue [$mg \cdot dm^{-3}$]	0.24	0.25	0.23	0.01	3	0.24	0.25	0.24	0.01	3	0.23	0.24	0.22	0.01	3
Ash content [$mg \cdot dm^{-3}$]	0.18	0.19	0.17	0.01	4	0.18	0.19	0.17	0.01	4	0.17	0.18	0.16	0.01	4
Ca [$mg \cdot dm^{-3}$]	53.74	59.00	47.50	3.85	7	56.49	60.40	53.00	3.63	6	50.00	55.20	45.70	3.96	8
Na [$mg \cdot dm^{-3}$]	8.56	10.00	4.80	1.71	20	9.11	9.60	8.30	0.52	6	8.38	10.00	3.20	2.60	31
K [$mg \cdot dm^{-3}$]	2.49	2.80	2.00	0.33	13	2.56	3.00	2.10	0.29	11	2.33	2.70	2.00	0.33	14
Mg [$mg \cdot dm^{-3}$]	6.76	9.70	5.30	1.48	22	6.54	8.40	5.30	1.12	17	6.93	10.60	5.10	1.94	28
Cl [$mg \cdot dm^{-3}$]	24.99	44.37	11.47	12.73	51	25.40	35.23	15.38	8.55	34	19.03	29.80	9.00	8.60	45
HCO_3 [$mg \cdot dm^{-3}$]	119	128	114	5	5	119	128	114	5	5	137	185	114	30	22
NO_2-N [$mg \cdot dm^{-3}$]	0.030	0.069	0.007	0.024	80	0.037	0.086	0.012	0.028	77	0.022	0.058	0.004	0.023	103
NO_3-N [$mg \cdot dm^{-3}$]	0.70	0.99	0.20	0.25	35	0.70	1.15	0.26	0.27	38	0.38	0.79	0.13	0.21	57
NH_4-N [$mg \cdot dm^{-3}$]	0.15	0.67	0.01	0.22	151	0.13	0.66	0.01	0.22	169	0.15	0.58	0.01	0.20	137
N_{min} [$mg \cdot dm^{-3}$]	0.88	1.10	0.71	0.13	15	0.87	1.18	0.68	0.18	21	0.55	1.01	0.18	0.34	61
PO_4-P [$mg \cdot dm^{-3}$]	0.28^{II}	0.37	0.21	0.07	25	0.28^{II}	0.43	0.20	0.09	33	0.15	0.21	0.11	0.04	30
P_{total} [$mg \cdot dm^{-3}$]	1.18^{V}	1.78	0.76	0.37	32	1.04^{V}	1.56	0.64	0.35	34	0.83^{IV}	1.51	0.25	0.49	60

Table 2

Vegetation of the outlet section of the Kwacza River before restoration

Cl. *Potametea* R.Tx. et Prsg 1942
O. *Potametalia* Koch 1926
All. *Potamion* Koch 1926 em. Oberd. 1957
1. Ass. *Elodeetum canadensis* (Pign. 1956) Pass. 1964
All. *Ranunculion fluitantis* Allorge 1922
2. Ass. *Ranunculetum aquatilis* (Sauer 1937) Géhu 1961
3. Ass. *Ranunculo-Sietum erecto-submersi* Oberd. 1957 em. Müll. 1977
4. Comm. *Callitriche cophocarpa* (= *Callitriche polymorpha*)
5. Ass. *Beruletum submersae* Roll 1938
Cl. *Phragmitetea* R.Tx. et Prsg 1942
O. *Phragmitetalia* Koch 1926
All. *Phragmition* Koch 1926
6. Ass. *Sagittario-Sparganietum emersi* R.Tx. 1959
7. Ass. *Sparganietum erecti* Roll 1938
8. Ass. *Phragmitetum australis* (Gams 1927) Schmale 1939
9. Ass. Zespół *Glycerietum maximae* Hueck 1931
All. *Magnocaricion* Koch 1926
10. Ass. *Iridetum pseudacori* Eggler 1933
11. Comm. *Scirpus sylvaticus*
12. Ass. *Caricetum ripariae* Soó 1928
13. Ass. *Caricetum acutiformis* Sauer 1937
14. Ass. *Phalaridetum arundinaceae* (Koch 1926 n.n.) Libb 1931
All. *Sparganio-Glycerion fluitantis* Br.-Bl. et Siss. in Boer 1942
15. Ass. *Glycerietum fluitantis* Wilzek 1935

Syntaxonomic unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Number of species occurrence	Species cover coefficient
Number of records in the table	5	9	15	15	8	93	5	5	5	5	5	1	1	1	1		
Number of species in the table	6	7	24	15	13	26	12	10	11	8	16	3	4	4	6		
Average number of species in the record	3	3	7	3	3	3	5	6	4	2	5	3	4	4	6		
Min. number of species in the record	2	1	3	1	2	1	1	5	2	2	4	3	4	4	6		
Max number of species in the record	4	7	12	13	6	10	8	6	5	4	7	3	4	4	6		
Average cover [%]	74	49	59	62	52	40	61	51	69	67	70	86	15	75	100		
Minimum cover [%]	50	5	8	5	1	5	5	25	50	5	50	86	15	75	100		
Maximum cover [%]	100	90	100	100	100	100	100	80	90	100	80	86	15	75	100		
Record area [m^2]	2-25	2-16	4-36	1-64	1-9	5-80	5-20	5-100	2-16	1-4	1-25	25	25	25	25		
Ch. et. D. Ass.																	
Elodea canadensis Michx.	**V-5250**	III-506	I-70	II-273	•	II-130	•	•	I-10	•	•	•	•	•	•	43	227
Batrachium aquatile (L.) Dumort.	•	**V-3472**	**V-1417**	•	•	•	•	•	•	•	I-10	•	•	•	•	26	302
Callitriche cophocarpa Sendtn.	III-300	IV-867	**II-367**	**V-6467**	II-69	III-234	III-375	V-230	II-110		II-110		+	•	1	97	797
Berula erecta (Huds.) Coville	•	•	**V-2573**	•	**V-4094**	I-88	III-138	•	I-10	•	I-10	•	+	•	•	44	462
Sparganium emersum Rehmann	III-610	IV-400	IV-760	IV-280	II-131	**V-4019**	IV-388	V-800	III-300	•	III-600	+	+	•	•	143	2363
Sparganium erectum L. Emend. Rchb. s. str.	•	•	I-70	I-70	I-125	I-80	**V-4312**	II-210	•	I-100	•	•	•	•	•	21	164
Phragmites australis (Cav.) Trin. ex Steud.	•	•	•	•	•	•	•	**V-4900**	•	•	•	•	•	•	•	5	141

Table 2 contd.

Syntaxonomic unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Number of species occurrence	Species cover coefficient
Glyceria maxima (Hartm.) Holmb.	I-200	•	I-103	I-3	•	I-11	•	III-500	**V-6250**	•	•	•	•	•	•	15	215
Iris pseudacorus L.	•	•	I-33	•	I-125	I-12	•	•	•	**V-6700**	•	•	•	•	+	11	208
Scirpus sylvaticus L.	•	I-6	II-137	I-33	I-6	I-22	II-250	•	•	•	**V-750**	•	•	1	•	20	230
Carex riparia Curtis	I-100	•	•	•	•	•	•	•	•	•	•	**4**	•	•	•	2	39
Carex acutiformis Ehrh.	•	•	•	•	•	•	II-125	•	•	•	•	•	**5**	•	•	2	53
Phalaris arundinacea L.	I-10	•	II-77	I-33	I-6	I-3	II-250	•	•	•	•	•	•	**4**	•	15	53
Glyceria fluitans (L.) R. Br.	•	•	I-67	•	I-6	I-1	•	•	•	•	•	•	•	•	**4**	5	43
Ch. Cl., O., All. *Potametea*																	
Veronica beccabunga L.	•	•	I-10	I-37	•	I-2	•	•	I-200	•	•	•	•	•	•	9	11
Batrachium fluitans (Lam.) Wimm.	•	•	•	•	•	I-1	•	II-110	I-200	•	•	•	•	•	•	4	9
Butomus umbellatus L.	•	•	I-3	•	•	•	•	•	•	•	•	•	•	•	•	1	3
Callitriche verna L. Emend. Lönnr. s. str.	•	•	I-3	•	•	I-2	•	I-10	•	I-10	I-10	•	•	•	•	8	2
Potamogeton pectinatus L.	•	•	•	•	•	I-4	•	•	•	•	•	•	•	•	•	7	2
Ch. Cl., O., All. *Phragmitetea*																	
Alisma plantago-aquatica L.	•	•	I-3	I-37	•	I-14	•	•	I-10	I-100	I-10	•	•	•	+	15	15
Sium latifolium L.	•	•	I-37	•	I-62	I-6	II-12	•	•	•	•	•	•	•	•	7	10
Rumex hydrolapathum Huds.	•	•	I-70	•	•	•	•	•	•	•	•	•	•	•	+	3	6
Veronica anagallis-aquatica L.	•	•	•	I-33	•	I-3	•	•	•	•	•	•	•	•	•	6	4
Typha latifolia L.	•	•	•	•	•	I-1	•	•	•	•	I-100	•	•	•	•	3	3
Equisetum fluviatile L.	•	•	•	•	•	•	•	•	•	•	I-10	•	•	•	•	1	3
Comp.																	
Mentha aquatica L.	•	I-6	III-597	I-33	II-1062	I-36	II-12	•	I-100	I-10	II-110	+	•	+	•	32	130
Poa trivialis L.	•	•	II-207	I-3	II-131	I-18	•	•	•	•	II-210	•	•	•	•	17	40
Scrophularia umbrosa Dumort.	•	•	I-73	I-7	II-12	I-2	II-12	I-100	•	I-100	II-110	•	•	+	1	17	21
Lemna minor L.	•	I-56	II-80	•	•	I-5	II-12	III-30	I-100	•	•	•	•	•	•	13	17
Myosotis palustris (L.) L. emend. Rchb.	•	•	I-73	•	•	I-1	II-12	I-10	•	•	•	•	•	•	•	7	7

Table 2 contd.

Syntaxonomic unit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Number of species occurrence	Species cover coefficient
Solanum dulcamara L.	•	•	I-7	I-3	•	I-7	•	•	I-10	•	I-10	•	•	•	•	9	5
Lysimachia vulgaris L.	•	•	•	•	I-62	•	•	•	•	•	I-10	•	•	•	•	2	3
Equisetum pratense Ehrh.	•	•	•	•	•	•	•	•	•	•	I-10	•	•	•	•	1	3
Lycopus europaeus L.	•	•	•	•	•	I-1	•	•	•	•	•	•	•	•	•	1	3
Mentha arvensis L.	•	•	•	•	•	•	•	•	•	•	I-10	•	•	•	•	1	3
Poa palustris L.	•	•	•	I-3	•	•	•	•	•	•	•	•	•	•	•	1	3
Poa pratensis L. s. str.	•	•	•	•	•	•	•	•	•	I-10	•	•	•	•	•	1	3
Ribes nigrum L.	•	•	•	•	•	I-18	•	•	•	•	•	•	•	•	•	1	3
Rumex aquaticus L.	•	•	•	•	•	•	•	•	•	I-10	•	•	•	•	•	1	3
Symphytum officinale L.	•	•	I-3	•	•	•	•	•	•	•	•	•	•	•	•	1	3

11th of February 2004 on the classification used in surface and ground water quality assessment, guidelines for monitoring and the interpretation of results [14].

Vegetation research was performed in July 2007 along the 2.5 km long outlet section of the Kwacza River. For the purpose of biomonitoring, the detailed floristic lists were made at 10 sampling profiles located along the water course, at which restoration works were supposed to be performed [9]. At each profile there were 3 lists prepared, separately for 3 sampling sites. Apart from the selected profiles also all the distinct vegetation lobes were analysed. Altogether 174 phytosociological records were taken which later were presented in the form of synthetic table (Table 2). It included the number of phytosociological records, number of species, cover of herb layer and the area of vegetation lobes. The constancy degree and cover coefficient for a given plant species were calculated from at least 5 phytosociological records. Additionally the frequency of occurrence and cover coefficients for the consecutive species were given in the Table 2. The nomenclature was used according to Mirek [15]. The share of rare and endangered species was determined on the basis of the following studies by Zukowski and Jackowiak [16] and Jasnowska and Jasnowski [17]. The syntaxonomy of plant communities used was according to Matuszkiewicz [18] as well as Brzeg and Wojterska [19].

Results and discussion

Hydrochemical parameters and water quality

The Kwacza River is considerably influenced by anthropopression in terms of physico-chemical parameters, even more than the Slupia River. That results in higher concentrations of most of the factors connected with anthropogenic source of supply comparing to Slupia [11].

The analysis of concentrations of nitrogen mineral forms in the Kwacza River revealed that they accumulated by biosorption mainly in the river valley (buffering zone). The contents of NO_3-N at sites K1 and K10 were significantly lower than the average for the whole study period (ie 0.7 mg · dm^{-3}) and reached the level of 0.57 mg · dm^{-3}. The low content of nitrates is typical for eutrophic waters, when in summer nitrates are removed mainly by aquatic vegetation. Conducted study indicated the increase in nitrate concentration over winter both in Kwacza and Slupia Rivers and then the content of NO_3-N was higher at site K10 than at K1.

The concentration of NH_4-N over the study period varied considerably and showed the downward trend along the watercourse. The coefficient of variability (CV) for ammonium nitrogen at site K1 was high and equal to 151 % while at site K10 it reached 169 %. NH_4-N content was by around 12 % lower at K10 than at K1.

Among the other parameters analysed the attention should be paid to COD-Cr as an indicator of rate of biogeochemical processes. The level of COD at sites K1 and K10 reached on average 23 mg · dm^{-3} and varied between 12.80 and 44.40 mg · dm^{-3}. The section of the Kwacza River to be restored underwent higher fluctuations in COD (CV = 44–45 %) comparing with the Slupia waters (CV = 15 %).

The quality of Kwacza waters as regards most of the studied physicochemical parameters was rather good as the average values were slightly lower than thresholds for I class waters of very good quality. However, according to the Decree of the Minister of Environment [14] which introduced the five-grade scale, the quality of Kwacza waters was bad due to the concentration of total phosphorus which exceeded the threshold level for V class waters of bad quality. According to that decree, bad quality waters:

a) do not meet the requirements for surface waters used as the source of drinking water,

b) biological characteristics of such waters reveals changes consisting in the disappearance of considerable part of populations due to anthropopression.

As for the rest of the parameters, COD values decreased the Kwacza water quality down to III class waters of satisfactory quality while phosphates(V) to II class waters of good quality.

Vegetation

At the lower section of the Kwacza River were found 40 hydrophyte species which represented 21 families. Those families had various share of the consecutive species. The most abundant group were the families with singular species: *Alismataceae*, *Iridaceae*, *Potamogetonaceae*, *Typhaceae* and *Lemnaceae*. The remaining families were represented by 2–5 taxa. Vegetation in the Kwacza River was predominated by *Sparganium emersum*, *Callitriche cophocarpa*, *Berula erecta*, *Elodea canadensis* and *Batrachium aquatile*. Those species occurred most frequently and reached the highest cover coefficient values (Table 2). Rather small areas in the riverbed were covered by *Scirpus sylvaticus*, *Glyceria maxima*, *Iris pseudacorus*, *Sparganium erectum*, *Phragmites australis* and *Mentha aquatica*. One of the species – *Ribes nigrum* – was legally protected. As for rare and endangered species we observed *Butomus umbellatus* (peat land flora) and *Rumex aquaticus,* endangered in the area of West Pomerania and Greater Poland. The species typical of *Calitricho-Batrachion* rivers also occurred in Kwacza and those were: *Batrachium fluitans*, *Batrachium aquatile*, *Callitriche cophocarpa*, *Berula erecta*, *Veronica beccabunga*, *Veronica anagalis-aquatica* and *Butomus umbellatus* [18].

The Kwacza riverbed was inhabited by 15 phytocoenoses (plant societies and communities) belonging to 2 vegetation classes. Five of them were freshwater macrophyte communities of *Potametea* class while 10 belonged to rush communities with aquatic plants of *Phragmitetea* class (Table 2).

Phytosociological and ecological characteristics of selected plant communities

The *Sagittario-Sparganietum emersi* society was as key community in the studied river section. It formed low rushes on the riverbed at the depth not exceeding 1 m. Only one species (*Sparganium emersum)* typical of the society was always present. The average frequency of occurrence reached *Callitriche cophocarpa* while rather rarely appeared *Elodea canadensis*. The remaining species occurred seldom and among them the highest cover coefficient reached *Mentha aquatica*. The number of species in the studied lobes varied between 1 and 10 (3 on average) while their cover ranged from 4 to 100 % of the studied area (40 % on average) (Table 2).

The *Elodeetum canadensis* society formed submerged waterweed thicket, often 2–4 species aggregations at the river bottom, predominated by *Elodea canadensis*. *Sparganium emersum* and *Callitriche cophocarpa* reached the average frequency of occurrence. The rest of the species – *Glyceria maxima, Carex riparia* and *Phalaris arundinacea* – appeared rarely. The area of the studied lobes amounted to 2–25 m^2 while their coverage ranged between 50 and 100 % (74 % on average).

Considerable share of *Sagittario-Sparganietum emersi* phytocoenoses (93 lobes with the area of 5–80 m^2) as well as the presence of *Elodeetum canadensis* can be explained by point source inflow of nutrients, mainly nitrogen and phosphorus compounds. *Sparganium emersum* represents communities rather insensitive to contamination [18, 20, 21]. The presence of communities with the predominant role of *Elodea Canadensis* is typical for contaminated, eutrophic waters [18, 22, 23].

Phytocoenoses predominated by *Callitriche cophocarp* also covered considerable riverbed area. Smaller lobes (1–4 m^2) with *Callitriche cophocarpa* were oval or lenticular. *Sparganium emersum* was common as well, while the remaining species appeared rarely. Altogether we found 15 species in the studied lobes and their number varied between 1 and 13 (3 on average).

The *Beruletum submersae* society occurred in the coastal zone as well as in the deeper zones (submerged form *Berula erecta* fo. *submersa*). The studies lobes contained 13 species (3 on average) and rare species prevailed. As regards cover coefficient, some lobes were predominated by *Mentha aquatica*.

The *Callitricho-Batrachion* communities were represented by two plant societies – *Ranunculetum aquatilis* and *Ranunculo-Sietum erecto-submersi*. The *Ranunculetum aquatilis* society contained not large number of species, between 1 and 7 (3 on average), but *Batrachium aquatile* was present permanently. *Callitriche cophocarpa* and *Sparganium emersum* also occurred frequently. Average occurrence but high cover coefficient reached *Elodea canadensis*. In turn, the *Ranunculo-Sietum erecto-submersi* society consisted of larger number of species, between 3 and 12 (7 on average). *Batrachium aquatile* and *Berula erecta* were present permanently, opposite to *Callitriche cophocarpa.* As for the accompanying species, high coverage reached *Sparganium emersum* and *Mentha aquatica*.

Communities predominated by *Callitriche cophocarpa* and *Berula erecta* were probably the impoverished forms of *Callitricho-Batrachion* phytocoenoses from alliance *Ranunculion fluitantis* (= *Callitricho-Batrachion*), which occur in cool, clean and well oxygenated waters [18]. Regulation works in the past as well as the constant inflow of biogenes probably caused changes in the structure and distribution of the studied phytocoenoses. The presence of *Ranunculion fluitantis* communities depends on many factors [24]. According to Puchalski [5], the ecological factors that influence the structure and distribution of those communities are: mid climate conditions, hydrological stability of rivers, groundwater supply, light conditions, water transparency and the availability of biogenes (mainly nitrogen and phosphorus). One can conclude that the possible unavailability of biogenes for plants in the Kwacza River was compensated by the inflow from anthropogenic sources. The performed hydrochemical analyses revealed, that nitrogen compounds underwent biosorption by plants over the vegetation period.

Conclusions

1. The results of hydrochemical and phytosociological analyses are the basis of further ecological study after the planned restoration of the 2.5 km long section of the Kwacza River.

2. Synthetic analysis of vegetation indicated the presence of 15 syntaxa, both societies and communities. Among them there were *Callitricho-Batrachion* communities of *Ranunculion fluitantis* (*Callitricho–Batrachion*) alliance, rare in the Pomerania. They included the *Ranunculetum aquatilis* and *Ranunculo-Sietum erecto--submersi* societies.

3. The studied flora contained 40 vascular plant species. The rare and legally protected species were also present. Particular attention should be paid to the species typical of *Callitricho-Batrachion* rivers: *Batrachium aquatile, B. fluitans*, *Callitriche cophocarpa*, *Berula erecta*, *Veronica beccabunga*, *Veronica anagalis-aquatica*, *Butomus umbellatus*.

4. Chemical analyses of the Kwacza River indicated low water quality and the parameter which contributed to that situation the most was content of total phosphorus of anthropogenic origin. Mineral nitrogen forms over the vegetation period accumulated in macrophytes by biosorption. Further inflow of biogenes (mainly nitrogen and phosphorus) may cause the development of *Sparganium emersum* and *Elodea canadensis* phytocoenoses. They reveal high biomass production and considerable expansibility which can lead to the disappearance of valuable *Callitricho-Batrachion* communities of *Ranunculion fluitantis* alliance.

5. Restoration of the Kwacza River should be planned carefully due to the presence of legally protected plant species and natural habitats according to the Appendix I of the Habitat Directive. First the attention should be paid to the water and sewage management in the whole Kwacza river basin.

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ANALIZA FITOSOCJOLOGICZNO-EKOLOGICZNA DOLNEGO ODCINKA RZEKI KWACZY PRZED RENATURYZACJĄ (DORZECZE SŁUPI)

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Abstrakt: Na 2,5-kilometrowym odcinku rzeki Kwaczy (dopływ Słupi) przeprowadzono w 2007 roku badania hydrochemiczne i fitosocjologiczne. Celem badań było określenie jakości wód w rzece oraz rozpoznanie flory i roślinności makrofitów przed planowaną renaturyzacją rzeki. Badania hydrochemiczne przeprowadzono czterokrotnie (wiosna, lato, jesień i zima) na początku (K1) i na końcu badanego odcinka rzeki (K10). Dodatkowo, w celach porównawczych, wykonywano pomiary hydrochemiczne wód Słupi powyżej ujścia rzeki Kwaczy. Na całym odcinku rzeki badano roślinność metodą Braun-Blanquet, a wyniki zestawiono w formie syntetycznej tabeli fitosocjologicznej. Analizy chemiczne wykazały, że rzeka na całej długości prowadzi wody pozaklasowe, a parametrem obniżającym klasę jakości była zawartość fosforu. W okresie wegetacji mineralne formy azotu ulegały znacznej akumulacji w wyniku biosorpcji przez rośliny. Na podstawie analizy 174 zdjęć fitosocjologicznych stwierdzono w korycie rzeki 15 fitocenoz z klasy *Potametea* i *Phragmitetea*, w tym rzadko opisywane na Pomorzu zbiorowiska ze związku *Ranunculion fluitantis* (*Callitricho-Batrachion*): *Ranunculetum aquatilis*, *Ranunculo-Sietum erecto-submersi* i *Beruletum submersae*. Dominujący udział w korycie rzeki zespołu *Sagittario-Sparganietum emersi* oraz dynamiczny rozwój płatów *Elodeetum canadensis* jest efektem zanieczyszczania wód, co z czasem może doprowadzić do całkowitego wyparcia cennych zbiorowisk rzek włosienicznikowych ze związku *Ranunculion fluitantis*. Planowane prace renaturyzacyjne należy przeprowadzać z dużą ostrożnością ze względu na obecność prawnie chronionych gatunków roślin i siedlisk przyrodniczych. W pierwszej kolejności należy uporządkować gospodarkę wodno-ściekową w obrębie całej zlewni rzeki Kwaczy.

Słowa kluczowe: roślinność, makrofity rzeczne, hydrochemia wód, renaturyzacja, rzeka Kwacza, dorzecze Słupi