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BIOLOGICAL PROPERTIES OF SOIL CONTAMINATED WITH THE AURORA 40 WG HERBICIDE*

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K e y w o r d s: Aurora 40 WG, herbicides, enzymatic activity, soil microbial counts, spring barley, yield.

A b s t r a c t

The objective of this study was to determine the effect of the Aurora 40 WG herbicide on soil microbial counts, soil enzymatic activity and spring barley yield. Soil samples with the granulometric composition of loamy sand and sandy clay loam with pH_{KCl} 7.0 were used. The herbicide was applied at the optimal dose (recommended by the manufacturer) and at doses 2-, 4- and 40-fold higher than the recommended dose. Samples of uncontaminated soil served as control. In selected treatments, soil was mixed with basalt meal and finely ground spring barley straw (5 g kg^{-1}). On day 25 and 50 of the experiment, soil samples were analyzed to determine the counts of organotrophic bacteria, bacteria of the genus *Azotobacter*, Actinobacteria and fungi, and the activity levels of the following enzymes: *β*-glucosidase, arylsulphatase and catalase. The yield of spring barley dry matter was determined on the last day of the experiment.

It was found that soil contamination with the Aurora 40 WG herbicide led to an increase in the counts of organotrophic bacteria and fungi, and to a decrease in *Azotobacter* abundance. Arylsulphatase was most sensitive to increased contamination with the tested herbicide – its activity levels were lower in contaminated soil than in the control treatment. In most treatments. Aurora 40 WG applied in overdose stimulated the activity of *β*-glucosidase, whereas catalase exhibited the weakest response to the herbicide. When applied at the highest dose (40-fold higher than the optimal dose) Aurora 40 WG modified also spring barley yield.

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BIOLOGICZNE WŁAŚCIWOŚCI GLEBY ZANIECZYSZCZONEJ HERBICYDEM AURORA 40 WG

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S ł o w a k l u c z o w e: Aurora 40 WG, herbicyd, aktywność enzymatyczna, liczebność drobnoustrojów glebowych, plon, jęczmień jary.

A b s t r a k t

W pracy określono wpływ herbicydu Aurora 40 WG na liczebność drobnoustrojów, aktywność enzymów oraz plonowanie jęczmienia jarego. W badaniach wykorzystano dwie gleby o składzie granulometrycznym piasku gliniastego i gliny piaszczysto-ilastej o pH_{KCl} – 7,0. Środek chwastobójczy zaaplikowano w dawce optymalnej oraz 2-, 4- i 40-krotnie większej od technologicznej. Próbkę kontrolną stanowiła gleba niezanieczyszczona. Ponadto do gleby w odpowiednich obiektach dodano mączkę bazaltową i drobno zmieloną słomę jęczmienia jarego w ilości 5 g kg^{-1}. W 25 i 50 dniu trwania doświadczenia oznaczono liczebność bakterii organotroficznych, *Azotobacter*, promieniowców i grzybów oraz aktywność następujących enzymów: *β*-glukozydazy, arylosulfatazy i katalazy. W dniu likwidacji doświadczenia określono również plon suchej masy jęczmienia jarego.

Stwierdzono, że zanieczyszczenie gleby herbicydem Aurora 40 WG przyczyniło się do zwiększenia liczebności bakterii organotroficznych i grzybów oraz zmniejszenia liczebności *Azotobacter*. Na zwiększone zanieczyszczenie gleby testowanym preparatem najbardziej wrażliwa okazała się arylosulfataza, czego dowodem jest obniżenie jej aktywności w stosunku do gleby niezanieczyszczonej. Nadmierne ilości herbicydu Aurora 40 WG na ogół stymulowały aktywność *β*-glukozydazy, natomiast katalaza w najmniejszym stopniu reagowała na ten preparat. Zanieczyszczenie gleb testowanym środkiem chwastobójczym w dawce największej (40-krotnej) modyfikowało również plon jęczmienia jarego.

Introduction

Herbicides are highly effective and widely used weed killers characterized by different rates of degradation in soil. Herbicides, similarly as other biocides, contain various chemical substances which may pose a threat to living organisms. In most cases, their transformation occurs through hydrolysis, oxidation, photolysis and microbial degradation. The ability of microorganisms to metabolize chemical compounds is determined primarily by their structure and bioavailability (UZIAK and STENBRICH 2005).

Modern herbicides are applied at lower doses and become biodegraded more rapidly. However, when misused, they can affect the population size and species composition of soil-dwelling microbes, as well as the biochemical processes they are involved in (DIGGLE et al. 2003, RAHMANSYAH et al. 2009, VIG et al. 2008). The activity levels of soil microorganisms are affected by both the active ingredient of a herbicide and its degradation products which may be

more toxic than the original compound (ARIAS-ESTÉVEZ et al. 2008). Changes induced in the soil environment by stress factors, including herbicides, can be evaluated based, among others, on the abundance, biomass and enzymatic activity of various microbial groups. The activity of soil microorganisms is of outmost importance for soil health and quality, and it may serve as a guideline for environmental protection measures (SØRENSEN et al. 2003).

The aim of this study was to determine the effect of the Aurora 40 WG herbicide on soil microbial counts, soil enzymatic activity and spring barley yield.

Materials and Methods

A pot experiment was carried out to investigate the effect on the Aurora 40 WG herbicide on the biological properties of soil. The active ingredient of the tested herbicide is carfentrazone-ethyl at a concentration of 40%, which belongs to the aryl thiazolinone group. The dose recommended by the manufacturer is 50 g ha^{-1}. The experimental conditions have been described by BAĆMAGA et al. (2012). The experiment was performed in 4 replicates in two soils with a particle size of clay loam and sandy clay with pH_{KCl} – 7.0. Plant was cultivated barley varieties Orthega (12 plants per pot). The experimental variables were: herbicide dose in mg kg^{-1} soil DM: 0 (control), 0.017 (optimal), 0.033 (2-fold higher than the recommended dose), 0.066 (4-fold higher than the recommended dose), 0.664 (40-fold higher than the recommended dose); soil species: loamy sand and sandy clay loam; the type of neutralizing substance in the amount of 5 g kg^{-1} soil DM: basalt meal and finely ground spring barley straw; the date of soil sampling: experimental days 25 and 50.

The abundance of the following microbial groups was determined in soil samples by direct plate counting, in two times: bacteria of the genus *Azotobacter* – by the method proposed by FENGLEROWA (1965), organotrophic bacteria – as described by LÖCHNIS (1920) on nutrient agar with soil extract, Actinobacteria – on Küster and Williams' medium containing nystatin and actidion (PARKINSON et al. 1971), and fungi – on MARTIN'S medium (1950). The activity levels of the following soil enzymes were determined at the same time, in three replications: β-glucosidase, arylsulphatase and catalase – by the method proposed by ALEF and NANIPIERI (1998). The results were processed statistically by Duncan's multiple range test, and two-way and three-way ANOVA. All calculations were performed using STATISTICA software (2010).

Results and Discussion

The results of our study show that soil contamination with excessive quantities of the Aurora 40 WG herbicide upsets the natural balance of soil. The growth rate of soil microorganisms was determined not only by the herbicide dose, but also by soil species and the type of neutralizing substance (Table 1). The application of Aurora 40 WG at the highest dose (0.664 mg kg^{-1}) led to a 1.3-fold increase in the counts of organotrophic bacteria in sandy clay loam, and in loamy sand it stimulated the growth of organotrophic bacteria and fungi whose count increased 1.9-fold and 1.6-fold, respectively, in comparison with uncontaminated soil. The positive impact of this product on the multiplication of microorganisms could be due to supply them with organic compounds that are the source of many nutrients necessary for the growth and development of soil microorganisms. Some herbicides may contribute to the proliferation of microorganisms that have the ability to biodegrade these measures (Błaszak i in. 2011, Miloševiã, Govedarica 2002). The tested herbicide exerted an opposite effect on *Azotobacter* and Actinobacteria which were found in greatest abundance in uncontaminated soil. The application of Aurora 40 WG at the highest dose (0.664 mg kg^{-1}) decreased the counts of *Azotobacter* and Actinobacteria in loamy sand by 27.7% and 52.9%, respectively. In sandy clay loam, the population size of *Azotobacter* and Actinobacteria decreased 1.6-fold and 1.2-fold, respectively, relative to the control treatment. Miloševiã and Govedarica (2002) believe that the bacteria of the genus *Azotobacter* are the most sensitive to herbicides, and are therefore a reliable indicator of soil biodiversity. The growth rate of soil microorganisms was also affected by the granulometric composition of soil. All microbial groups were present in greater abundance in sandy clay loam than in loamy sand. The highest differences between those two soil types were observed with respect to the proliferation rate of *Azotobacter* whose count were 1.6-fold higher in sandy clay loam than in loamy sand. The microbiological properties of soil were also determined by the addition of neutralizing substances. In loamy sand, the neutralizing substances led to an increase in the counts of the analyzed microbial groups, in comparison with the control treatment. Different trends were noted in sandy clay loam. The addition of basalt meal stimulated the growth of Actinobacteria, while the addition of spring barley straw supported the development of fungi. Both neutralizing substances reduced the population size of the other microbial groups. The current results corroborate the findings of Wyszkowska (2004), Kucharski and Wyszkowska (2008) who observed a decrease in microbial populations when herbicides were applied in overdose. Radivojević et al. (2006) applied the herbicide atrazine at 8.40 and 80 mg kg^{-1} soil DM and reported that it initially inhibited the growth of bacteria,

Table 1

The effect of the Aurora 40 WG herbicide on soil microbial counts subject to soil species and the type of neutralizing substance (CFU 10^n kg^{-1} DM)

Herbicide dose [mg kg^{-1}]	Organotrophic bacteria x10^8		*Azotobacter* x10^3		Actinobacteria x10^8		Fungi x10^6	
	loamy sand	sandy clay loam	loamy sand	sandy clay loam	loamy sand	sandy clay loam	loamy sand	sandy clay loam
1	2	3	4	5	6	7	8	9
soil without neutralizing substance								
0.000	103.34	172.43	29.21	49.54	200.18	134.92	13.60	23.86
0.017	182.27	224.19	34.82	53.00	194.96	182.68	20.27	30.41
0.033	231.10	242.32	28.73	52.36	178.40	164.24	22.02	29.10
0.066	224.07	297.40	25.15	42.30	130.86	209.70	26.00	28.17
0.664	197.61	216.81	21.11	30.49	94.21	111.66	21.80	21.06
Mean	187.68	230.63	27.80	45.54	159.72	160.64	20.74	26.52
r	0.18	-0.09	-0.77	-0.92	-0.85	-0.65	0.21	-0.75
soil with basalt meal								
0.000	152.47	225.96	32.26	45.43	223.58	213.03	23.38	19.15
0.017	176.19	276.65	30.24	47.06	237.99	216.38	24.53	30.52
0.033	194.86	211.68	30.60	47.15	182.94	236.85	24.80	24.05
0.066	160.22	207.80	28.32	46.51	141.16	251.90	20.07	22.14
0.664	135.32	170.29	25.19	46.34	109.26	168.06	18.53	21.52
Mean	163.81	218.47	29.32	46.50	178.98	217.24	22.26	23.47
r	-0.69	-0.73	-0.89	-0.09	-0.77	-0.82	-0.78	-0.25

cont. Table 1

1	2	3	4	5	6	7	8	9
soil with spring barley straw								
0.000	208.54	258.06	38.69	36.61	153.45	175.36	26.79	51.15
0.017	214.63	275.33	36.87	48.98	182.42	160.04	33.30	42.34
0.033	264.99	194.40	33.14	46.70	213.97	159.78	37.64	27.59
0.066	317.27	141.54	37.11	48.16	218.84	184.88	30.48	24.24
0.664	245.49	122.27	26.46	43.39	221.18	215.06	20.62	22.28
Mean	250.18	198.32	34.45	44.76	197.97	179.02	29.76	33.52
r	0.02	-0.68	-0.92	-0.10	0.51	0.90	-0.77	-0.57
$LSD_{0.05}$	a – 5.24; b – 3.32; c – 4.06; $a\ b$ – 7.41; $a\ c$ – 9.08; $b\ c$ – 5.74; $a\ b\ c$ – 12.84		a – 1.28; b – 0.81; c – 0.99; $a\ b$ – 1.80; $a\ c$ – 2.21; $b\ c$ – 1.40; $a\ b\ c$ – 3.12		a – 4.25; b – 2.69; c – 3.29; $a\ b$ – 6.01; $a\ c$ – 7.37; $b\ c$ – 4.66; $a\ b\ c$ – 10.42		a – 0.97; b – 0.61; c – 0.75; $a\ b$ – 1.37; $a\ c$ – 1.68; $b\ c$ – 1.06; $a\ b\ c$ – 2.37	

* Key: $LSD_{0.05}$ for: a – herbicide dose, b – soil species, c – type of neutralizing substance, r – coefficient of correlation.

Actinobacteria and fungi, but their abundance increased again at the end of the study. ARAŬJO et al. (2003) noted a stimulating effect of glyphosate on soil microorganisms.

The Aurora 40 WG herbicide affected also the activity levels of soil enzymes (Table 2). When applied at the highest dose (40-fold higher than the recommended dose), it increased *β*-glucosidase activity 1.3-fold in loamy sand, while less profound changes were observed in sandy clay loam. The changes that occurred in the case of *β*-glucosidase in loamy sand, may be associated with the provision of suitable substances having the effect of increasing the rate of enzymatic reactions. Substrates that can be carfentrazone-ethyl, which can be a source of organic material for the microorganisms. Arylsulphatase was most sensitive to soil contamination with Aurora 40 WG. The herbicide applied at 0.664 mg kg^{-1} inhibited the activity of arylsulphatase by 7.4% in loamy sand and by 3.3% in sandy clay loam, compared with control. Aurora 40 WG did not alter significantly catalase activity. Another factor determining soil enzymatic activity was soil species. The highest activity levels of the studied enzymes were observed in sandy clay loam. The highest differences between soil types were noted with regard to arylsulphatase activity which was 2.2-fold higher in sandy clay loam than in loamy sand. The addition of substances alleviating the adverse effects of Aurora 40 WG to soil, i.e. basalt meal and spring barley straw, modified the activity levels of all tested enzymes. The activity of *β*-glucosidase was enhanced by finely ground spring barley straw and basalt meal. It increased by 13.6% on average in both soil type enriched with straw. Basalt meal contributed to a 6.5% increase in *β*-glucosidase activity in sandy clay loam, while no significant changes were found in loamy sand. Spring barley straw also increased arylsulphatase activity, by 18.5% in loamy sand and by 10.3% in sandy clay loam on average. Basalt meal had no effect on arylsulphatase activity. The application of finely ground spring barley straw had a clearly positive influence on catalase and significantly stimulated its activity. Basalt meal did not alter the activity of catalase. SUKUL (2006) studied the effect of metaxyl residues on the biochemical properties of soil and reported that metalaxyl inhibited the activity of arylsulphatase and *β*-glucosidase. Similar results with respect to arylsulphatase were obtained by KUCHARSKI et al. (2009) who tested the Harpun 500 SC herbicide. The activity of catalase was not inhibited by increased doses of Aurora 40 WG. Catalase responded similarly to acetamipirid applied in overdose (YAO et al. 2006), and differently to excessive amounts of Izoproturon 500 SC and Expert Met 65 WG (TELESIŃSKI et al. 2006) – the first of the above herbicides had no effect on catalase and the other two inhibited its activity.

The results of the present study indicate that spring barley negatively responded to the Aurora 40 WG herbicide applied in overdose (Figure 1). When

Table 2

The effect of the Aurora 40 WG herbicide on soil enzymatic activity subject to soil species and the type of neutralizing substance

Herbicide dose [mg kg^{-1}]	β-glucosidase [mmol PNP kg^{-1} DM h^{-1}]		Arylsulphatase [mmol PNP kg^{-1} DM h^{-1}]		Catalase [mol O_2 kg^{-1} DM h^{-1}]	
	loamy sand	sandy clay loam	loamy sand	sandy clay loam	loamy sand	sandy clay loam
1	2	3	4	5	6	7
soil without neutralizing substance						
0.000	0.190	0.415	0.325	0.760	0.140	0.250
00.017	0.220	0.475	0.375	0.775	0.155	0.260
00.033	0.220	0.495	0.365	0.780	0.150	0.255
0.066	0.235	0.425	0.305	0.620	0.145	0.265
0.664	0.230	0.405	0.300	0.635	0.135	0.235
Mean	0.219	0.443	0.334	0.714	0.145	0.253
r	0.42	-0.54	-0.58	-0.61	-0.70	-0.84
soil with basalt meal						
0.000	0.200	0.435	0.310	0.710	0.160	0.250
0.017	0.210	0.455	0.350	0.770	0.160	0.235
0.033	0.230	0.455	0.325	0.655	0.145	0.230
0.066	0.235	0.475	0.335	0.580	0.140	0.235
0.664	0.215	0.485	0.310	0.530	0.135	0.225
Mean	0.218	0.461	0.326	0.649	0.148	0.235
r	-0.04	0.75	-0.50	-0.74	-0.69	-0.64

cont. Table 2

1	2	3	4	5	6	7
soil with spring barley straw						
0.000	0.315	0.475	0.325	0.790	0.155	0.260
0.017	0.290	0.520	0.435	0.795	0.160	0.265
0.033	0.300	0.490	0.360	0.805	0.155	0.260
0.066	0.285	0.475	0.320	0.675	0.160	0.265
0.664	0.210	0.450	0.305	0.540	0.155	0.260
Mean	0.280	0.482	0.349	0.721	0.157	0.262
r	-0.97	-0.71	-0.49	-0.92	-0.37	-0.37
$LSD_{0.05}$	a – 0.007; b – 0.004; c – 0.006; $a\ b$ – 0.010; $a\ c$ – 0.012; $b\ c$ – 0.008; $a\ b\ c$ – 0.017		a – 0.004; b – 0.003; c – 0.003; $a\ b$ – 0.006; $a\ c$ – 0.007; $b\ c$ – 0.005; $a\ b\ c$ – 0.011		a – 0.001; b – 0.001; c – 0.001; $a\ b$ – 0.001; $a\ c$ – 0.002; $b\ c$ – 0.001; $a\ b\ c$ – 0.002	

* Refer to the key under Table 1.

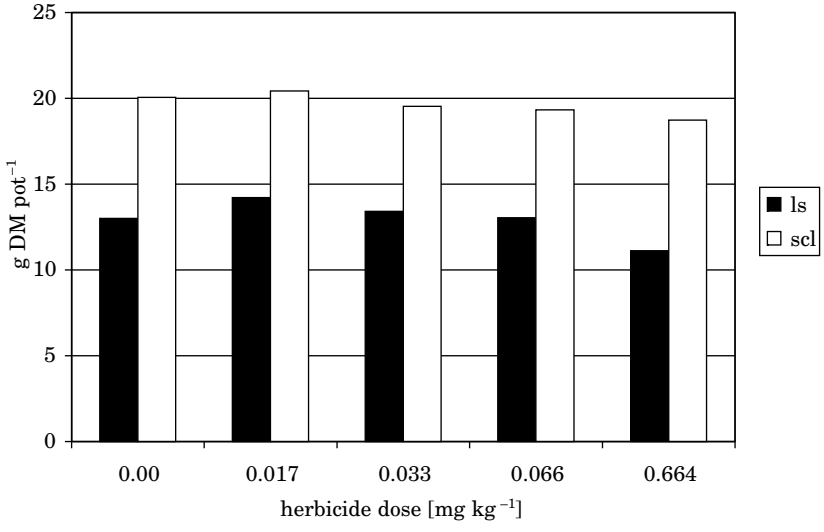

Fig. 1. The effect of soil contamination with the Aurora 40 WG herbicide on spring barley yield [g DM pot^{-1}]. $LSD_{0.05}$ for: *a* – herbicide dose – 2.41; *b* – soil species – 1.54, *a b* – 3.45; ls – loamy sand, scl – sandy clay loam

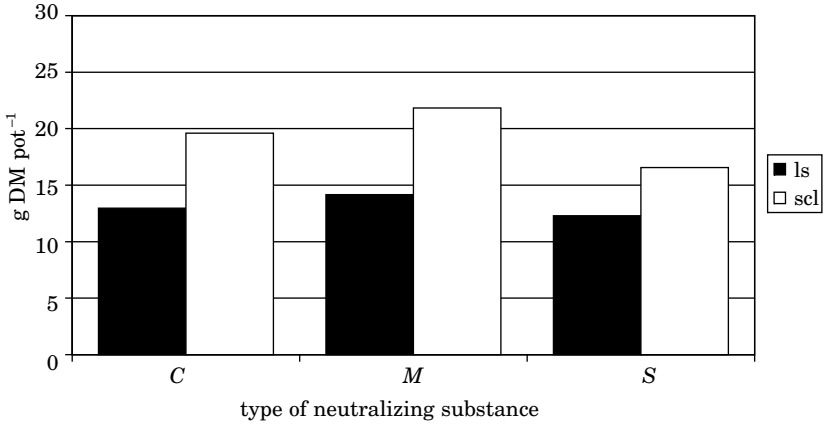

Fig. 2. The effect of neutralizing substance on spring barley yield in soil contaminated with the Aurora 40 WG herbicide [g DM pot^{-1}]. $LSD_{0.05}$ for: *a* – soil species – 1.54; *b* – type of neutralizing substance – 1.86; *a b* – 2.69; *C* – control; *M* – basalt meal; *S* – spring barley straw; ls – loamy sand; scl – sandy clay loam

applied at the dose 40-fold higher than the optimal dose, Aurora 40 WG reduced spring barley yield by 14.5% in loamy sand and by 6.2% in sandy clay loam on average, in comparison with uncontaminated soil. Adverse effects of two herbicides, Starane 250 EC and Harpun 500 SC, on spring barley yield were also noted by KUCHARSKI et al. (2004) and KUCHARSKI et al. (2009).

The inhibitory effect of the above herbicides was proportional to their doses. Spring barley yield was differently affected by the neutralizing substances applied to alleviate the adverse effects of Aurora 40 WG (Figure 2). The negative impact of Aurora 40 WG on the development of spring barley plants was not neutralized by the application of barley straw, but an alleviating effect was exerted by basalt meal which increased spring barley yield by 11.05% in loamy sand and by 10.48% in sandy clay loam on average, compared with the control treatment.

Conclusions

1. Soil contamination with the Aurora 40 WG herbicide led to an increase in the counts of organotrophic bacteria and fungi, and to a decrease in *Azotobacter* abundance. Aurora 40 WG stimulated the activity of β-glucosidase and inhibited the activity of arylsulphatase.

2. The addition of spring barley straw to soil contributed to an increase in the counts of Actinobacteria and fungi, while the addition of basalt meal stimulated the growth of bacteria of the genus *Azotobacter* and Actinobacteria. Spring barley straw had a beneficial influence of the activities of all studied enzymes. Basalt meal had an inhibitory effect on the activity of arylsulphatase.

3. When applied at the dose 40-fold higher than that recommended by the manufacturer, Aurora 40 WG reduced spring barley yield. Basal meal stimulated the growth and development of spring barley plants, whereas straw did not alleviate the adverse effects of the herbicide on the tested crop.

Translated by Aleksandra Poprawska

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AN INFLUENCE OF A FEED SUPPLEMENT ON VALUES OF SELECTED HEMATOLOGICAL INDICATORS AND QUALITY OF MOVEMENT OF RECREATIONAL HORSES

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K e y w o r d s: hematological parameters, feed additives, recreational horses.

A b s t r a c t

The study pertained to a group of 25 warm-blooded horses, used for recreational purposes within the Kujavian-Pomerania Province for a period of 6 months. The aim of the study was to determine the effect of selected feed additives a quality of movement of the working horses'. Throughout the experiment the horses were fed livestock feed (i.e. oats, barley and hay) twice a day. For a period of 180 days the horses' diet included supplements with set values of selected ingredients: calcium (Ca), magnesium (Mg), iron (Fe), selenium (Se), vitamin C, vitamin A, lysine and biotin. A quality of movement of the animals was determined by testing the quality of movement and hematological parameters. The animals were assessed three times: before supplementation was commenced, during the 3^{ed} month of supplementation and after 180 days of supplementation. The tests show that feed supplements had a beneficial effect on the condition of horses undergoing intensive workouts.

WPŁYW DODATKU PASZOWEGO NA WYBRANE WSKAŹNIKI HEMATOLOGICZNE I JAKOŚĆ RUCHU KONI REKREACYJNYCH

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S ł o w a k l u c z o w e: wskaźniki hematologiczne krwi, dodatki paszowe, konie rekreacyjne.

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Abstrakt

Badaniami objęto grupę 25 koni ras gorącokrwistych użytkowanych rekreacyjnie w województwie kujawsko-pomorskim przez 6 miesięcy. Celem opracowania było określenie wpływu wybranych dodatków paszowych na kondycję koni pracujących. W czasie trwania doświadczenia zwierzęta żywione były 2 razy dziennie paszami gospodarskimi (owies, jęczmień, siano). Przez 180 dni do codziennego żywienia włączono suplementację z określoną zawartością składników takich jak: wapń (Ca), magnez (Mg), żelazo (Fe), selen (Se), witamina C, witamina E, lizyna i biotyna. Jakość ruchu zwierząt określono z wykorzystaniem testów jakości ruchu oraz wskaźników hematologicznych. Oceny zwierząt dokonano trzykrotnie: przed rozpoczęciem podawania preparatów, w 3 miesiącu podawania preparatów oraz w 180 dniu po zakończeniu suplementacji. Z przeprowadzonych badań wynika, iż dodatki paszowe korzystnie wpływają na kondycję koni poddawanych intensywnej pracy.

Introduction

A diet balanced to suit the individual needs of horses – both in the case of utility horses and horses used for breeding purposes – is of key nutritional importance. Digestibility and absorption depend not only on the quality of nutritional substances but also on their quantitative structure (YUR et al. 2008). Apart from basic groups of nutritional compounds, i.e. proteins, carbohydrates and fats, so-called feed supplements are necessary for the animals to function properly. Feed supplements include micro and macro-elements, vitamins and amino acids. The need to supplement primary feed increases along with the intensity with which the horses work. The right selection of supplements has a direct impact on the animals' physiological condition (BROWN et al. 2000).

A horse's physical condition can be observed during everyday workouts, and is thus linked with work potential. The value of basic hematological parameters is often determined when evaluating a horse's health and its workout potential (WINNICKA 2004, SZARSKA 2002). The levels of hematological parameters selectively determine the structure of diet supplements (GRELA et al. 2003).

In the case of horses, lack of mineral balance or a deficit of elements can lead to hindered energy balance, a decrease of utility potential, changes of temperament, decreased immunity, heart problems, and cause the skeletal system to be susceptible to breaks (DOBROWOLSKI et al. 2009, CHACHUŁOWA 1998).

The aim of the study was to determine the effect an influence of selected feed supplements on values of hematological indicators and quality of movement of the horses.

Study Group and Methods

The study encompassed a group of 25 warm-blooded horses of various breeds, aged 8-15, utilized in a recreational riding stable in the Kujavian--Pomerania Province. Group consisted of 13 mares and 12 geldings. Throughout the study the all horses were utilized with a constant and repetitive intensity. The horses were fed livestock feed, i.e.: oats, barley and hay. The dosages were individualized. Feed was given twice a day and the horses were kept in boxes that were lined daily with fresh hay. Throughout the study period the water and feed were from the same source. Before beginning the experiment the horses were examined by a veterinarian who called all the animals healthy.

The animals' initial condition was assessed subjectively by awarding points for movement quality during workouts and additionally via a subjective method, by determining the levels of hematological parameters.

All animals were assessed three times, thus creating three groups:

– before the supplements were administered – group I;
– on the 90^{th} day of supplementation – group II;
– on the 180^{th} day of supplementation – group III.

Blood for testing was procured at rest from the external jugular vein with the use of the Vacuette blood collection system. The following hematological parameters were determined: (leukocytes), RBC T/l (erythrocytes), HGB g/l (hemoglobin), HCT l/l (hematocrit), PLT G/l (blood platelets).

A scale of 1 to 6 was used to assess movement (Table 1). Every workout test consisted of a set of exercises conducted on a lounge; the exercises lasted approximately 30 minutes (starting with 5 minutes of walking to loosen and warm up muscles, 15 minutes of trotting and 10 minutes of gallop, jumping obstacles – horizontal bars and logs situated on the ground). Each horse was assessed at the end of each test by 3 people in three samples (before the supplements were administered, on the 90^{th} and the 180^{th} day of supplementation).

During the study, selected mineral and vitamin supplements were added to the feed in the form of pellets (for ingredients see Table 2).

A statistical analysis of the data was conducted using Statistica 9PL StatSoft software. An arithmetic mean and standard deviation were established in each study group for the various hematological parameters. Statistical differences between groups of animals were verified using the Kruskal-Wallis test.

Table 1

Point evaluation of the quality of movement of the recreational horses

Points	Evaluation
1	– the animals moved apathetically – positions of the head and neck were compensated by a prominent traction of the front limb's movement – lack of the trunk's balance – hind limbs faintly engaged in the hind's movement – the horse visibly and often stumbled while taking the obstacles
2	– the animals moved rhytmically – positions of the head and neck were compensated by a prominent traction of the front limb's movement – the trunk was slightly flexible – hind limbs faintly engaged in the hind's movement – the horse visibly stumbled while taking the obstacles
3	– the animals moved rhytmically with their head and neck position allowing a free movement of their front legs – a slight balance of the trunk (up and down) – hind limbs engaged in the hind's movement – the horse occasionally stumbled while taking the obstacles
4	– the animals moved energetically and rhytmically with their head and neck position allowing a free movement of their front legs – a slight balance of the trunk – hind limbs engaged in the hind's movement – the horse occasionally stumbled while taking the obstacles
5	– the animals moved energetically and with their head and neck position allowing a free movement of their front legs – putting visibly hind legs under the trunk – a visible balance of the trunk – the bars and logs were taken without stumbling
6	– the animals moved energetically and with their head and neck position allowing a free movement of their front legs – putting visibly their hind legs under the trunk – visibly substitution of the hind legs under the back – an elastic and clear balance of the trunk – the bars and logs were taken without stumbling

Table 2

Composition of used dietary supplement

The component of the feed additive	The content of the daily dose in grams per day
Calcium (Ca)	11.25
Magnesium (Mg)	0.59
Iron (Fe)	0.10
Selenium (Se)	0.01
Vitamin C	0.38
Vitamin E	0.38
Lysine	0.18
Biotin	0.04

Results and Discussion

Points awarded to specific animals comprising groups during workout tests are shown on Figure 1. An initial assessment of parameters of the horses' quality of movement, prior to supplementation, shows a low level of physiological efficiency, visible during training – group I. Most animals were awarded 3 to 4 points before supplementation commenced. The movements of only one animal were awarded 5 points, while 7 animals received 1 or 2 points. The introduction of a mineral and vitamin supplement for a period of 3 months increased the amount of awarded points and additionally evened out the animals' results pertaining to movement quality: 12 animals received 3 points, 13 animals received 4 points in group II. Subsequent to 6 months of supplementation, group III displayed a larger diversity in movement assessment, and their scored ranged between 4 and 6, showing an improvement in workout parameters.

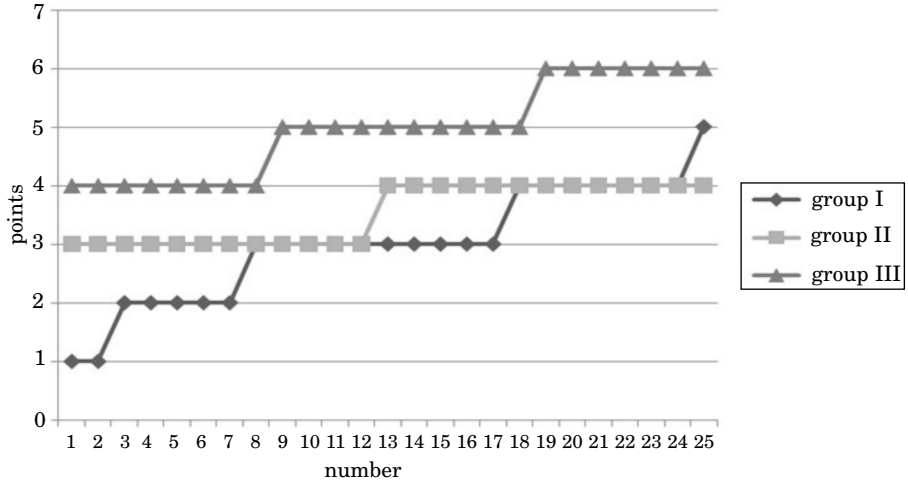

Fig. 1. Results of workout tests for individual animals in study groups

Throughout the vitamin and mineral supplementation period, the value of hematological parameters in the study groups underwent a change. A change was noted in all indicated values of hematological parameters in group III, when compared to group I. Statistically significant differences were observed ($p \leq 0.01$) between groups III and I for the average number of white blood cells. The number of erythrocytes also increased, but a statistically significant difference between the groups was not revealed. Average values of hemoglobin parameters in groups II and I and III increased, and the increase was statistically significant. The study showed an increase in the number of

Table 3
Level of chosen hematological indicators and time when measurements were taken

Hematological values	Statistical measures	The term hematological indices mark			Statistical differences between groups
		group I	group II	group III	
Leukocytes (WBC) G/l	$\bar{x}$ Sd	8.10 0.18	9.04 0.31	11.10 1.61	III–I** III–II*
Erythrocytes (RBC) T/l	$\bar{x}$ Sd	6.07 0.93	7.13 0.90	7.19 1.09	– –
Hemoglobin (HGB) g/l	$\bar{x}$ Sd	118.96 11.70	119.20 12.30	120.16 12.29	II–I, III**
Hematocrit (HCT) l/l	$\bar{x}$ Sd	0.30 0.04	0.30 0.03	0.32 0.04	– –
Platelets(PLT) G/l	$\bar{x}$ Sd	110.40 30.74	120.40 43.12	122.72 41.48	III, II–I**

** Statistically significant differences at $p \leq 0.01$
* Statistically significant differences at $p \leq 0.05$

platelets in group III when compared to groups I and III; the increase was significantly high and statistically significant (Table 3).

Research indicated that daily, long-term (180 days) feed supplementation of specific elements (shown in Table 2) increased the value of hematological parameters in every animal comprising group III, as well as the animals' efficiency during work (Table 3).

In all horse groups, physical effort lead to a significant increase of Hb concentration in the blood, compared to values obtained when the animals were resting. According to KĘDZIERSKI and PILLINER (2002) and KĘDZIERSKI et al. (2007) the increase of this parameter was proportional to the intensity of effort and is not linked with the level to which the studied animals were trained.

According to PILLINER (2008) horses fed livestock feed, i.e. oats and hay, display a deficiency of many microelements, such as Ca, Mg, Fe, Se, vitamin C, vitamin E, lysine and biotin. Supplementing these elements in the animals' daily diet, especially if the horses are intensely trained, improves work efficiency. Selection of elements comprising the supplement depends on the animals' requirements during workouts.

According to KĘDZIERSKI (2007) and SZARSKA (1994), research conducted during the General Three-Day Event (Wszechstronny Konkurs Konia Wierzchowego) indicated that animals with higher levels of Hb at rest were better prepared for physical effort. The research indicated that animals with higher levels of haemoglobin received more points for the parameters of quality of movement (Figure 1).

The authors selecting the feed supplements were influenced of the ingredient by a role the played in the horse's organism. An influence of the ingredients was directly confronted with a descriptive assessment of parameters of movement quality.

Due to the considerable inclusion of grains in feed portions, horses are at risk of calcium deficiency. Working animals, those that train, lose large amounts of calcium in their sweat. The element is necessary not only for proper bone development but it also aids proper blood coagulation and maintains nerve and muscle health (BUCHHOLZ-BRYANT 2001, PILLINER 2008).

The Ca:P ratio should amount to 1.6:1; adult horses tolerate a ratio of 5:1 and weans a ratio of 3:1. Not maintaining this ratio can lead to disorders in young horses (DOBROWOLSKI et al. 2009, JODKOWSKA et al. 1997, KOŚLA and ANKE 1986). Supplementation of this element seems to be substantiated.

Magnesium activates enzymes that participate in muscle and nerve cell turnover and is an essential supplement during workouts. Animals with magnesium deficiency are weaker and lack concentration during workouts (MEYER and MANFRED 2009).

Iron is an element that directly impacts cardiorespiratory functions. Iron participates in the synthesis of hemoglobin and myoglobin proteins which are responsible for carrying oxygen. Horses with iron deficiencies have lower amounts of erythrocytes (RBC) and breathing difficulties, which translates into lowered work efficiency, muscle pain and general weakness (JANUSZEWSKA and KRUCZYŃSKA 2002).

Selenium is yet another element that synergizes with vitamin E. Research conducted by HAGGETE et al. (2010) indicated that the need for selenium and vitamin E is displayed especially by sport horses during workouts as well as in stressful situations. Selenium supplements stimulate the production of leukocytes (WBC) and limit the harmful effects of peroxides and heavy metals (YUR et al. 2008).

Lysine renews tissue and is necessary for the production of antibodies, hormones and enzymes. It is essential during the growth process, aids mental concentration during workouts and affects the metabolism of fatty acids (*Normy żywienia...* 1994).

Horse researchers, trainers and breeders believe biotin to be a necessary supplement that should be added to the animals' everyday diet. Its addition improves the quality of the hoof by intensifying the keratinization process. Although biotin does not affect the level of hematological parameters directly, it does allow the hoof to function properly.

GRELA et al. (2003) noted the beneficial effect of nutrition on the number of erythrocytes and hemoglobin concentration. Similarly, ROGA-FRANC et al. (1994) observed the increase of erythrocytes in cows that were given mineral

supplements. CALAMARI (2009) and BROWN (2000) observed the effect of selenium supplements on the increase of blood and plasma parameters, confirming the results of their research.

Summing up the research indicates the need for vitamin and mineral feed additives, especially in the case of utility horses that undergo physiological strain linked with daily work under saddle. The research indicated that balanced feed supplements improve the animals' intra-organic immunity, increase respiratory health as well as quality of movement during daily work in recreation.

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EFFECTS OF CYANOBACTERIAL TOXINS, MICROCYSTINS ON FRESHWATER INVERTEBRATES

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K e y w o r d s: cyanobacteria, microcystins, bivalves, gastropods, copepods, cladocerans.

A b s t r a c t

Cyanobacteria, also known as blue-green algae, are prokaryotic, phototrophic microorganisms that may form massive blooms in eutrophic water reservoirs. Some cyanobacterial strains are able to produce secondary metabolites – cyanotoxins that may be hazardous to aquatic and terrestial animals. These compunds can be grouped into: hepatotoxins, neurotoxins, cytotoxins dermatotoxins and irritant toxins. Microcystins are well-known cyclic heptapeptides acting as inhibitors of protein phosphatases type 1 and 2A. These cyanotoxins induce various adverse effects in freshwater invertebrates including biochemical, physiological and behavioral changes. Moreover, accumulation of microcystins in different tissues occurs, therefore transfer of these cyanotoxins through the food chain to animals being at higher trophic levels may be possible. The purpose of this paper is to review the knowledge on the effects of microcystins on three main groups of freshwater invertebrates: zooplankton, higher crustaceans, mollusks and to indicate possible ecotoxicological consequences of this impact on aquatic environment and invertebrate aquacultures.

DZIAŁANIE TOKSYN SINICOWYCH, MIKROCYSTYN NA SŁODKOWODNE BEZKRĘGOWCE

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Abstrakt

Cyjanobakterie (sinice) są prokariotycznymi, fototroficznymi mikroorganizmami, które w eutroficznych zbiornikach wodnych mogą masowo proliferować, tworząc zakwity. Niektóre szczepy sinic zdolne są do produkcji cyjanotoksyn, wtórnych metabolitów, które mogą stanowić zagrożenie dla zwierząt wodnych oraz lądowych. Związki te można podzielić na: hepatotoksyny, neurotoksyny, cytotoksyny, dermatotoksyny oraz toksyny drażniące. Mikrocystyny są dobrze opisanymi cyklicznymi heptapeptydami będącymi inhibitorami białkowych fosfataz typu 1 oraz 2A. Wywołują rozmaite szkodliwe efekty u słodkowodnych bezkręgowców, np. zmiany biochemiczne, fizjologiczne oraz behawioralne. Mikrocystyny dzięki zdolności do akumulacji w różnych tkankach mogą ponadto ulegać transferowi do zwierząt będących na wyższych poziomach łańcucha troficznego. Celem artykułu jest przegląd stanu wiedzy na temat oddziaływania mikrocystyn na trzy główne grupy bezkręgowców słodkowodnych: zooplanktonu, wyższych skorupiaków i mięczaków oraz wskazanie jego możliwych konsekwencji ekotoksykologicznych na środowisko wodne i akwakultury bezkręgowców.

Introduction

Cyanobacteria, (*Cyanophyta, Cyanoprocaryota*) also known as blue-green algae are phototrophic, prokaryotic microorganisms frequently found in many environments, from tropical regions to arctic ice. They play important ecological role as oxygen producers, they also have adaptation to fix atmospheric nitrogen and to tolerate a wide range of temperature (GŁOWACKA et al. 2007, BERMAN-FRANK 2003, WHITTON and POTTS 2000). Some species of cyanobacteria may produce secondary metabolites known as cyanotoxins, which are very harmful to aquatic and terrestial animals (BŁASZCZYK et al. 2010, VALERIO et al. 2010). Some cyanotoxins (such as cylindrospermopsin) may be constantly released during cyanobacterial growth, however most of these compounds pass directly from cyanobacterial cells to surrounding water during the bloom collapse posing a risk of intoxication to various organisms. Toxic effects of various cyanotoxins are well documented in mammals: humans, cattle, dogs and in aquatic organisms such as bacteria, algae, higher plants, invertebrates and vertebrates such as fish. (CARMICHAEL 1997, GRIFFITHS and SAKER 2003, BOWNIK et al. 2012).

Cyanobacterial toxins can be divided on the basis of its toxic action into: hepatotoxins, neurotoxins, cytotoxins, dermatotoxins and irritant toxins (lipopolysaccharides) (WIEGAND and PFLUGMACHER 2005). Hepatotoxins produced by cyanobacteria include heptapeptide microcystins and pentapeptide nodularin, neurotoxins: anatoxin-a, anatoxin-a(s), homoanatoxin-a, saxitoxins- also known as paralytic shellfish poisons (PSPs). A variety of cytotoxic effects in many organs are induced by cyanobacterial alkaloid cytotoxin – cylindrospermopsin. Irritant cyanotoxins are lipopolysaccharides which are constituents of cyanobaterial cell wall (SIVONEN 2009).

Microcystins are produced by cyanobacterial genera such as *Microcystis, Anabaena, Planktothrix (Oscillatoria), Anabaenopsis, Nostoc, Hapalosiphon, Aphanizomenon* (CARMICHAEL 1992, KAEBERNICK and NEILAN 2001, WIEGAND and PFLUGMACHER 2005) common in many types of freshwater environments such as dam reservoirs, lakes and ponds. These well-known cyanotoxins are cyclic heptapeptides consisting of seven amino acids including two characteristic amino acids: methyldehydroalanine (Mdha) and 3-amino-9methoxy-2,6,8--trimethyl-10-phenyldeca-4,6-dienoic acid (Adda). Currently, more than 85 of their structural variants have been described and microcystin-LR (MC-LR) is one of the most frequently detected in freshwater reservoirs (SIVONEN 2009) (Figure 1). Results from the studies performed on vertebrates indicate that MC-LR targets the liver causing fatal cytoskeletal disruption of hepatocytes induced by specific inhibition of protein phosphatases type 1 (PP1) and 2A (PP2A) (TOIVOLA et al. 1994).

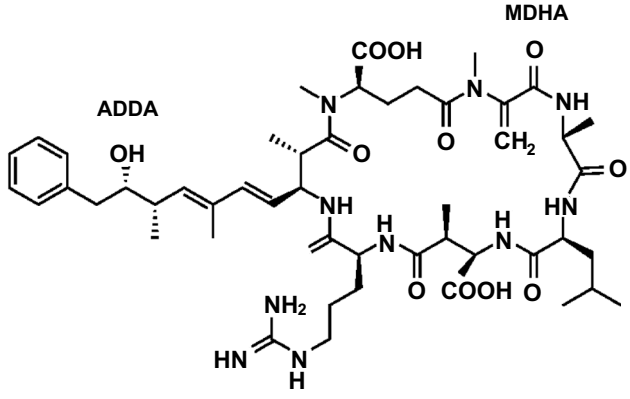

Fig. 1. Structure of microcystin-LR

Effects of microcystins on zooplankton

Zooplanktonic organisms feed on microorganisms such as phytoplankton and bacteria, on the other hand, they are a food source for other predatory species, particularly for fish fry. Scientific data indicate that some cyanobacterial species producing microcystins interact with some zooplanktonic species but the responses are different among closely related species and even individuals (BLANCHTTE and HANEY 2002). Toxic strains of *Microcystis aeruginosa* may increase the production of cyclic heptapeptides in the presence of certain zooplanktonic organisms or their infochemicals (JANG et al. 2008). This type of defensive reaction of phytoplankton usually leads to reduction of grazing

activity of zooplankton. However, there are reports indicating no inhibitory influence on grazing particularly in wild mesoplankton consuming toxic and non-toxic strains of *Microcystis aeruginosa* at similar rates (DAVIS and GOBLER 2011). Consumption of toxic cyanobacterial cells or direct absorbtion of cyanotoxins dissolved in water may induce a variety of toxic changes in susceptible zooplanktonic invertebrates. ROHRLACK et al. (2001, 2005) demonstrated lethal effects in *Daphnia galeata* exposed to cell-bound microcystins. On the other hand, there are reports indicating low impact of microcystins on survival of zooplanktonic species, but showing physiological changes such as disturbances in the heartbeat and the movements of the thoracic limbs, mandibles, second antennae, decreased activity of the foregut, histopathological changes in the midgut and stimulation of its muscles (CHEN et al. 2005).

Microcystin-producing strains of cyanobacteria may induce changes in growth and development of some zooplanktonic species. The growth rate of *Daphnia magna* is reduced after comsumption of *Microcystis aeruginosa* producing microcystins (LÜRLING 2003). Survival of the offsprings is lower when their parents are previously intoxicated with MC-LR. Deformations of the neonates such as incomplete development of the antennae and unrejected tail spin also occur (DAO et al. 2010).

Microcystins induce biochemical changes in zooplanktonic organisms and their mechanism of toxic action seems to be similar to those in mammals. The activity of protein phosphatases P1 and P2A from the extracts of invertebrates *Daphnia pulex*, *Daphnia pulicaria* and *Diaptomus birgei* are inhibited by MC-LR (DEMOTT and DHAWALLE 1995). The cyanotoxins are metabolized by zooplanktonic enzymes which is manifested by stimulation of lactate dehydrogenase and alterations in the levels of glutahione and glutathione-S-transferases in *Daphnia magna*. The changes of acetylcholinesterase activity in *Daphnia pulicaria* may suggest disturbances in neuronal stimulation in daphnids. Microcystins also inhibit the activity of gut proteases, trypsin and chymotrypsin in *Moina macrocopa* and *Daphnia magna* and this may explain their lower feeding activity during cyanobacterial blooms (AGRAWAL et al. 2001, 2005, CHEN et al. 2005).

Although cyanobacteria producing microcystins turned out to be harmful to certain zooplanktonic species, cladocerans developed some mechanims to reduce their toxicity (GUO and XIE 2006, BEDNARSKA 2006). Zooplanktonic organims that are frequently exposed to microcystins seem to be less sensitive in comparison to those crustaceans which had not earlier contact with the cyanotoxins. It was shown that *Daphnia magna* previously exposed to toxic strain of *Microcystis* sp. are more resistant to microcystins than the individuals without prior treatment, which is manifested by their increased survial and larger size (GUSTAFSSON and HANSON 2004).

There are some species-dependent differences in tolerance of zooplankton to microcystins. Toxicological comparative studies indicated that *Daphnia galeata* is more sensitive to MC-LR than *Daphnia magna*. Moreover, pretreatment of these daphnids with purified cyanobacterial lipopolysaccharide (LPS) from *Microcystis CYA 43* increased their resistance to MC-LR (LINDSAY et al. 2006). It was also shown that smaller cladocerans are usually more tolerant than large-sized *Daphnia* in a simultaneous exposure to microcystin-positive strains of *Microcystis aeruginosa* and this could explain the replacement of dominant *Daphnia* by smaller species during summer cyanobacterial blooms (GUO and XIE 2006). Morover, laboratory experiments have shown that blooms of toxic *Microcystis aeruginosa* reduce the numer of large-bodied daphnid cladocerans, such as *Daphnia ambigua* and increase the quantity of smaller copepods such as *Diaptomus reighardi* (FULTON and PAERL 1988). Susceptibility of zooplanktonic organisms to microcystins may also depend on the structural variant and activity of other toxic substances such as microviridins or cyanopeptolins (JUNGMAN and BENNDORF 1994).

Zooplanktonic species possess some adaptations and mechanisms enabling them to reduce the toxic effects of cyanotoxins, however the ability to tolerate toxic cyanobacteria is varied between species. Zooplankton sensitivity to microcystins is different even in closely related species of *Daphnia* that reside in water reservoirs of various trophic profile. The individuals from eutrophic lakes where frequent blooms of toxic strains of cyanobacteria occur may develop mechanisms of resistance which are not present in those organisms from oligotrophic reservoirs (BLANCHETTE and HANEY 2002). Some daphnids are able to select their food and may avoid toxic cyanobacteria. The non-toxic strains were observed to be faster consumed by *Daphnia magna* than the microcystin-positive species (DEGANS and DE MEESTER 2002). On the other hand, *Daphnia pulicaria* was shown to feed unselectively on toxic strains of *Microcsytis aeruginosa*. Physiological sensitivity in addition to a lack of food selectivity make these crustaceans very sensitive to microcystin-producing cyanobacteria (DEMOTT et al. 1991).

Grazing activity and food selectivity of those animals may affect the amount of the ingested cell-bound microcystins and, in a consequence, their toxic impact. For example, it was noted that a crustacean, *Diaptomus birgeri* which is physiologically sensitive to microcystins, inhibits feeding in the presence of toxic *Microcystis aeruginosa*. Reduced grazing activity observed in *Daphnia magna* during the exposure to *Microcystis aeruginosa* may be a type of defensive reaction leading to inhibition of ingestion of cyanobacterial cells containing microcystin (ŁOTOCKA 2001) This effect is possibly induced by reduction of trypsin and chymotrypsin in the gut (AGRAWAL et al. 2005). On the other hand, in some zooplanktonic species such as *Daphnia*

pulicaria, the ingestion rate was not diminished during the exposure to microcystin. As a consequence, these crustaceans may absorb high concentrations of microcystins in addition to their physiological sensitivity (DEMOTT et al. 1991).

Effects of microcystins on decapods and mollusks

Most of freshwater decapods (*Decapoda*) are scavengers and they are vital organisms in maintaining the recycle of organic matter. These animals are senstitive to microcystin-producing strains of cyanobacteria and they may be exposed to microcystins dissolved in water, when grazing on cyanobacterial cells suspended in water or when consuming the detritus containing the decaying material from the bloom with absorbed cyanotoxins. However, they may exhibit symptoms of oxidative stress after the exposure to cyanobacterial cyclic heptapeptides. Production of oxidative stress enzymes was noted in the internal organs such as hepatopancreas and gills of the estuarine crab *Chasmagnathus granulatus* (*Decapoda Brachyura*). Cyanobacterial extracts containing microcystins increased consumption of oxygen, catalase activity, glutathione S transferase and lipid peroxides Microcystins may also induce other toxic effects such as disturbance of the sodium pomp functioning by the reduction of Na^+ and K^+ ATP-ase activity leading to disorders in the metabolism of various cells. (MONTAGNOLLI et al. 2004, PINHO et al. 2005a, 2005b). Decapods are able to metabolize microcystins. The elevated glutathione S-transferase level found in crabs indicated the biotransformation of these heptapeptides (VINAGRE et al. 2002).

Bivalves and gastropods are mollusks including a huge number of species abundant in freshwater environments. Bivalves play important ecological role as filter feeders consuming small organisms and organic particles suspended in water. These organisms may absorb cyanotoxins both in a dissolved form and from ingested cyanobacterial cells. The ability to expell living toxic cyanobacteria into pseudofeces and very efficient depuration of tissues from microcystins are distinct physiological processes enabling these mollusks to tolerate cyanobacterial blooms harmful to other organisms. However, these adaptations are varied among the species.

Although bivalves are resistant to microcystins and do not develop symptoms of acute toxicity, they may show some biochemical changes after a prolonged time of exposure to low concentrations of the heptapeptides. Similarly to decapods, bivalves exposed subchronically to toxic *Microcystis aeruginosa* are prone to oxidative stress by the incereased activity of superoxide dismutase by 50%, catalase by 66% and glutathione-S-transferase by 60% (SABATINI et al.

2011). A zebra mussel, *Dreissena polymorpha* exposed to MC-LR (10 μg/L) for 24 hours exhibited elevated level of glutathione S-transferase in the whole tissue, digestive gland and gills. The activity of antioxidant enzymes, catalase and superoxide dismutase was also increased. However, oxidative stress induced by microcystins is not observed in all bivalves. A mussel, *Unio tumidus* exposed to MC-LR at a concentration of 10 μg/L showed unchanged activity of superoxide dismutase and glutathione S-transferase in the digestive gland and gills (BURMESTER et al. 2012).

Toxic strains of *Microcystis aeruginosa* were noted to induce cytotoxic effects in a freshwater clam, *Corbicula fluminea*. Changes in the expression of proteins involved in the cytoskeleton assembly of cytosolic fraction of gills and digestive tract were noted. (MARTINS et al. 2009). The disruptive effects of microcystins on the cytoskeleton is associated with the inhibitory action of microcystins on protein phosphatases PP1 and P2A

Freshwater gastropods are scavengers and detritus feeders that can assimilate cyanotoxins dissolved in water or they may be intoxicated by consumption of organic matter from the sediments containing these compounds. Another route of intoxication could be grazing on benthic cyanobacteria producing cyanotoxins. The scientific data on the effects of microcystins on gastropods is very scarce. Some results are associated with the accumulation of cyanotoxins other than microcystins in various freshwater snail species. Cyanobacteria producing microcystins induce toxic changes in gastropods found in the pulmonate *Lymnea stagnalis* exposed to the purified MC-LR. The animals exibited reduced egg production and impaired locomotion (GÈRARD et al. 2005).

Accumulation of microcystins in the invertebrates

The results of field and experimental studies suggest that various aquatic animal species tend to accumulate cyanotoxins in the target organs. The increasing concentrations of microcystins observed in the foodchain may be hazardous to predatory species absorbing the heptapeptides with the consumed food.

It is suggested that some invertebrate species may deposit microcystins in their bodies. Microcystins may be accumulated in zooplanktonic organisms that do not feed selectively and may ingest high amounts of toxic cyanobacterial cells. It is estimated that among invertebrates, zooplanktonic crustaceans possess the highest ability to accumulate microcystins reaching the highest values over 1000 μg g^{-1} of DW (Dry Weight) and the avarage values of about 383 μg g^{-1} of DW (FERRÃO-FILHO and KOZLOWSKY-SUZUKI 2011). It was

shown by ELISA (Enzyme Linked Immunosrobent Assay) assay that *Daphnia magna* accumulated microcystins up to 24.5 μg g^{-1} after the exposure to the toxic cells of *Microcystis aeruginosa* CYA228/1 (THORSTRUP and CHRISTOFFERSEN 1999). Microcystins assimilated in zooplankton may be then transferred to predators being at the higher trophic levels such as fish.

Higher crustaceans such as crayfish and freshwater shrimps accumulate microcystins in various organs, mostly in the hepatopancreas and gonads. Mortalities of white shrimps noted in Texas aquaulture ponds with blooms dominated by *Microcystis aeruginosa* and *Anabaena* sp. were associated with assimilation of MC-LR in their tissues. The cyanotoxin was detected in the hepatopancreas at 55 μg g^{-1}, however the toxin concentration in muscles was estimated to be below 0,1 μg g^{-1}. Other crustacean species seem to have a different profile of microcystin distribution. An edible red swamp shrimp (*Procambarus clarkii*) turned out to assimilate the cyanotoxins in the intestine and abdominal muscle (TRICARICO et al. 2008, LIRÅS et al. 1998) and crabs from Brasilian Sepetiba Bay in the muscle tissue (MAGALHÃES et al. 2003).

Bivalves ingest microcystins by filtering the water abundant in toxin-positive cyanobacteria. Results obtained by BAKER et al. (1998) suggested that *Microcystis* cells are selectively consumed by the zebra mussel and filtered out of the water. However, other authors showed that bivalves can reject living toxic *Microcystis* cells with unsuitable food by transporting them to pseudeofeces, a characteristic fluid consisting of mucus and the expelled particles (PIRES et al. 2004, JUHEL et al. 2006). Interestingly, a zebra mussel, *Dreissena polymorpha* is even suspected to be responsible for toxic blooms of *Microcystis aeruginosa* in Lake Erie by expeling pseudofeces containing living cyanobacterial cells (VANDREPLOEG et al. 2001).

Microcystins may be also a hazard to humans in case of their accumulation the edible invertebrates and further comsumption of the contaminated animals. High concentrations of microcystins was noted in an estuarine blue crab (*Callinectes sapidus*) living in a hyper-eutrophic freshwater lake, Lac des Allemands, located in the Barataria estuary system of southeastern Louisiana. The highest tissue concentrations of the cyanotoxins were detected in the hepatopancreas (820 μg kg^{-1}), viscera (65 μg kg^{-1}), muscle (105 μg kg^{-1}) (GARCIA et al. 2010). The amount of the assimilated cyanotoxins during counsumption of these animals would be more than the TDI guideline value 0.04 μg kg^{-1}/day for MC-LR proposed by World Health Organization (WHO) assumed for human body weight (WHO 1999). The most prone organs to microcystins accumulation in invertebrates are hepatopancreas and gonads. If the edible invertebrates are caught for culinary use and are suspected to have previous contact with cyanobacterial blooms, the internal organs should be removed before cooking for health safety.

In summary, freshwater invertebrates should be considered as organisms sensitive to microcystins. Cyanotoxins released during and after cyanobacterial blooms to the aquatic environment may reduce population of invertebrates not only by acute intoxication but also by chronic exposure leading to physiological, biochemical and behavioral changes inducing disturbances in grazing and reproduction. Moreover, the accumulated microcystins observed in invertebrates may be transferred to higher throphic levels in the food web of the aquatic ecosystem (SMITH and HANEY 2006). Higher crustaceans, bivalves and gastropods are also essential for human consumption in some countries. The knowledge on toxic effects and accumulation of microcystins in different organs of invertebrate organisms is very important for human health. Proper periods of animal depuration from microcystins established prior to their culinary use would reduce the risk of microcystin retention in the edible invertebrates (CHEN and XIE 2007). Therefore, constant monitoring of cyanobacteria such as *Microcystis aeruginosa* in ponds and aquacultures where these animals are kept for consumption should be maintained.

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THE STRUCTURE OF *MATTEUCCIA STRUTHIOPTERIS* POPULATION IN THE NATURE RESERVE "PIÓROPUSZNIKOWY JAR"

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K e y w o r d s: fern ecology, ordination, canopy cover.

A b s t r a c t

This study describes the correlations between demographic, environmental and floristic profiles of *Matteuccia struthiopteris* populations colonizing the banks of river Lisi Parów, with special emphasis on relative variation in resources allocated to sexual (sporophyll production) and asexual reproduction (production of new small ramets). In total, 507 rootstocks were measured, and they had developed a total of 4007 trophophylls and 324 sporophylls. Data from 17 are study sites were analyzed. Trophophyll height ranged from 22 to 159 cm, and one rootstock contained 1 to 16 trophophylls. Trophophyll height was not correlated with the number of trophophylls in a rootstock, but when the number of trophophylls exceeded nine, there was no general increase in frond height. Rootstock diameter varied from 21 to 156 mm (average of 62.3 mm), and the number of emerging trophophylls showed a linear correlation with the thickness of each ramet. There were 1 to 9 sporophylls per rootstock, and most ramets had 1 to 5 sporophylls. Sporophyll height was determined in the range of 22 and 84 cm, but the majority of sporophylls measured from 40 to 60 cm. A significant linear increase in the number of sporophylls was observed with an increase in the number of trophophylls and an increase in trophophyll height. In general, the production of *M. struthiopteris* sporophylls began upon the emergence of more than six trophophylls taller than 100 cm and when rhizome thickness exceeded 55 mm.

The applied ordination techniques (PCA, RDA) did not result in a clear-cut classification of the examined sites with regard to their spatial location (upstream/downstream, river bank/river terrace/river valley). Variations in the floristic composition of the studied populations relative to environmental factors were presented with the use of the RDA technique. The Monte Carlo test revealed that environmental variables had a significant effect on the analyzed parameters of *Matteuccia struthiopteris* populations for the first canonical axis ($p = 0.002$; $F = 70.34$). Environmental factors explained 58.3% of variance in population traits and 97.4% of variation in population traits as well as environmental factors. The Monte Carlo test revealed that canopy cover was statistically significant ($p = 0.002$; $F = 10.34$).

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STRUKTURA POPULACJI *MATTEUCCIA STRUTHIOPTERIS* W REZERWACIE PRZYRODY „PIÓROPUSZNIKOWY JAR"

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S ł o w a k l u c z o w e: ekologia paproci, ordynacja, pokrywa drzew.

A b s t r a k t

W pracy opisano relacje między demograficznymi, środowiskowymi i florystycznymi danymi dotyczącymi populacji *Matteuccia struthiopteris* zasiedlającej teren wzdłuż rzeki Lisi Parów. Szczególnie uwzględniono względną zmienności udziału rozmnażania płciowego i bezpłciowego. Na 507 rozetach łącznie zmierzono 4007 trofofili i 324 sporofili. Analizy prowadzono w oparciu o dane pochodzące z 17 powierzchni badawczych. Wysokość trofofili wynosiła od 22 i 159 cm, a ich liczba w jednej rozecie – od 1 do 16. Nie stwierdzono, by wysokość trofofili rosła wraz ze wzrostem ich liczby w rozecie, ale kiedy liczba trofofili w rozecie przekroczyła dziewięć, nie notowano wzrostu wysokości liści. Średnica rozet wynosiła od 21 do 156 mm (średnia 62,3 mm). Stwierdzono liniowy wzrost liczby trofofili wraz z wzrastającymi grubościami poszczególnych rozet. Liczba sporofili w rozecie wynosiła od 1 do 9 (w większości przypadków od 1 do do 5). Miały one wysokość od 22 do 84 cm, a większość z mierzyła od 40 do 60 cm. Wraz z wzrostem liczby i wysokości trofofili nastąpił znaczny liniowy wzrost liczby sporofili. Stwierdzono, że *M. struthiopteris* rozpoczęła produkcję sporofili, gdy liczba trofofili przekraczała 6, trofofille mierzyły ponad 100 cm, a grubość kłączy była większa niż 55 mm.

Zastosowanie technik ordynacyjnych (PCA, RDA) nie poskutkowało wyraźnym podziałem badanych powierzchni pod względem ich usytuowania przestrzennego. Zróżnicowanie składu florystycznego badanych populacji względem czynników środowiskowych przedstawiono za pomocą RDA. W teście Monte Carlo wykazano, że wpływ warunków środowiskowych na analizowane cechy badanych populacji *Matteuccia struthiopteris* jest istotny statystycznie dla pierwszej osi kanonicznej (p = 0.002; F =70,34). Wyjaśniono 58,3% zmienności w zbiorze cech populacji oraz aż 97,4% zróżnicowania cech populacji i zmiennych środowiskowych ujętych łącznie. W teście Monte Carlo wykazano, że wpływ pokrywy drzew jest istotny statystycznie (p = 0,002; F =10,34).

Introduction

Plants have developed a high degree of morphological plasticity in response to varied environmental conditions (COOK 1985, DE KROON et al. 1994, ELLISON et al. 2004, GRZYBOWSKI et al. 2004, 2005, GRZYBOWSKI and ENDLER 2008), therefore the plant growth standard represents the combined effect of all environmental variables. Population differences result from demographic transformations, and they take place in response to variations in habitat conditions. Ecological studies aim to objectively analyze the adaptation of a species to its specific environment. In the broadest sense, varied environmental factors lead to different types of plant reproduction (PEARS 1985). Mutual competition has been observed between sexually reproducing and asexually reproducing species, but the relative share of sexual and asexual

reproduction has been found to differ along the environmental gradient in certain species (ABRAHAMSON 1980).

Matteuccia struthiopteris is very well suited for population studies because the species produces separate frond rootstocks. The ostrich fern has two distinct leaf forms: trophophylls, which supply the plant with nutrients, and sporophylls, spore-producing leaves that are found separately. However, also hybrids between these may be frequent under certain environmental conditions.

The differences between ecological and / or spatial variations in natural plant populations have been studied in various fern species (e.g. ODLAND et al. 2006). In Lithuania (ODLAND et al. 2006), the variations in the production of *M. struthiopteris* sporophylls were significantly correlated with geographical location (distance from river bank), canopy cover and the floristic composition of the examined populations (ODLAND 2007).

The geographic range of *M. struthiopteris* covers Europe, Caucasus, Siberia, Central and Eastern Asia and North America. The southern range limit of the discussed species intersects Poland (PIĘKOŚ-MIRKOWA, MIREK 2003). In Poland, *M. struthiopteris* is relatively rare with anywhere from 101 to 500 growth sites (PIĘKOŚ-MIRKOWA, MIREK 2003). It is encountered mostly in the foothills of the Carpathians and the Pieniny Mountains, in the Western Sudetes (up to 600 m above sea level), Świętokrzyskie Mountains and Bieszczady (up to 720 m above sea level) (PIĘKOŚ-MIRKOWA, MIREK 2003). Scattered populations of *M. struthiopteris* have been observed in the regions of Roztocze, Masovia, Pomerania, Masurian Lakeland, Augustów Primeval Forest, Borecka Primeval Forest, on rivers Nysa and Bóbr and on Warmia Plain (in the floristic reserve of Pióropusznikowy Jar – Ostrich Fern Ravine, which is the object of this study). In Olsztyn area, the ostrich fern has been found on river Orzechówka and in Górowskie Hills (ENDLER et al. 2006). In Poland, *M. struthiopteris* colonizes the banks of streams, damp hill slopes, water-logged meadows and forest clearings. Its habitats are found mainly along river banks, often in oxbow lakes, on fertile and moist brown alluvial soils, humus-rich and stony soils (in the mountains) with weakly acidic to neutral pH (5.5–6.9) (PIĘKOŚ-MIRKOWA, MIREK 2003). The ostrich fern is sporadically encountered on weakly acidic brown gley soils. The species thrives in semi-shaded areas, but it tolerates full shade, the competition of tree roots and depleted soils. The ostrich fern produces extensive rhizomes, it frost resistant and sensitive to soil drying. The growth, development and morphology of *M. struthiopteris* has been described extensively by PRANGE et al. (1984), PRANGE and VON ADERKAS (1985), VON ADERKAS and GREEN (1986), ODLAND (1995, 2004) and ODLAND et al. (2006). The optimal habitat for the ostrich fern is nutrient-rich soil (base saturation optima between 56 and 64%) with a high moisture content (opti-

mum water content of 42.8%) (ODLAND et al. 1998, AARRESTAD 2002). The northern boundary of the species range is probably determined by summer temperature limits, but factors that affect the ostrich fern's distribution patterns in southern regions are more difficult to identify (PRANGE and VON ADERKAS 1985).

Studies of plant populations supply vital information about the analyzed species' environmental requirements and its response to changes in habitat conditions. Such data support evaluations of the species' future survival and the need for corrective actions in resource management policies. Many authors have noted that the characteristic traits of the analyzed populations play a key role in differentiating *M. struthiopteris* communities because they are susceptible to environmental changes (e.g. BERGERON and LAPOINTE 2001, DE KROON et al. 1994, KENKEL 1993, 1997, ODLAND 1992, 1995, 2004, ODLAND et al. 1998, 2004, 2006, PECK et al. 1990, PRANGE 1980, PRANGE et al. 1984, 1985, VON ADERKAS and GREEN 1986).

This study describes the relations between demographic, environmental and floristic profiles of *M. struthiopteris* populations colonizing the banks river Lisi Parów, with special emphasis on relative variation in resources allocated to sexual (sporophyll production) and asexual reproduction (production of new small ramets).

Materials and Methods

Study sites

The field study was carried out between July and September 2010 along a 20-km-long, afforested section of the Lisi Parów River. Thirty percent of the examined population of *M. struthiopteris* is found in the Pióropusznikowy Jar (Ostrich Fern Ravine) Nature Reserve. The surveyed area is located in the Region of Warmia, north-east Poland, and it is afforested in 100%. The Lisi Parów River is the hydrographic axis of the investigated river valley. In the surveyed region, the Lisi Parów River intersects an isolated forest complex enclosed by farm fields and meadows in a deep and steep erosion valley where local differences in elevation reach 50 m and the slope gradient exceeds 70° in the most extreme locations. The investigated area consists of largely natural riparian and beech forests which are grown for commercial purposes outside the reserve. The presence of helocrene springs which feed other water courses in the area is a characteristic feature of the examined valley.

Field methods and variables

This study examined a total of 17 plots on both sides of the river where *M. struthiopteris* was the dominant species (more than 75% of cover). A representative 2 x 2 m plot was randomly selected in each site to collect demographic data, perform morphological measurements and measure environmental variables.

Phytosociological data were acquired in each growth site, and a total of 17 phytosociological releves were collected with the use of the the Braun-Blanquet method (BRAUN-BLANQUET 1964). The releves analyses done based on the whole stand, covered an area of 120–600 m^2. Vascular plant taxa names follow RUTKOWSKI (2004).

The location of the analyzed plots was determined with the use of the Garmin SX60 portable GPS receiver with the accuracy of ±3–7 m (depending on satellite signal strength). The obtained data and the information about the location of fern plots relative to the river (right/left bank, river terrace (rt)/river valley (rv)/river bank (rb) were included as nominal explanatory variables.

The abundance of every vascular plant species was determined to analyze the correlations between morphological and demographic profiles of *M. struthiopteris* and its floristic composition. The total cover of canopy layers were estimated in percentage for each plots. Slope was measured in degrees.

M. struthiopteris is a clonal plant, and all rootstocks within a population may genetically represent the same genome. In this study, we investigated the morphological and demographic traits of various rootstocks within samples. The fern produces both fertile (sporophyll) and sterile (trophophyll) leaves. The following morphological traits were analyzed in each rootstock: number of trophophylls (nT), number of sporophylls (nS), sporophyll height (hS), trophophyll height (hT) and rootstock diameter (dR).

The following demographic variables were calculated in each quadrat: number of rootstocks (nR), height of the tallest frond in the rootstock (hTmax), total number of rootstocks in the quadrat (nF), mean trophophyll height in the quadrat (mTh), mean number of trophophylls in the quadrat (mnT), mean rootstock diameter in the quadrat (mdR), maximum rootstock diameter in the quadrat (maxR), number of trophophyll-producing rootstocks shorter than 6 dm (n6), number of trophophyll-producing rootstocks taller than 12 dm (n12), number of rootstocks with diameter smaller than 2 cm (d2), number of rootstocks with diameter larger than 10 cm (d10) and percentage of sporophyll-producing rootstocks (F).

Statistical analyses

Simple regression analysis was used to investigate the relationship between demographic trait of the population. These analysis were performed using Statistica 7.1 for Windows application. Differences between demographic trait of the population the means of two independent samples were verified by the Mann-Whitney U-test at the significance level of $p = 0.05$.

The results have been presented with the use of two ordination techniques. The above procedure was adopted to verify the structure of the examined data set based on eigenvalues (SD) and determine whether the studied set had a linear or a unimodal character (TER BRAAK and SMILAUER 2002, PIERNIK 2003). A preliminary detrended correspondence analysis (DCA) revealed the first gradient length of 1.38 SD, indicating that models based on linear species response models were appropriate for the data structure (TER BRAAK and SMILAUER 1998, LEPŠ and ŠMILAUER 2007).

The contemporary *M. struthiopteris* pulation in 17 plots was explored using redundancy analysis (RDA), a constrained form of principal component analysis (Hotelling 1933) in CANOCO (TER BRAAK and ŠMILAUER 2002). The following demographic variables were used in PCA/RDA: number of rootstocks (nR), height of the tallest frond in the rootstock (hTmax), total number of rootstocks in the quadrat (nF), mean trophophyll height in the quadrat (mTh), mean number of trophophylls in the quadrat (mnT), mean rootstock diameter in the quadrat (mdR), maximum rootstock diameter in the quadrat (maxR), number of trophophyll-producing rootstocks shorter than 6 dm (n6), number of trophophyll-producing rootstocks taller than 12 dm (n12), number of rootstocks with diameter smaller than 2 cm (d2), number of rootstocks with diameter larger than 10 cm (d10) and percentage of sporophyll-producing rootstocks (F). In addition, the RDA as environment variables adopted: canopy cover (canopy), indices hill slopes (slope) and position relative to the river [river bank(rb), river valey (rv)]. Statistical significance tests were carried out using Monte Carlo permutation tests. A Monte Carlo test was used to examine the significance of axis eigenvalues generated in the analysis and the species-environmental correlation (using 5000 unrestricted iterations).

Results

In total, 507 rootstocks were measured, and they had developed a total of 4007 trophophylls and 324 sporophylls. *M. struthiopteris* populations colonizing the examined river section were characterized by morphological vari-

ations. Trophophyll height ranged from 22 to 159 cm, and one ramet contained 1 to 16 trophophylls. Trophophyll height was not correlated with the number of trophophylls in a rootstock, but when the number of trophophylls exceeded nine, there was no general increase in frond height (Figure 1, Table 1).

May be it would be easier for the reader that some of the statistical analyses were given in a table?

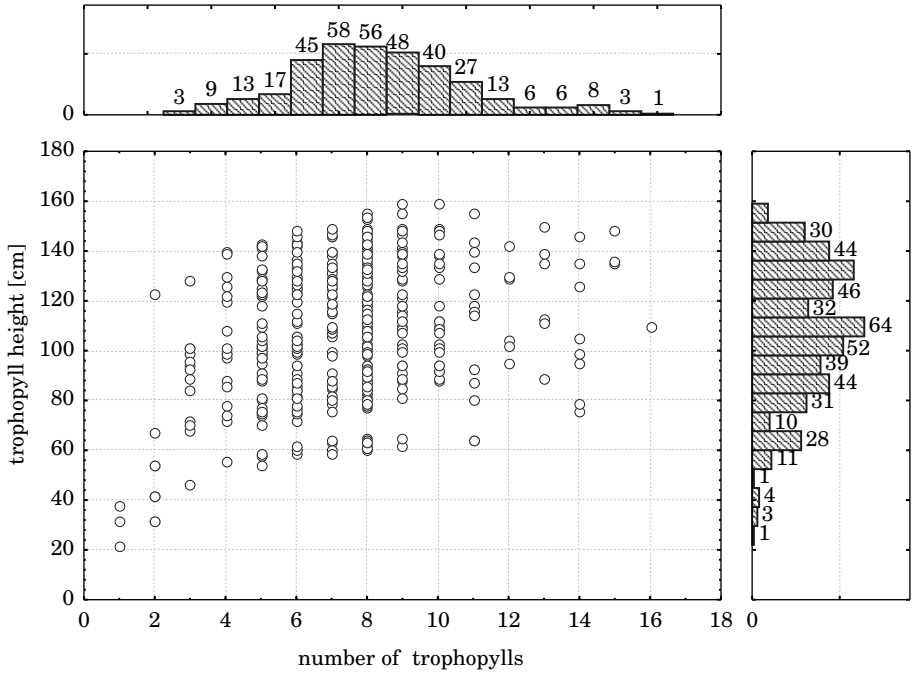

Fig. 1. Relationship between the number of trophophylls and trophophyll height in 507 rootstocks. The figure also shows size distribution histograms

Table 1

Geographic location of the studied populations and demographic data from the sampled quadrats (Q)

Q	Size	nR	mTh	mnT	mhS	mdR	maxR	N6	N12	nS	nF	D2	D10	F%	Canopy cover
1.	200	18	113.5	9.5	48.2	54.6	100	1	3	6	5	1	2	27.8	21
2.	120	19	110.4	9.6	47.2	54.2	99	1	2	5	4	0	2	26.3	48
3.	220	21	122.5	9.7	49.3	77.2	104	1	2	3	3	0	2	14.3	31
4.	180	12	92.2	6.4	46.3	50.3	98	2	0	3	3	0	0	25.0	31
5.	320	22	127.2	10.2	52.3	80.2	120	0	4	6	4	0	4	18.2	33
6.	280	19	117.7	7.6	49.5	74.3	112	2	2	4	4	1	2	21.1	45
7.	360	23	139.2	10.6	57.5	84.6	119	0	12	12	8	0	6	34.8	35
8.	330	22	138.5	10.1	56.9	80.9	120	0	19	16	8	0	5	36.4	37
9.	310	19	118.2	8.3	50.3	62.0	96	3	6	4	4	1	0	21.1	38
10.	190	17	102.8	7.9	44.3	60.2	96	3	0	3	3	1	0	17.6	51
11.	160	11	100.2	5.6	–	59.2	91	0	1	0	6	0	0	0.0	51
12.	340	22	108.2	8.1	–	61.9	92	2	2	0	0	0	0	0.0	53
13.	380	25	98.4	7.6	42.0	60.5	90	5	0	10	8	0	0	32.0	53
14.	600	24	88.8	6.0	–	50.3	89	0	0	0	0	0	0	0.0	53
15.	230	17	64.2	5.8	–	46.2	80	9	0	0	0	0	0	0.0	54
16.	120	13	88.0	5.8	38.5	52.3	86	6	0	2	2	0	0	15.4	54
17.	190	16	72.2	6.2	–	50.1	82	6	0	0	0	0	0	0.0	59
Mean	–	19	106.7	7.9	48.5	62.3	98	2	3	4	4	0	1	17.1	48
SD	–	4	21.9	1.8	5.5	12.4	13	3	5	5	3	0	2	12.9	10.7

Q – quadrats: 1 – oNRd rt; 2 – oNRd rt; 3 – oNRd rv; 4 – oNRd rb; 5 – oNRd rv; 6 – oNRd rv; 7 – NR rv; 8 – NR rv; 9 – NR rv; 10 – NR rt; 11 – NR rb; 12 – oNRu rv; 13 – oNRu rv; 14 – oNRu rv; 15 – oNRu rt; 16 – oNRu rb; 17 – oNRu rt; NR = nature reserve; oNRd = Off – nature reserve downstream; oNRu = Off – nature reserve upstream; rb = river bank, rt = river terrace, rv = river valley. Size = approximate population size in m^2; SD – standard deviation, for an explanation of demographic abbreviations, refer to Materials and Methods

Rootstock diameter varied from 21 to 156 mm (average of 62.3 mm), and the number of emerging trophophylls showed a is positive correlated with the thickness of each rootstock ($r^2 = 40.1$; $p < 0.0001$) – Figure 2.

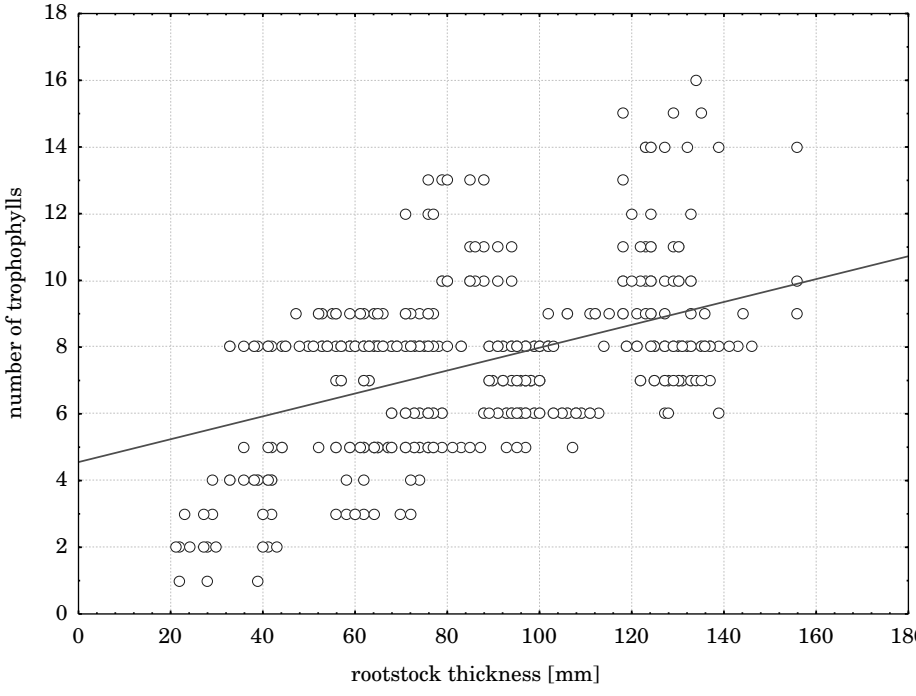

Fig. 2. Relationship between rootstock diameter and the number of trophophylls. A fitted linear regression line is shown

A positive correlated was reported between the number of trophophylls and rootstock thickness ($r^2 = 51.0$; $p < 0.0001$). There were 1 to 9 sporophylls per rootstock, and most ramets had from 1 to 5 sporophylls. Plants with trophophylls shorter than 90 cm and rootstocks smaller than 50 mm in diameter also produced sporophylls, but above those thresholds, there was a general increase in the number of trophophylls per plant (Figure 3 and Figure 4).

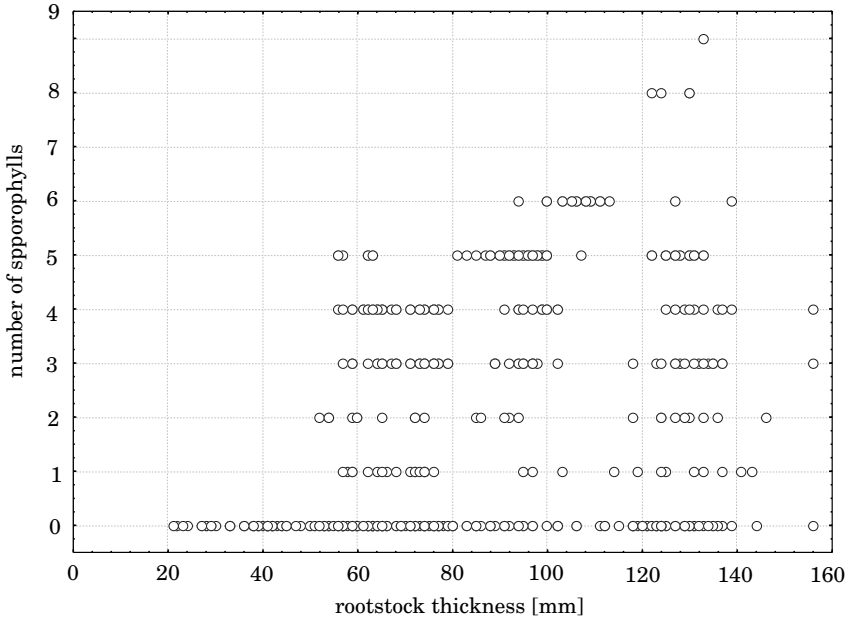

Fig. 3. Relationship between rootstock diameter and the number of developed sporophylls

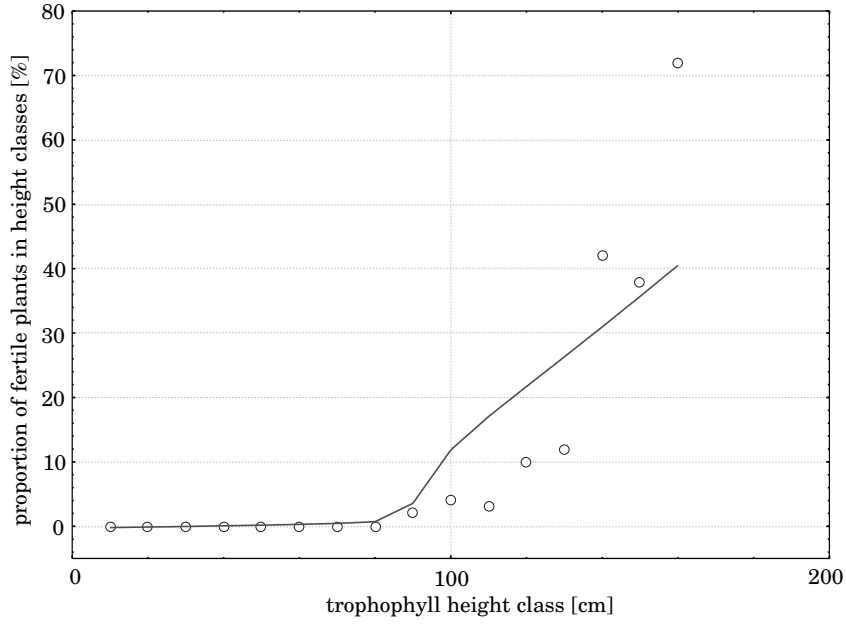

Fig. 4. The proportion of sporophyll-producing rootstocks in different trophophyll size classes. A locally weighted scatterplot smoothing line (LOWESS) is shown

Sporophyll height was determined in the range of 22 and 84 cm, but the majority of sporophylls measured from 40 to 60 cm. (Figure 5) A significant linear increase in the number of sporophylls was observed with an increase in the number of trophophylls (r^2 = 46.1, p < 0.0001) and an increase in trophophyll height (r^2 = 46.4, p < 0.0001), but the tallest sporophylls were noted in ramets where trophophylls reached the height of 130 to 150 cm. In general, the production of *M. struthiopteris* sporophylls began upon the emergence of more than six trophophylls higher than 100 cm and when rhizome thickness exceeded 55 mm.

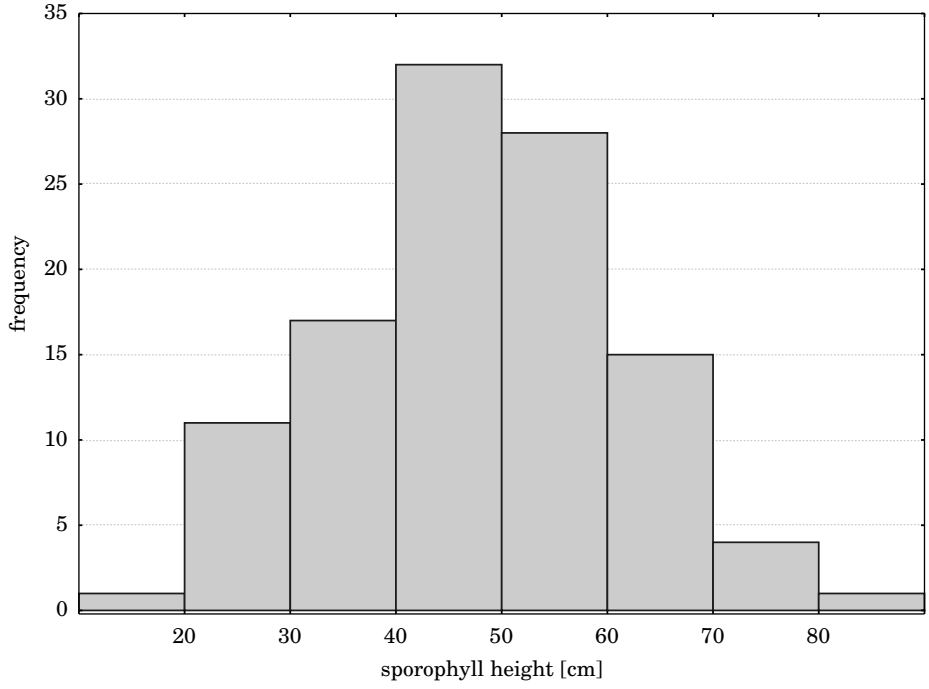

Fig. 5. Histogram of sporophyll size distribution

All of the studied populations had tree canopy cover or they occupied canopy gaps. A higher number of rootstocks measuring less than 2 cm in diameter was reported in areas where canopy cover was 30% lower in comparison with the remaining sites (U = 68.6; p = 0.05). The following vascular plants were most frequently associated with *M. struthiopteris* in the 17 analyzed stands are shown in Table 2.

Table 2
The frequency of vascular plants associated with *M. Struthiopteris* in the 17 analyzed stands

Species	Frequency [%]
Matteucia struthiopteris (L.) Todaro	100
Aegopodium podagraria L.	71
Urtica dioica L.	65
Myosoton aquaticum (L.) Moench	47
Equisetum pratense Ehrh.	41
Alnus glutinosa (L.) Gaertn.	41
Corylus avellana L.	41
Oxalis acetosella L.	41
Glechoma hederacea L.	35
Aconitum variegatum L.	35
Padus avium Mill.	35
Rubus idaeus L.	35
Fagus silvatica L.	35
Chaerophyllum aromaticum L.	29
Circaea lutetiana L.	29
Anemone nemorosa L.	24
Asarum europaeum L.	24
Impatiens parviflora DC	24
Fraxinus excelsior L.	24
Neottia nidus-avis (L.) Rich	18
Aconitum variegatum L.	18
Actaea spicata L.	18
Campanula latifolia L.	12
Cardamine flexuosa L.	12
Daphne mezereum L.	6
Platanthera bifolia (L.) Rich.	6

Show the results of the DCA analyses: gradient length and eigenvalues for the main axes. Why not show the species and their frequency in a table?

The correlations between population variables were tested by PCA with the use of data collected from all experimental plots (Figure 6, Table 3). A relatively small difference in eigenvalues of the first and second axes indicates that the variables characterizing those axes had a similar effect on variations in the studied population.

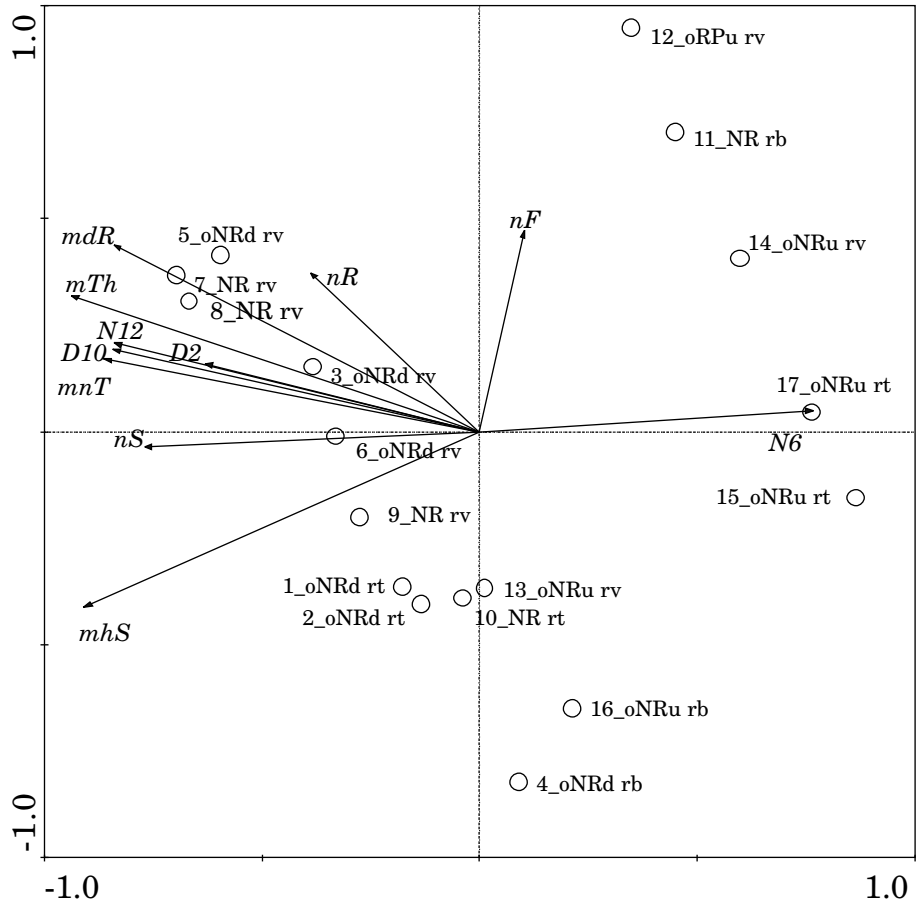

Fig. 6. Distribution of *Matteuccia struthiopteris* populations based on principal component analysis (PCA) results and demographic and morphological traits of the analyzed plots. For an explanation of demographic abbreviations, refer to Materials and Methods

The applied ordination methods did not classify the studied quadrants with regard to their spatial location (upstream/downstream; river bank/river terrace/river valley).

The calculated correlations revealed environmental variables that were most closely linked with the first two PCA axes. Axis 1 explained 81.4% of total variance in population traits (Table 3).

Variations in the floristic composition of the studied populations relative to environmental factors were investigated by RDA (Figure 7). The RDA shows the importance of different environmental and explanatory variables in order to explain the variation in population variables. The Monte Carlo test (Table 4) revealed that environmental factors had a significant impact on

Table 3
Results of principal component analysis (PCA) *Matteucia struthiopteris* in the 17 analyzed stands

AXES	1	2	3	4	Total variance
Eigenvalues	0.814	0.140	0.020	0.012	1.000
Cumulative percentage variance of species data	81.4	95.4	97.4	98.6	–
Sum of all eigenvalues variables correlated with axis 1	–	–	–	–	1.000
Species scores (adjusted for species variance)					
AXES NAME	1	2	3	4	Weight
nR	-0.3906	0.3736	-0.2963	0.7239	1.00
mTh	-0.9402	0.3196	0.1152	0.0185	1.00
mnT	-0.8648	0.1696	0.0788	0.2060	1.00
mhS	-0.9100	-0.4136	-0.0227	-0.0014	1.00
mdR	-0.8426	0.4370	-0.2901	-0.1199	1.00
N6	0.7654	0.0493	-0.2034	0.2760	1.00
N12	-0.8413	0.2071	0.0139	0.0511	1.00
nS	-0.7714	-0.0371	-0.2235	0.3489	1.00
nF	0.1023	0.4727	-0.5337	0.0523	1.00
D2	-0.6308	0.1592	-0.1268	0.0039	1.00
D10	-0.8441	0.1923	-0.1016	0.1185	1.00

For an explanation of demographic abbreviations, refer to Materials and Methods

the analyzed traits of *M. struthiopteris* populations for the first canonical axis. The eigenvalues of the first two axes were 1 = 0.809 and 2 = 0.621, and they explained 68.3% of variance in the data set of population traits and 97.4% of variance in population traits as well as environmental variables. The results of the Monte Carlo test revealed that canopy cover was a significant variable for 4 canonical axes (Table 4).

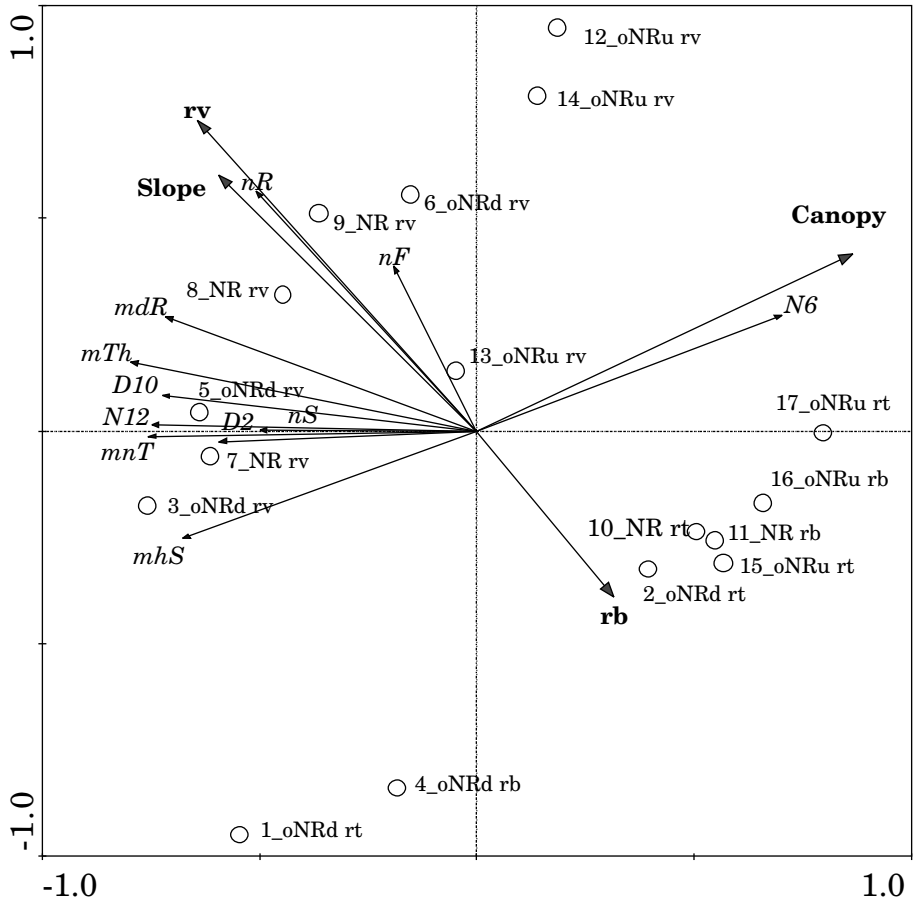

Fig. 7. Scatterplot showing the location of 17 plots relative to redundancy analysis (RDA) axes 1 and 2. For an explanation of demographic abbreviations, refer to Materials and Methods

Table 4

Results of redundancy analysis (RDA) forward selection conditional effects

Analyses variables	λ	P	F
Canopy	0.41	0.002	10.34
rv	0.16	0.022	5.30
Slope	0.02	0.570	0.51
rb	0.01	0.702	0.36
AXIS 1	0.06	0.002	70.34
AXIS 2	0.06	0.376	2,44
AXIS 3	0.05	0.216	1.37
AXIS 4	0.02	0.732	0.60

λ conditional effect, Canopy – canopy cover, rb – river bank, rv – river vlley; statistical significance was assessed by < 500 permutations

Discussion

In a phytosociological study, the populations colonized *Ficario-Ulmetum* ash-alder streamside forests in the river terrace (rt) and *Galio odorati-Fagetum* lowland beech forests (in the river valley (rv). A total of 48 vascular plant species were reported in 17 sites. The number of tracheophytes varied from 6 to 21, with an average of 12.6 plants per 1 m^2. Similar values were reported in Norway (ODLAND 1992) and Lithuania (ODLAND et al. 2006). No significant correlations were observed between variations in species composition and the studied sites location relative to the river.

M. struthiopteris has been characterized as a half-shade adapted plant (ZARZYCKI et al. 2002) with an Ellenberg light factor of 3 half-shade. Both excessive and insufficient exposure to light could hinder optimal development of the species. In the studied populations of the Lisi Parów River, canopy cover varied between 10 and 90%. In selected sites, tree and shrub canopies were too dense to support optimal fern growth. The affected plants developed short trophophylls, and their sporophyll production was low (e.g. quadrats in the upper right corner of Figure 7). In Canada, only 1% of sporophyll-producing plants were found in shaded sites (PRANGE and VON ADREKAS 1985). Lower canopy cover density and greater exposure to direct sunlight seem to boost the reproductive performance of *M. struthiopteris*. In this study, a higher number of rootstocks measuring less than 2 cm in diameter was reported in areas where canopy cover was 30% lower in comparison with the remaining sites. Similar results were reported by other researchers (PRANGE and VON ADERKAS 1985, VON ADERKAS and GREEN 1986, BERGERON and LAPOINTE 2001). According to PRANGE and VON ADERKAS (1995), plant survival rates decreased with an increase in light intensity. Although the results of our study do not support the above conclusion, a number of observed trends could validate this hypothesis in a multi-year study. In two of the examined sties with canopy cover of less than 80%, a large number of brown fern trophophylls performed assimilative functions, it is believed that hybrids between trophophylls and sporophylls. A high share of herbs and shrubs in canopy cover (mainly *Frangula alnus*) probably inhibited the reinstatement of *M. struthiopteris* individuals. The above observation is validated by the results of an experiment carried out by DYKEMAN (1981).

Our findings indicate that forest management practices should be continuously monitored to prevent excessive clearance of *Matteucia struthiopteris* growth sites, which poses a particular threat to populations encountered outside nature reserves. The results will be the basis for extending the borders reserve "Pióropusznikowy Jar". Tree maintenance should be a gradual process to guarantee the survival *Matteucia struthiopteris* which readily

adapts to the local light regime and may remain in a state of secondary dormancy for one to three years (NAUJALIS 1995).

Demographic data revealed variations between *Matteucia struthiopteris* populations. The analyzed sites along river Lisi Parów were generally colonized by large plants, but plant density was low. There was an average of 5.4 rootstocks per unit of plot area (1 m^2) with mean trophophyll height of 106.7 cm. Trophophyll height is an indicator of plant age (ODLAND 2004). Trophophylls in the examined sites along river Lisi Parów were generally higher than those investigated in Canada and Norway (VON ADERKAS and GREEN 1986, ODLAND 2004), but somewhat shorter than Lithuanian specimens (ODLAND et al. 2006). In Canada, the mean rootstock density was 8 to 10 (KENKEL 1997) with mean trophophyll height of 90 cm (VON ADERKAS and GREEN 1986), whereas Lithuanian populations were characterized by mean trophophyll height of 116 cm and an average of 3 rootstocks per area unit (ODLAND et al. 2006).

Matteucia struthiopteris is capable of both sexual and asexual reproduction. In this experiment, we did not observe plants developed from gametophytes, and similar findings were reported by authors who studied other regions (PECK et al. 1990, KENKEL 1997, ODLAND 2004).

The mean rootstock diameter was 62.3 mm, which is below the values noted in Lithuania (68.7 mm) (ODLAND et al. 2006) and higher than the results reported in Canada (43 mm) (VON ADERKAS and GREEN 1986). According to Prange and VON ADERKAS (1985) as well as VON ADERKAS and GREEN (1986), fern rootstocks have to reach a certain age or developmental phase to produce sporophylls. Developed sporophylls were rarely observed in rootstocks with a diameter smaller than 4 cm and trophophylls shorter than around 120 cm (ODLAND 2004). The above values may be achieved three years after rootstock formation, but even then, sporophylls are not produced every year (PRANGE and VON ADERKAS 1985, VON ADERKAS and GREEN 1986, KENKEL 1997). A close linear correlation generally exists between trophophyll height, rootstock diameter and sporophyll production (VON ADERKAS and GREEN 1986, ODLAND et al. 2006). A ramet may produce from one to nine sporophylls per year, but only 4% of rootstocks in fertile habitats were found to produce more than six sporophylls (ODLAND 2004). Our results confirm that an increase in the number of sporophylls was correlated with an increase in the number of trophophylls and trophophyll height in the studied populations. In general, the production of *M. struthiopteris* sporophylls began upon the emergence of more than six trophophylls taller than 100 cm and when rhizome thickness exceeded 55 mm, a minimum number of trophophyll beyond which is a strong increase of sporophylls has also been observed for other ferns as *Osmunda regalis* (LANDI and ANGIOLINI 2010)

KENKEL (1997) suggested that some rootstocks are "programmed" for fertility, whereas the majority of clonal plants remain sterile. Annual fluctuations in the number of rootstocks and sporophyll production were not observed in dense populations (NAUJALIS 1995, KENKEL 1997). In a five-year study, KENKEL (1997) demonstrated a low variation in the number of fertile and sterile rootstocks (around 5%) per studied quadrant (25 m^2). The above experiment revealed that the number of sporophyll-producing rootstocks guaranteed species survival, and rootstock fertility ranged from 0.45 to 4.45% throughout the period of the study. The cited author also observed positive and statistically significant correlations between the number of vegetative fronds produced by rootstocks over time. Multi-annual research is needed to verify Kenkel's findings, and subjective observations seem to validate the need for such investigations.

The studied populations along the banks of river Lisi Parów were characterized by a small number of new rootstocks and a high share of sporophyll-producing ramets (up to 33.5%, 14.7% on average). Similar results were noted in Lithuania (ODLAND et al. 2006) where the analyzed populations had a small number of new rootstocks, a high percentage of sporophyll-producing ramets (up to 54.5%) and a mean fertility rate of 14.8%. In Canada, VON ADERKAS and GREEN (1986) found that 17% of the plants produced sporophylls, whereas in Kenkel's study, rootstock fertility varied from 0.45 to 4.45% (KENKEL 1997). The above findings are consistent with plant behavior patterns noted along temperature gradients which show that plants are more likely to reproduce asexually at low temperatures (ODLAND et al. 2004).

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WATER QUALITY AND PHYTOPLANKTON COMMUNITY IN SELECTED RECREATIONAL LAKES AND RESERVOIRS UNDER RESTORATION MEASURES IN WESTERN POLAND*

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K e y w o r d s: nutrients, phytoplankton, recreational lakes, restoration measures.

A b s t r a c t

The goal of our studies was to determine the taxonomic composition of phytoplankton and physico-chemical water properties in selected lakes and reservoirs in Western Poland to estimate the influence of restoration measurements. Polimictic Maltański Reservoir (restored by means of phosphorus inactivation and biomanipulation) was characterized by increased concentrations of ammonium nitrogen as well as chlorophyll a (over 100 $\mu g\ l^{-1}$ in autumn 2011), related to cyanobacteria bloom. Slightly lower values of chlorophyll-a were noted in Sławskie Lake (ca. 42 $\mu g\ l^{-1}$, sewage inflow divertion), where organic nitrogen and orthophosphate content increased in time in analyzed season. Lowest concentrations of phosphorus were noted in Głębokie Lake (aeration and phosphorus inactivation), while a little bit higher were observed in polimictic Turawa Średnia Reservoir (also aeration and phosphorus inactivation). The latter water body was characterized by some increases in the abundance of cyanobacteria in warm months.

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JAKOŚĆ WÓD I SKŁAD FITOPLANKTONU WYBRANYCH, WYKORZYSTYWANYCH REKREACYJNIE I REKULTYWOWANYCH ZBIORNIKÓW I JEZIOR ZACHODNIEJ POLSKI

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S ł o w a k l u c z o w e: związki mineralne, fitoplankton, jeziora wykorzystywane rekreacyjnie, zabiegi rekultywacyjne.

A b s t r a k t

Celem pracy było określenie składu taksonomicznego fitoplanktonu oraz fizyczno-chemicznych cech jakości wody wybranych jezior i zbiorników wodnych o walorach rekreacyjnych położonych w zachodniej Polsce. Określono także wpływ podjętych w nich działań rekultywacyjnych. Polimiktyczny Zbiornik Maltański (rekultywowany metodą inaktywacji fosforu i biomanipulacji) cechowały wysokie stężenia azotu amonowego oraz najwyższa spośród badanych akwenów koncentracja chlorofilu a, wynosząca ponad 100 μg l^{-1} jesienią 2011 r., związana z sinicowym zakwitem wody. Nieco niższa zawartość barwnika cechowała dimiktyczne Jezioro Sławskie (ok. 42 μg l^{-1}, wyeliminowanie dopływu ścieków), w którym w sezonie wegetacyjnym wzrastały stopniowo stężenia azotu organicznego i ortofosforanów. Najniższe zawartości fosforu notowano w Jeziorze Głębokim (natlenianie i inaktywacja fosforu), niewiele wyższe w polimiktycznym Zbiorniku Turawa Średnia (również natlenianie i inaktywacja fosforu). Ostatni z akwenów cechowały zwiększone liczebności sinic w cieplejszych miesiącach.

Introduction

Many water bodies in Western Poland suffer from harmful phytoplankton blooms as a result of increased nutrient concentrations. This phenomenon limits recreational exploitation by means of angling, boating and swimming, therefore restoration treatment is conducted by local authorities. The goal of our studies was to determine the taxonomic composition of phytoplankton and physico-chemical water features in selected lakes to estimate the influence of restoration measurements.

Materials and Methods

Four water bodies situated in Western Poland were studied. Lake Sławskie, located in Lubuskie province is characterized by greatest water surface area and depth among studied reservoirs (Figure 1). Głębokie Lake in Szczecin and

Maltański Reservoir in Poznań have maximum depth ca 5 m, whilst Turawa Średnia Reservoir near Opole is shallowest. Only Sławskie Lake is dimictic, the others are polimictic. All water bodies are used for recreational purposes. Sławskie Lake is surrounded by multiple holiday resorts and as the greatest lake in region, is famous for sailing. Głębokie Lake due to the nearness of Szczecin is a popular swimming and resting area for inhabitants. The same role is played by Turawa Średnia for Opole citizens. Maltański Reservoir is used for international canoeing and rowing boats competitions. Due to low water quality expressed by phytoplankton blooms restoration treatments are conducted. The measures are based on water aeration (wind-driven pulverizing aerator on Głębokie Lake and Turawa Średnia Reservoir, in the first lake coupled with biomanipulation) or mobile aeration with phosphorus inactivation (Maltański Reservoir, coupled with biomanipulation). In the case of Lake Sławskie sewage inflow was diverted from the lake in 2008.

No.	Surface area [ha]	Max. depth [m]	Mean depth [m]
1	31	5	2.4
2	64	5	3.1
3	817	12.3	5.2
4	17	4	3

Fig. 1. The location of study objects: *1* – Głębokie Lake, *2* – Maltański Reservoir, *3* – Sławskie Lake, *4* – Turawa Średnia Reservoir

The phytoplankton composition as well as selected water properties were analyzed monthly from April to October 2011 in surface water layer. Concentrations of nitrogen and phosphorus forms and chlorophyll a were analyzed spectrophotometrically, according to standard methods (ELBANOWSKA et al. 1999). Phytoplankton composition and abundance were analyzed in Sedgwick-Rafter chambers in Olympus microscope and 5 ml sedimentation chambers with inverted microscope.

Results and Discussion

Mineral nitrogen concentrations differ among studied water bodies. The highest values were observed in Maltański Reservoir, whilst in other lakes values were similar (Figure 2a). Ammonium nitrogen dominated among

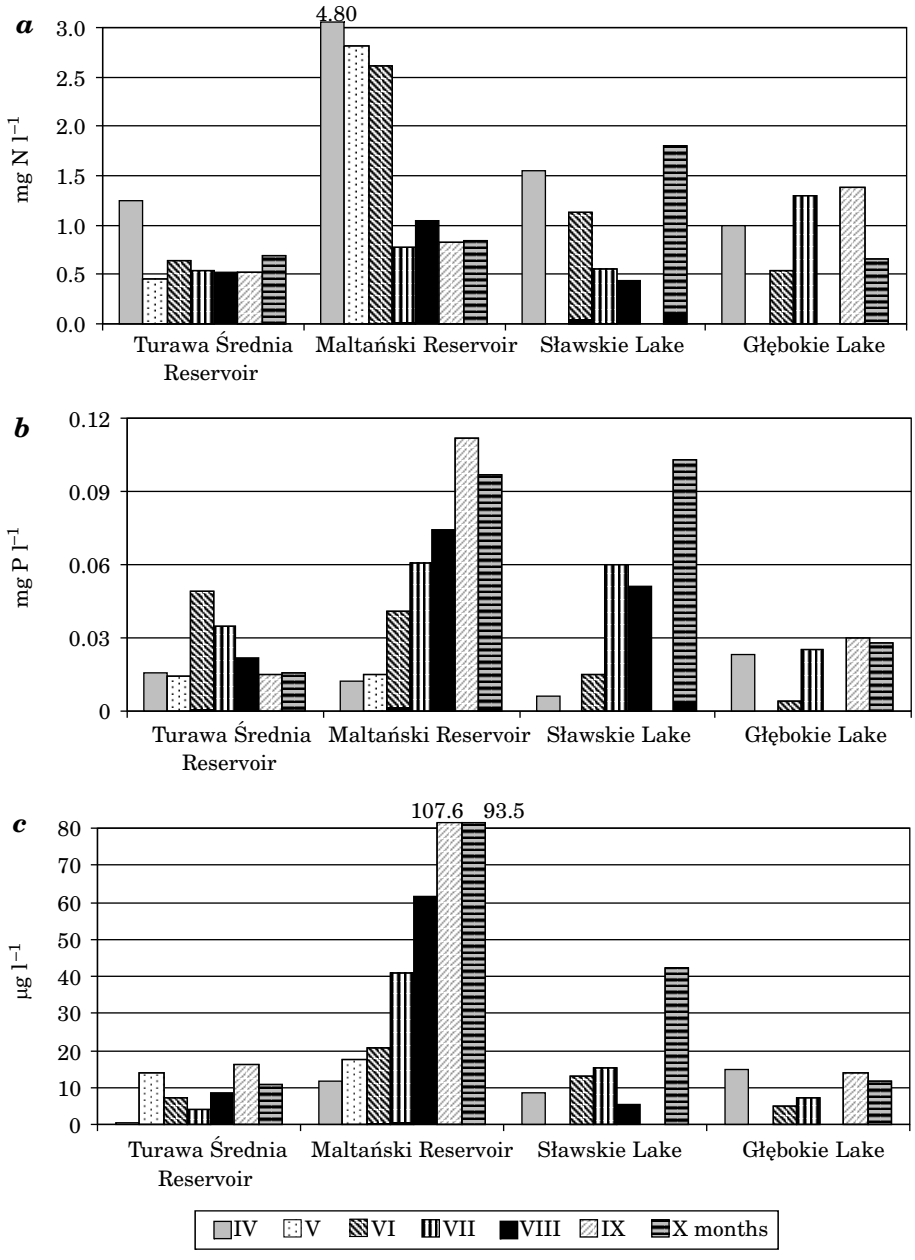

Fig. 2. The concentrations of mineral nitrogen (*a*), orthophosphates (*b*) and chlorophyll a (*c*) in particular months in analyzed lakes and reservoir

mineral nitrogen forms in studied lakes. Only in Maltański Reservoir from April to June the contribution of ammonium nitrogen varied from 14 to 35% of mineral nitrogen (the rest was nitrate nitrogen), while in the rest of months and in other lakes 100% of mineral nitrogen was ammonium. The highest amounts were found in Maltański Reservoir (over 1 mg $N\text{-}NH_4$ l^{-1}), therefore the mean value in analyzed period reached 0.87 mg $N\text{-}NH_4$ l^{-1}. In other water bodies ammonium concentrations usually did not exceed 0.7 mg $N\text{-}NH_4$ l^{-1}. This difference is a result of river water external loading. Maltański Reservoir is loaded by fertile waters of Cybina River (DONDAJEWSKA et al. 2010, KOZAK et al. 2009, KOZAK and GOŁDYN 2004). Turawa Średnia Reservoir and Głębokie Lake are not throughflow, which decreases the negative impact of catchment. In case of Sławskie lake, sewage inflow to Czernica River was directed into drainage fields, what significantly diminished nutrient concentrations, both in river and Sławskie Lake. The ecological state improved from weak in 2009 to moderate in 2010 (www. zgora.pios.gov.pl). Nitrite nitrogen concentrations were low in all water bodies, as this form of mineral nitrogen is intermediate in transformation from ammonia to nitrates in nitrification process, occurring with no obstacles in oxygen conditions in surface water layer. The uptake by phytoplankton influenced nitrates concentrations, which were in all lakes usually below detectable values. Only in Maltański Reservoir, nitrate nitrogen was found in spring (over 4 mg $N\text{-}NO_3$ l^{-1}), what was affected by runoff from agriculture catchment of Cybina River (DONDAJEWSKA et al. 2010) and influenced significantly the content of mineral forms at that period (Figure 2a).

Orthophosphates concentrations were lowest in Turawa Średnia Reservoir and Głębokie Lake, usually not exceeding 0.03 mg P l^{-1}. Such values were already observed in Głębokie Lake in systematical analyzes during intensive restoration, including also mobile water aeration with PIX application in 2008 and 2009 (HOLONA 2010). Higher values were noted in Turawa only in June and July, what indicates the impact of internal loading from bottom sediments in warm summer days (Figure 2b). Much greater content of bioavailable phosphorus was noted in Maltański Reservoir and Sławskie Lake. In hte reservoir concentrations increased gradually in time, reaching over 0.1 mg P l^{-1} in autumn. This phenomenon was a result of intense riverine water external loading, playing a crucial role especially in case of Maltański Reservoir (KOWALCZEWSKA-MADURA 2003). Additionally, internal loading was responsible for increased phosphorus content in water as anaerobic conditions were noted in over bottom water layer in windless summer days. A significant increase of orthophosphates concentrations in Sławskie Lake during autumn may be a result of water circulation and therefore, loading of fertile hypolimnetic water.

The amount of nutrients influenced the chlorophyll-a content. Very high amounts were observed in Maltański Reservoir from August till October, exceeding 100 μg l^{-1} (Figure 2c), what indicates not sufficient restoration treatment. 2011 was a third year in a 4-year period of intervals of water flushing in and out of the reservoir. Hence, the proportion of predatory fish to non-predatory was unfavorable in the light of biomanipulation. Similar situations were noted in previous years as a result of income of non-predatory fish to reservoir with Cybina waters (ANDRZEJEWSKI et al. 2010). Increased values of chlorophyll-a were also stated in Sławskie Lake in the same season (ca. 42 μg l^{-1}) as an answer to nutrient load from hypolimnion. In the rest of water bodies chlorophyll a content shaped on the level below 17 μg l^{-1}, remaining with relation to lower nitrogen and phosphorus concentrations (Figure 2c).

The dynamic changes in the abundance of the phytoplankton were noted in the investigated period. In the springtime chrysophytes, diatoms and chlorophytes were the most abundant in the investigated lakes and reservoirs (Figure 3*a*). In Głębokie Lake (in April) the most numerous species was *Erkenia subaequiciliata* Skuja. The most abundant phytoplankton organism reached $15.9 \cdot 10^3$ cells ml^{-1}. *E. subaequiciliata* can occur in the water at all times of the year, although it is usually noted in high densities in winter e.g in Maltański Reservoir in December 1995 (KOZAK 2005). The same species was also noted in the other investigated water bodies, but less abundant. It reached $4.1 \cdot 10^3$ cells ml^{-1} in Sławskie Lake in October and $7.3 \cdot 10^3$ cells ml^{-1} in June in the Maltański Reservoir, whilst only 200 cells ml^{-1} in Turawa Średnia Reservoir in November.

The highest density of phytoplankton was noted in the Maltański Reservoir, where the maximum value was found in September, reaching $60 \cdot 10^3$ org. ml^{-1} (Figure 3*b*). The intensive development of cyanobacteria in Maltański Reservoir was noted from July until the end of vegetative season. The most numerous was *Pseudanabaena limnetica* Lemmermann from Geitler. Other taxa such as *Aphanizomenon gracile* Lemmermann, *Limnothrix redeckei* (Van Goor) Meffert and *Planktolyngbya limnetica* (Lemmermann) J. Komárková-Legnerová & Cronberg were also important, but less numerous. These are common species and usually cause water blooms in eutrophic reservoirs and lakes (KOZAK 2009, PEŁECHATA et al. 2009) They are potentially toxic (MARIE et al. 2012), therefore may be dangerous for animals and humans (LEDREUX 2010). Toxins from decaying cyanobacteria may affect water quality, and render the water unsafe for recreational purposes.

The restoration procedures overtaken in the reservoir (biomanipulation and chemical reagents used for phosphorus inactivation based on iron(III) sulphate) to decrease development of phytoplankton, especially cyanobacteria (KOZAK et al. 2009, DONDAJEWSKA et al. 2010) were insufficient in this period.

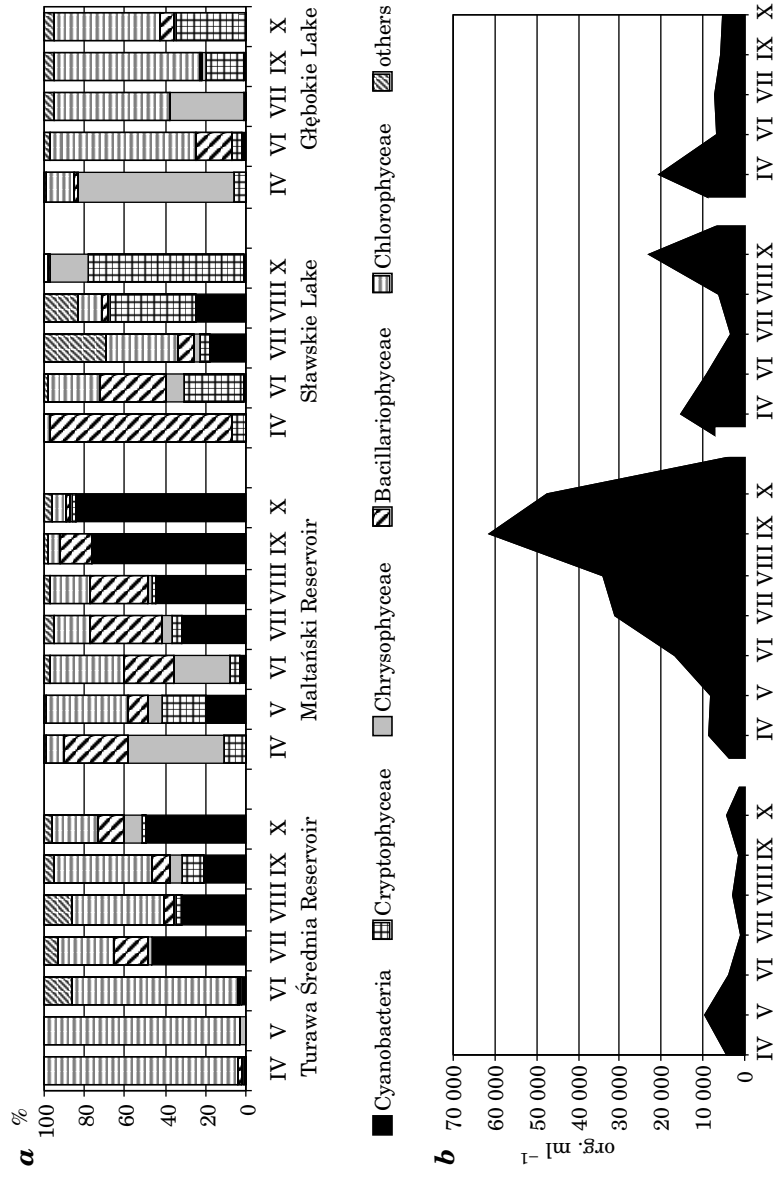

Fig. 3. The contribution of particular phytoplankton groups (*a*) and their abundance (*b*) in the surface water layer of the investigated lakes and reservoirs

In the rest of the investigated lakes the abundance of cyanobacteria were lower. In Turawa Średnia this group of phytoplankton developed from August to October (achieving maximally 2000 org. in 1 ml, dominant species was *Anabaena flos-aquae* Brebisson). In both, Sławskie and Głębokie lakes cyanobacteria were rarely noted (Figure 3a). In these lakes other groups of phytoplankton were developed in summer. In Sławskie Lake: dinophytes (mainly *Ceratium hirundinella* F.B.Muller Bergh), green algae and cryptophytes, whilst in Głębokie Lake: green algae (*Tetraedron minimum, Scenedesmus ecornis, Didimocystis* sp.), conjugatophytes (*Cosmarium bioculatum* var. *depressum*) and chrysophytes (*E. subaequiciliata*). As these taxa do not produce toxins, lake condition was more beneficial for recreational use.

The highest density of *Ceratium hirundinella* in Lake Sławskie was noted on the depth of 1m (in August it was a dominating species and reached 50% of the abundance of all taxa). Similar water blooms caused by dinophytes were also noted in nutrient-rich lakes in Wielkopolska Region (GOŁDYN and KOWALCZEWSKA-MADURA 2008, STEFANIAK et al. 2005) and other countries e.g. Lake Loskop in Africa (OBERHOLSTER and BOTHA 2011) and Lake Tortum in Turkey (KIVRAK 2006). *Ceratium hirundinella* is able to migrate in a vertical profile and reach high density of cells (FREMPONG 1984).

In autumnal period the most abundant were cryptophytes e.g *Cryptomonas marssonii* and *Rhodomonas lacustris* in Lake Głębokie, Besides these two, there was significant contribution of *Cryptomonas reflexa* Skuja in Sławskie Lake.

In Turawa Średnia in October the abundance of cyanobacteria was the highest due to the development of *Anabena* species, while in November chrysophytes started to develop. The most abundant were *Dinobryon divergens* and *D. acuminatum*. Chrysophytes are developing in clear waters with low concentrations of nutrients (confirmed by low N and P concentrations in this lake) and low water temperature (SOMMER et al. 1986, SZELĄG-WASIELEWSKA 2006). *Dinobryon divergens* was noted in all investigated reservoirs as well as in many eutrophic water bodies in Wielkopolska e.g. Lake Rosnowskie Duże (CELEWICZ-GOŁDYN 2005), Maltański Reservoir (KOZAK 2005), Lake Wielkowiejskie (CELEWICZ-GOŁDYN et al. 2010) and five shallow lakes in the Promno Landscape Park (KOZAK and MADURA 2010).

Conclusions

Analyzed water-bodies are examples of different restoration measures resulting in water quality improvement, hence the effects varies in seasons. In case of Sławskie Lake, changes in water and sewage management system were sufficient in improving water state. Turawa Średnia and Głebokie Lake

are examples of efficient restoration of reservoirs with limited catchment influence. Maltański Reservoir was characterized in 2011 by deteriorated water quality in comparison with other lakes regardless restoration treatment, however in previous years water quality improved. The influence of river waters feeding this reservoir is significant, therefore it shall be considered as a goal of supplementary activities aiming at decreasing the nutrient concentrations. Proper water and wastewater management is a crucial step in efforts to improve lake water quality aiming at increased recreational denotation, especially in case of deeper lakes with good tolerance to degradation, what was confirmed by Sławskie Lake. Analyzed examples of shallow water bodies indicates much more difficult and complex restoration measures with unstable results.

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USING LANDUSE AND ECOLOGICAL INDICATORS TO CHARACTERIZE LAKESHORE CONDITIONS

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K e y w o r d s: lakeshore assessment, shallow lake, landscape protection, landscape architecture, Lake Velence.

A b s t r a c t

The purpose of the study was to develop a method for lakeshore assessment, and to make assessment for the shore of Lake Velence that can serve as basis for management and restoration. The study area is a landscape part located 50 m from the legal shoreline both towards the land (riparian zone) and the water-surface (littoral zone). For Lake Velence 17 assessment viewpoints were defined comprising natural landscape-ecological features, land use, and other lakeshore affecting factors. These indicators can be regarded as the most essential factors, which can jointly describe the general conditions of lakeshores, therefore being able to determine the key issues for management practice.

WYKORZYSTANIE RODZAJU UŻYTKOWANIA GRUNTU I WSKAŹNIKÓW EKOLOGICZNYCH DO CHARAKTERYSTYKI WARUNKÓW BRZEGOWYCH JEZIOR

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S ł o w a k l u c z o w e: ocena brzegów jeziora, jezioro płytkie, ochrona krajobrazu, architektura krajobrazu, jezioro Velence.

A b s t r a k t

Celem badań było opracowanie metody oceny brzegów jezior, która mogłaby posłużyć jako podstawa do zarządzania i ochrony tego obszaru, a także zastosowanie jej do oceny brzegów jeziora Velence. Miejscem prowadzenia badań była część krajobrazu oddalona 50 m w kierunku lądu od

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oficjalnej granicy brzegowej jeziora (strefa nadbrzeżna) oraz obszar między lustrem wody a lądem (strefa litoralu). Określono 17 punktów oceny brzegów jeziora Velence, do których należały m.in. cechy naturalnego i ekologicznego krajobrazu, rodzaj użytkowania gruntu oraz inne czynniki mające wpływ na ogólny stan brzegów jeziora. Umożliwiło to określenie kluczowych zagadnień występujących w praktyce zarządzania tym obszarem.

Introduction

The increased use of lakes resulted in disadvantageous change of their environmental condition at several places all over the world. The environmental problems occur more intensively in shallow lakes having primary recreational utilization in many cases. Proper management of lakes is often hindered by the missing information and knowledge of their status, especially as for their most sensitive part, i.e. lakeshores. As lakeshores are determinant for the whole lake's condition, they are worth getting special attention during the landscape-developing – protecting, and restoration activities.

In the international professional literature you can find sources which elaborate the ecological and landuse significance of lakeshores jointly (OSTENDORP et al. 2004, PIECZYNSKA 1990, SCHMIEDER 2004, STRAYER and FINDLAY 2010). Most lakeshore researches focus on their special functions (e.g. transitional habitats, buffer-function, recreational use) in addition to other impacts of lake-utilization. The analysis of ENGEL and PEDERSON (1998), LÖFFLER (1990), NESS (2006), STRAYER and FINDLEY (2010) regarding the effects of lakeshore-development belong to the most complex ones, similarly to the works of SCHMIEDER (2004) on human disturbances of Europe's lakeshores.

Most of the authors, processing survey, assessment and evaluation methods of lakeshores, treat shores as part of surveying wetland habitats (including lakes) (e.g. INNIS et al. 2000, Survey of the Nation's Lakes 2007, ROWAN 2008). A part of the literature regarding survey of lakeshores aims at assessing a certain feature of the lake concerned. The assessments and evaluation methods in the USA that focus on defining the ecological sensitivity of lakeshores (MCPHERSON and HLUSHAK 2008, PERLEBERG et al. 2009) are well applicable also for spatial planning purposes. In connection with the Water Framework Directive, OSTENDORP (2004) studied the assessment methods of lakeshores and a method has been elaborated also in Italy to evaluate the ecological status of lakeshores (SILIGARDI et al. 2010). FURGALA-SELEZNIOW et al. (2012) made assessment of a lake in Poland with regard to recreation-tourism landuse and pressures at the shore. At the Faculty of Landscape Architecture of Corvinus University of Budapest (Hungary) assessments have been made on the mining lakes in Délegyháza since 2009 by 20x30 m assessment plots of the shore (SALLAY and BOROMISZA 2011).

Having in mind the complexity and difficulty of lakeshore management, the objective of this study is to develop a methodology for lakeshore assessment, keeping in view the landuse and (landscape)ecological aspects equally. In order to utilize the results effectively during spatial planning practice, lake management, or even in lake restoration processes, the assessment has to be implemented in a fine scale, with a wide range of variables (indicators).

Materials and Methods

Study area. Lake Velence is one of the largest Hungarian shallow lakes (24 km^2), the average water depth is 1.45 m (SZILÁGYI et al. 1989) – Figure 1. The lake has a length of 10.8 km, and an average width of 2.3 km (BARANYI 1980).

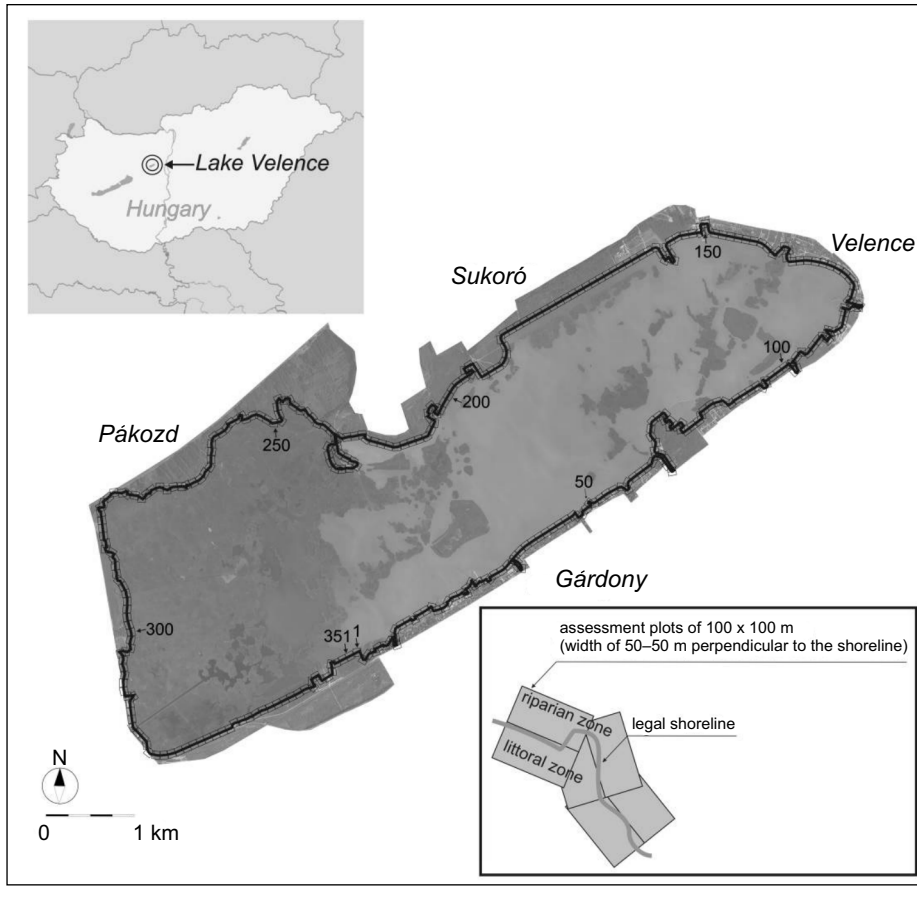

Fig. 1. The location of the study area and the diagram of the assessment plots

The full length of legal shoreline (including piers) makes 40.67 km, belonging to four settlements (Gárdony, Velence, Sukoró, Pákozd). In the last 150 years, the lake and lakeshore have undergone a dramatic change; the starting point was the construction of the Southern Railway (1859–1861) next to the shoreline. Since 1880, the water-level became more regulated and the extensive recreational land use began to develop. After the Second World War, this was followed by a purposefully planned, comprehensive lake regulation (dredging, filling the shallow littoral areas, constructing artificial shore fortification works) and intensive recreational developments were carried out. The current utilization of the lake and the lakeshore can be characterized by the duality of intensive recreational use and nature conservation.

Assessment methodology. The lakeshore's detailed survey was made by dividing the legal shoreline into 100 m long sections towards land direction (riparian zone) and water direction (littoral zone), both in a distance of 50–50 m (BOROMISZA 2010). By this method 351 assessment plots were placed along the shoreline (Figure 1). During the assessments the following basic maps were used: topographic map 1:10 000 (1986), colour, high-resolution ortophoto (2009) used by Central-Danubian Water Authority. As a primary assessment method, on-site field survey was applied. The partial researches on the study area have been carried out since 2004, including various seasons and shore sections. Between June-September 2011, during my field survey, including the whole lakeshore, the earlier results were made up-to-date and also completed.

For Lake Velence 17 assessment viewpoints (indicators) were defined comprising natural landscape-ecological features, land use and other lakeshore affecting factors. The indicators below can be regarded as the most essential landscape shaping factors (FARINA 1998), which can jointly describe the general conditions of lakeshores, therefore being able to determine the key issues for management practice. Among the landscape-ecological features the soil conditions of riparian zone, wave-exposure, riparian slope, shoreline development, littoral emergent vegetation, width of zone having emergent vegetation cover, riparian vegetation cover, naturalness of vegetation and vegetation zonation were surveyed. The assessment aspects of land use conditions and lakeshore affecting factors include land use, shore fortification, point source of water pollution, structures in littoral zone, linear landscape elements in riparian zone, extent of human existence, shoreline access and ownership relations in riparian zone. All the 351 assessment plots were classified according to the 17 assessment viewpoints, into previously defined categories (Table 1). The categories were made on basis of that having the largest territorial share.

Table 1

The assessment viewpoints (indicators) and categories

Natural landscape-ecological features				Vegetation				
Soil conditions of the riparian area	*wave exposure*[a]	*riparian slope*	*shoreline development*[b]	*water surface coverage with emergent macrophytes* [%]	*typical width of the zone covered with emergent macrophytes* [m]	*vegetation coverage on the riparian zone* [%]	*naturalness of vegetation*[b]	*vegetation zonation*[c]
– natural soils – filled up surface – impervious surface	– sheltered inside – sheltered outside – exposed inside – sheltered outside – sheltered inside – exposed outside – exposed inside – exposed outside	– 0 – 30° – 30 – 75° – 75°< – varied	– high – moderate – low	0–10 10–40 40–70 70 <	< 1 1–4 4–20 20 <	0–40 40–70 70 <	– fully altered – heavily modified – moderately modified – slightly modified – near-natural	– near-natural zonation – partially modified zonation – lack of near-natural zonation

cont. Table 1

Landuse, lakeshore affecting factors							
Landuse[d]	*shore fortification*	*point sources of pollution*	*structures in the littoral zone*[e]	*significant linear landscape element in the riparian zone*[f]	*degree of human existence*[g]	*shoreline accessibility*[h]	*property conditions of the riparian zone*
– lake-dependent, extensive – not lake-dependent, extensive – lake-dependent, intensive – not lake-dependent, intensive	– sloping concrete works with riprap – shore wall – near-natural shore – other shore fortification	– available – not available	– significant – less significant – none	– significant – less significant – none	– much ntensive in whole year – medium intensive in whole year – less intensive in whole year – much intensive in season	– freely accessible – access is limited by landuse – access is limited by riparian vegetation – not accessible	– property of local government – property of regional government – state-owned property – private property – anglers' association property

[a] – inside and outside the plot (within 1000 m) "protected" and "exposed" types were separated on basis of Fetch-length, being perpendicular to the shoreline and on basis of riparian vegetation cover; [b] – while making the survey, the five-step scale of Seregelyes (FEKETE et al. 1997) was taken as starting-point; [c] – near-natural: the riparian vegetation zone is followed by a wet meadow; partially modified: at least riparian vegetation zone is present; [d] – lake-dependent, extensive: e.g. boat harbours, disposal areas; not lake-dependent, extensive: e.g. green spaces; lake-dependent, intensive: e.g. beaches, camp sites; not lake-dependent, intesive: e.g. hotels, residential areas, intesively managed forests; [e] – significant: concrete breakwaters; less significant: wooden piers; [f] – significant: paved roads, railway lines; less significant: embankments, ditches; [g] – based on relative emprirical comparasion; [h] – limited by landuse: beaches with entrance fee, camp sites; not accessible: e.g. nature reserves, private residential areas.

Results and Discussion

Soil conditions of the riparian area. 53% of the assessment plots are situated on filled up areas, while natural soil takes only 42% within the study area. Impervious surface was found on 5% of the assessment plots. Except for the western basin, the lakeshore can be characterized by longer sections of filled up areas, natural soils occur unevenly dispersed in single plots. On highly modified, filled up shores, natural soil can be found in the proximity of boat harbours, where the landward fringe of the harbour;s basin runs back to the original shoreline.

Wave exposure. The "sheltered inside-sheltered outside" category was found the most representative (57%), "exposed-sheltered" type takes 31%, followed by the "exposed inside-exposed outside" shores (8%) and "sheltered inside-exposed outside" ones(4%). Hydraulic studies (e.g. Józsa 2006) were performed in the recent times on Lake Velence, however, the exposure conditions of the shoreline had not been described previously, covering the spatial differences as well. The main explanation of the a.m. results is the high reed coverage on the western basin of lake, where the riparian vegetation is directly connected to the shoreline on longer sections. Boat harbours are sheltered against wave action as well, due to the short fetch-lengths and to the presence of riparian vegetation. The relatively high number of "exposed inside-protected outside" plots can be interpreted as a result of the earlier lake regulation interventions, where open water surfaces are desirable, particularly in the near-shore littoral areas, in order to support the recreational development.

Riparian slope. Different slope-categories occur in similar proportion within the shore zone of Lake Velence: < 30° = 33%, 30–75° = 31%, 75° < = 30%, varied = 6%. These results can be explained by presence of the natural slope conditions and the structure of the most prevalent shore fortification works. While flat slopes are characteristic in the western basin, as a result of natural shore processes, a few forms of the concrete shore fortification are determining the slope conditions on other shore sections. The longest section of steep slopes (75° <) belongs to the rowing course in Sukoró, which is dominated by vertical shore walls. It is also clear, that varied slope steepness is not specifically typical within the study area.

Shoreline development. As far as the shoreline's morphology is concerned, equable proportions of the different categories can be detected: moderate shoreline development – 36%, low shoreline development – 34% and high shoreline development – 30%. The location of different types along the shoreline shows a quite mosaic-like pattern, thus the effects of shore regulation do not explain this spatial structure. However, the results suggest, that

extremities (high and low shoreline development) originated in the processes of shore regulation.

Water surface coverage with emergent macrophytes. It was found that most of the assessment plots (33%) were covered with a lower amount (10%>) of riparian vegetation, while the high coverage-category (70%<) is also relatively dominant (30%), the "10–40%" category has 21% and the "40–70%" type involves 16% of the total assessment plots. These results show again the rough proportion of developed and undeveloped shore sections, and their intermediate forms. The two dominant categories occur also in longer section: the longest stretch with low coverage overlap with the area of the rowing course in Sukoró. The largest shore section with high riparian vegetation cover is situated on the northern shore in Pákozd, where natural depositional features are determining the shore's character.

Typical width of the zone covered with emergent macrophytes. The a.m. proportion and pattern can be detected more sharply concerning the width of riparian vegetation's zone. While the highest share of plots (40%) belongs to the "20 m <" category, the second most dominant one (37%) belongs to the "1 m>" category. 14% of the plots are classified to the "1–4 m" type, and 9% as "4–20 m". The absence of emergent macrophytes on the southern, south-eastern sections of the shoreline can be an indication of the cumulative effect of the strong wave action, shore and lake regulation and intensive recreational landuse, which are fundamentally hindering the colonization of the riparian vegetation. It was found, that the "1–4 m" category was typical for boat harbours and for sheltered shores under recreational utilization, where *Phargmites australis* and *Schoenoplectus lacustris* are spreading on silting up lakeside ripraps.

Vegetation coverage on the riparian zone. The results show, that 63% of the assessment plots have higher vegetation cover (70%<), while "40–70%" category is characteristic for 26% of the plots, and "40%" type takes only 11%. It is important to emphasis, that higher vegetation cover is also markedly dominant on intensively utilized shore sections.

Naturalness of vegetation. By the analysis of vegetation's naturalness, the shore zone of Lake Velence shows a substantial degree of disturbance. While the high proportion (42% of the plots) of "moderately modified" and "heavily modified" vegetation (40%) was expected, the extremely low proportion of "near-natural" (2%) and "slightly modified" (9%) vegetation type is remarkable and surprising. These results suggest that despite the nature conservation efforts, the combination of lakeshore regulation antecedents, the current water level regulation practice and other maintenance activities are having a serious impact on the lakeshore ecosystem. The "fully altered" vegetation-category was found only in 7% of the assessment plots.

Vegetation zonation. On 60% of the plots, near-natural zonation is completely lacking, 21% were classified to the partially modified type, and not more than 19% show near-natural zonation. In line with the results of POMOGYI (2005), it is found that starting from assessment plot No. 9. to the plot No. 195, a large continuous section occurs without natural vegetation zonation. These findings also justify the theory of KEDDY and FRASER (2000): the reduced (regulated) water level fluctuation limit the extent of transitional zones between the terrestrial and aquatic habitats. It is also detected, that the zone of wet meadows is generally missing. It is not the water level regulation that explains the results exclusively, the construction of linear landscape elements (e.g. roads, embankments, ditches) on riparian zone are among the reasons, as well.

Landuse. It was found, that "not lake-dependent, extensive" landuse forms were dominant (43%) within the study area, typically on previously filled up areas. The second most dominant types belong to the "lake-dependent, extensive" category and to the "lake-dependent, intensive" category (22–22%), what may sound surprising for a recreational lake. The "not lake-dependent, intensive" type takes only 13% of the assessment plots.

Shore fortification. Henceforward, the near-natural shores are the most characteristic for Lake Velence (44%). It was found, that sloping concrete works with riprap were dominating in 27% of the plots, in accordance with the results of PAPP (1995). Shore walls are typical in 23% of the plots, concentrated in longer, continuous sections. The other shore fortification forms (6%) are rather diverse, with respect to their technical build-up, habitat-function and aesthetic effect as well.

Point sources of pollution. Polluting sources were found in 9% of the plots (31 point sources), their distribution along the shoreline is rather equable. It was found, that creeks and storm water canals were also reaching the lake at boat harbours.

Structures in the littoral zone. Almost in half (49%) of the assessment plots there is no artificial structure in the littoral zone, whereas in a longer section in Gárdony (plot no. 13–57.), every plot can be characterized with some kinds of moles, docks etc. 27% of the plots are classified to "less significant", and 24% to the "significant" type.

Significant linear landscape element in the riparian zone. In 85% of the plots there are no significant linear landscape elements in the riparian zone. After having drawn the conclusions it has to be noted, that during this survey unpaved pathways and bicycle paths were not considered. The "significant" category is characteristic in 11% of the plots: a main road bordering directly the south-western part of the lakeshore can be regarded as a considerable ecological barrier, separating important wetland habitats. 4% of the plots

contain "less significant" linear elements. The embankments of the disposal areas (used for depositing dredged lake sediments) are also acting as ecological barriers. Besides, the higher terrain of the artificial embankments are breaking the continuity of the vegetation zonation, supporting the colonization of invasive terrestrial weeds, shrubs (e.g. *Elaeagnus angustifolia*).

Degree of human existence. At Lake Velence, the "much intensive in season" category has been found to be the most representative (46% of the plots). The "medium intensive" category is also prevalent within the study area (29%), especially on the western basin's shore. The "less intensive" type was found in 21% of the assessment plots, indicating that – owing to the dominant landuse forms – the landscape pattern (e.g. roads next to the shoreline), shore-use customs and maintenance practices (e.g. reed harvesting, recreational angling), the occurrence of undisturbed lakeshore sections are rare. The 4% proportion of the "much intensive in whole year" category reflects to the seasonal character of recreation, tourism.

Shoreline accessibility. A considerable proportion of the shoreline has limited accessibility because of the riparian vegetation (37% of the plots), mainly concentrated on the northern shore. Although the easy accessible shore sections were found to be relatively frequent (32%), this result is rather insufficient and undesirable for a recreational lake. 18% of the plots have limited accessibility because of the landuse (e.g. beaches with entry-fee), the inaccessible shore sections (13%) are fundamentally determined by the location of a nature reserve. Based on these results, it is revealed, that the unfavourable public accessibility of the shoreline is one of the most serious symptoms of intensive lakeshore development, which has to be managed in the future.

Property conditions of the riparian zone. 48% of the assessment plots are owned by the state, 32% by local government (especially beaches, boat harbours), 12% have private ownership, 6% belong to regional governments and the property of anglers associations takes only 2%.

Conclusions

The applied method and the indicators were proved to be suitable to establish the basis of lakeshores' complex assessment for spatial planning purposes. Although the plots were actually assessed with no regard to the local conditions, yet the assessment made possible to delineate homogenous sections of the lakeshore from different aspects. During the assessment, for many indicators, the field survey was the only possible source of information, what is also justifying the necessity of the detailed assessment. The results have

provided new data and viewpoints, particularly, to understand the manifold effects of urban development and lake regulation processes. The sharp difference of the developed shore sections from the shore on the western basin was clearly detectable from most of the points of view. It has been revealed that the lakeshore is dominated by rather extensive forms of landuse, in addition; the public access of the shoreline is substantially limited. Otherwise, because of the lack of similar, detailed assessments on the shore zone it is difficult to make the evaluation and verification of the results.

The expansion of the timescale of this study is essential from the management's aspect as well, making the evaluation of the dynamic processes (e.g. changes of shore use intensities, pattern of riparian vegetation) possible. Due consideration of different lakeshore features and processes, as to their relation with each other, – described by various indicators in this study – is expected to give more evidence of lakeshore assessments' significance. The study could be complemented with a survey of shore use customs and demands. It is also important to analyse the non-point sources of pollution, the habitat value of different shore fortification works, and the morphology and siltation of the lake basin, respectively. The results are utilizable for further landscape-ecological evaluation at lake- and landscape-scale, keeping in view the cumulative pressures, the carrying capacity of the lakeshore, the buffer-capacity and the connectivity and fragmentation of habitat patches. The results may be also suitable to support the regulation parts in the local plans, and can be use for the managing-maintenance tasks of water affairs or for nature conservation.

Owing to the complexity of the factors determining the lakeshore's condition, thus the long-term sustainability of lake and lakeshore utilization can be managed by the harmonization of urban development, recreational development, technical maintenance, lake research and environmental education. The study made clear, that the future developments have to be based on the restoration of the lakeshore, which is also reasonable from the aspects of recreational use and ecology as well.

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IMPROVING PUBLIC SAFETY THROUGH THE CREATION OF A NETWORK OF WATER RESCUE STATIONS ON THE GREAT MASURIAN LAKES

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K e y w o r d s: network of water rescue stations, water sports safety system, water rescue, Great Masurian Lakes.

A b s t r a c t

The project initiates the creation of a comprehensive solution to the question of safety on the waters of the Great Masurian Lakes through the creation of a network of water rescue stations.

The aims of the proposed project are to create a network of water rescue stations throughout the Great Masurian Lakes, to improve the equipment of the rescue services operating on the Great Masurian Lakes (rescue equipment), and to improve the skills of these rescue services (professional training).

The area of the Great Masurian Lakes constitutes a region of unique natural beauty of international importance. It provides perfect conditions for the development of sailing tourism, which in turn causes a rise of safety concerns. This situation calls for organizational changes and an increase in efforts to enhance the safety of tourists on the lakes.

The project aims to enhance the safety of navigation on the Great Masurian Lakes through complex solutions – the creation of a network of water rescue stations and the creation of favourable conditions for the further development of sailing tourism through ensuring safety and health services for both tourists and local residents.

The effect of the project will be economic growth in the region through rising revenue from sailing tourism, as well as a greater involvement of residents, social institutions, local administration and local businesses in promoting tourism and enhancing safety on the water.

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POPRAWA BEZPIECZEŃSTWA POWSZECHNEGO POPRZEZ BUDOWĘ SYSTEMU PORTÓW RATOWNICZO-ŻEGLARSKICH NA SZLAKU WIELKICH JEZIOR MAZURSKICH

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S ł o w a k l u c z o w e: sieć portów ratowniczo-żeglarskich, system bezpieczeństwa na wodzie, ratownictwo wodne, szlak Wielkich Jezior Mazurskich.

A b s t r a k t

W projekcie założono stworzenie kompleksowego rozwiązania w zakresie bezpieczeństwa wodnego na szlaku Wielkich Jezior Mazurskich poprzez stworzenie sieci portów ratowniczo-żeglarskich.

Celem projektu jest poprawa bezpieczeństwa żeglugi po Wielkich Jeziorach Mazurskich poprzez rozwiązanie systemowe – stworzenie sieci portów ratowniczo-żeglarskich oraz poprawę warunków do rozwoju turystyki żeglarskiej – doposażenie działających tam służb ratowniczych w sprzęt oraz doskonalenie ich umiejętności (specjalistyczne szkolenia) dla bezpieczeństwa i zdrowia turystów oraz mieszkańców regionu.

Wielkie Jeziora Mazurskie stanowią unikatowy zespół przyrodniczy o znaczeniu międzynarodowym. Sprzyja to rozwojowi turystyki żeglarskiej na tym akwenie, a z kolei to przyczynia się do wzrostu zagrożenia bezpieczeństwa. Sytuacja taka zmusza do zmian organizacyjnych i intensyfikowania działań związanych ze zwiększaniem bezpieczeństwa poruszania się turystów po jeziorach.

Efektem podjętych działań będzie wzrost gospodarczy regionu wynikający ze wzrostu przychodów generowanych przez rozwój turystyki żeglarskiej oraz aktywizacja mieszkańców, partnerów społecznych, samorządów oraz przedsiębiorców lokalnych na rzecz rozwoju turystyki i poprawy bezpieczeństwa wodnego.

Introduction

The project initiates the creation of a comprehensive solution to the question of safety on the waters of the Great Masurian Lakes through the creation of a network of water rescue stations.

It proposes measures to build water rescue stations on the Great Masurian Lakes, to improve the equipment of the rescue services operating on the Great Masurian Lakes (rescue equipment), and to improve the skills of these rescue services (professional training).

The area of the Great Masurian Lakes constitutes a region of unique natural beauty of international importance. It provides perfect conditions for

the development of sailing tourism, which in turn causes a rise of safety concerns. This situation calls for organizational changes and an increase in efforts to enhance the safety of tourists on the lakes (NARSTEDT 1998).

Within the framework of the project the following goals and objectives have been set:

- the creation of a system covering the whole region of the Great Masurian Lakes with respect to sailing tourism;
- enhancing the safety of navigation on the Great Masurian Lakes through comprehensive solutions – the creation of a network of water rescue stations;
- the creation of favourable conditions for the further development of sailing tourism through ensuring safety and health services for both tourists and local residents;
- enhancing the attractiveness of the region of Warmia and Masuria as a tourist destination;
- attracting new investments to the region as a result of improving its appeal to tourists;
- economic growth through rising revenue from tourism;
- greater involvement of residents, social institutions, local administration and local businesses in promoting tourism and enhancing safety on the water.

Scope of project

The measures proposed in the project concern the further development of tourism, especially sailing tourism, in the area of the Great Masurian Lakes, which relies on the ability to provide for the safety of tourists at their destination. Safety is often an important factor in the process of deciding on a holiday destination. Therefore, finding comprehensive solutions to the question of safety in concurrence with the law of the land, legal regulations and norms, opens prospects for sustainable growth of the tourism industry in the region (*Analiza techniczno-ekonomiczna...* 1997). The comprehensiveness of the proposed measures in turn guarantees the functionality of the system. In result it will add to the creation and the consolidation of the Great Masurian Lakes' image as a place that beyond its natural beauty provides for all needs and safety concerns of the tourist, especially the sailing tourist.

It needs to be pointed out here, that time is an all-important factor in the success of a water rescue operation – the time it takes the rescue team to reach the scene of an emergency or accident. Therefore the proposed comprehensive solutions include a network of water rescue stations to guarantee a high level of safety for the tourist. The measures intended to reach this goal are focused

on the creation of a network of water rescue stations on the Great Masurian Lakes (some of the stations, operated by the Voluntary Water Rescue Service (WOPR[1]), will operate all year round, others only during the summer holiday season), improving the equipment of the rescue services operating on the Great Masurian Lakes, and improving the skills of these rescue services.

Project description

The proposed system for developing sailing tourism through the creation of a network of water rescue stations on the Great Masurian Lakes is in concurrence with the national system of rescue services concerning safety on the water. The organizational structure of the system complies with all regulations of the applying law. The body administrating the network of water rescue stations to be established in the framework of the strategy will be the Voluntary Water Rescue Service (WOPR).

The law prescribes in detail the organisation of as well as the system of cooperation between the organizations that are part of the national system of rescue services, which constitutes the executive element of the public safety system which guarantees the undertaking of rescue operations whenever life, health, property or the environment are endangered. The organizations involved in the system of safety on the waters of the Great Masurian Lakes are all part of the national safety system, such as:

- the State Fire Service;
- the Police;
- the Masurian Voluntary Water Rescue Service;
- the Masurian Rescue Service;
- associations and foundations involved in water rescue services, as well as businesses interested in improving safety on the water.

The system will also include independent harbours and marinas, holiday resorts on the Great Masurian Lakes and the sailors themselves.

The network of water rescue stations will cover the whole territory of the Great Masurian Lakes. This area covers four administrative districts of the Voivodship of Warmia and Masuria – the Poviats (counties) of Węgorzewo, Giżycko, Mrągowo and Pisz (KLIMCZAK et al. 2011).

[1] Polish abbreviation for Wodne Ochotnicze Pogotowie Ratownicze.

Objective of the project and measures to be taken

The objective of the project is to create a network of water rescue stations on the Great Masurian Lakes, equipped with state-of-the-art infrastructure and equipment, increasing the safety of tourists on the water and enhancing the region's attractiveness for water sports tourism and active tourism in general. As results from an audit, the area of the Great Masurian Lakes lacks in infrastructure, i.e. water rescue stations, rescue equipment, and especially any comprehensive system to provide for safety on the water and the rescue of lives. Therefore it appears an imperative to create comprehensive solutions to the question of safety on the water which would cover the whole area of the Great Masurian Lakes, complying with the law of the land, legal regulations and norms, and the national system of rescue services, and integrating already existing rescue services in an effective way.

The organisational solutions of the system for safety on the waters of the Great Masurian Lakes are mainly based on the structures of the Masurian Voluntary Water Rescue Service (WOPR), which is the organization presently working most effectively in the field of water rescue. But the project also takes account of the need to provide equipment and training to the remaining services interested in active participation in the project, especially the State Fire Service and the Police. The complex solutions proposed in the project also cover the need of providing rescue equipment to participating marinas, harbours and holiday resorts, to enable them to provide basic help until the arrival of professional rescue services.

The implementation of the project is divided into three stages:

Stage 1. Information campaign to popularize the project among local residents, owners of harbours, marinas and holiday resorts as well as local governments in the area of the great Masurian Lakes. Aims: to inform about the introduction of the system, to gain support for the system, especially from local governments.

Stage 2. Implementation of the project, including:

– the construction of water rescue stations by the Mazurian Voluntary Water Rescue Service;

– providing new rescue equipment to the rescue services;

– improving the skills of rescue service staff by introducing a special training programme concerning safety on the water for all participating services;

– providing first-aid rescue equipment to harbours, marinas and holidays resorts;

– an information campaign directed towards sailors to inform about the new safety system.

Stage 3. PR campaign about the system and solutions to improve safety on the Great Masurian Lakes directed to tourists from Poland and abroad, and continuation of the information campaign directed towards sailors, tourists, and local residents.

The above stages define the scope and direction of measures to be taken.

The information campaign to popularize the project is essential to the successful implementation of the whole project. This concerns both the part of the campaign directed towards local residents and business people – owners of harbours, marinas and holiday resorts – and the part aiming for support from local governments (the cession or letting out on favourable conditions of building grounds for the construction of rescue stations; financial support for the equipment of the rescue stations). Furthermore the information campaign is aimed to reach as many potential beneficiaries as possible. Special emphasis will be put on the **complex solutions offered by the system** as well as on the fact, that the strategy opens the possibility of attaining **financial support from EU structural funds** for both the planned infrastructural investments as well as the training programmes and information campaigns.

Similarly important at this stage is a close cooperation of the involved parties with the Marshal's Office of the Voivodship of Warmia and Masuria and the Voivodship Office. These institutions ought to support the project, promoting it locally and helping to gain support from central authorities. Local self-government bodies, including the Marshal's Office of the Voivodship, have been engaged in the project from the first planning stages, considering the subject addressed by the strategy as highly important for regional development, which is an important step towards its successful implementation.

The next stage involves the undertaking of concrete investments in the region. This stage includes the development of infrastructure in the area of the Great Masurian Lakes serving the rescue of lives, the supply of new rescue equipment to the involved water rescue services, and the implementation of a training programme addressed to these services (including periodic training sessions). The applicant's own contribution may be contributed by local governments which are particularly interested in enhancing the safety of tourists on their territory (which is why the information campaign directed towards local governments constitutes such a vital part of the project).

Funds and costs of the project

The presented costs of the project are only estimates – aimed to provide an idea of the scale of investments that the region, including the participating institutions, has to make to achieve the primary goal of improving safety for both tourists and residents.

The estimated costs were established by an inquiry among the participating institutions into their needs for both rescue equipment and training courses. The participants reported their needs according to criteria earlier established by a group of experts and specified the kind of equipment and schooling support they requested.

The authors of the project estimated the overall costs of the project considering the needs of each of the participating services, at the same time recommending those investments that are of fundamental importance to a lasting improvement of the safety of tourists on the water (KLIMCZAK et al. 2012). The authors of the project did not interfere with the decisions of the rescue services as to their needs. They described the needs of the services in the same form as these presented their estimates.

Table 1

Overall costs of the project

Participants	Investment needs	Estimated costs (in PLN)
Masurian Voluntary Water Rescue Service	– infrastructure - all-year rescue stations - seasonal rescue stations – rescue equipment and boats – training programmes Total:	 834,000.00 2,348,000.00 67,000.00 3,249,000,00
State Fire Service	– rescue equipment – training programmes Total:	521,500.00 87,650.00 609,150.00
Police	– rescue equipment – training programmes Total:	1,810,000.00 9,000.00 1,819,000.00
Masurian Rescue Service	– rescue equipment Total:	2,225,000.00 2,225,000.00
Association for development and safety on the great masurian lakes	– promotion and marketing, including teaching aids Total:	500,000.00 500,000.00
Marinas and holiday resorts	– rescue boats + basic equipment – rescue equipment for rescue stations – first aid kits – training programmes Total:	1,250,000.00 300,000.00 190,000.00 120,000.00 1,860,000.00
Total		10,262,150.00

Source: Raport of Polish Tourism Development Agency (2009).

In the Table 2, investment costs have been divided according to the source of funding – national funds (public and private) and EU funds. In case of the Masurian Voluntary Water Rescue Service, the Masurian Rescue Service, and

associations, EU funds may cover up to 75% of the costs, while in the case of harbours and marinas, EU funds cover up to 50% of the costs.

Table 2

Investment costs according to the source of funding (in PLN)

Participant	National funds (public and private)	EU funds	Total
	a	*b*	$c = a + b$
Masurian Voluntary Water Rescue Service	812,250.00	2,436,750.00	3,249,000.00
Association for development and safety on the great masurian lakes	732,037.50	2,196,112.50	2,928,150.00
Masurian Rescue Service	556,250.00	1,668,750.00	2,225,000.00
Marinas and holiday resorts	930,000.00	930,000.00	1,860,000.00
Total:	3,030,537.50	7,231,612.50	10,262,150.00
Share [%]	29.5	70.5	100

Source: Raport of Polish Tourism Development Agency (2009).

Beneficiaries and involved institutions

The proposed safety system for the area of the Great Masurian Lakes involves entities that are part of the National Rescue System and provide water rescue services as well as associations in the region for which safety on the water is a high-priority issue. The entities involved in the system will participate in full compliance with the regulations set forward in the law on the system of rescue and fire-extinguishing services and the draft bill for the National Rescue System. NGOs and associations have declared their intention to participate in the system and have been taken into consideration in all further work on the project.

Participants of the system are the following entities:
- Association for Development and Safety on the Great Masurian Lakes;
- State Fire Service;
- Police;
- Masurian Voluntary Water Rescue Service;
- Masurian Rescue Service;
- businesses interested in the improvement of the safety system on the Great Masurian Lakes.

Apart from the abovementioned participants, the system will involve also independent harbours, marinas and holiday resorts in the area of the Great Masurian Lakes. These entities will receive the proposal to have their objects

equipped with basic rescue equipment and first aid kits. The system will thus not only include specialized services trained for water rescue operations, but also entities directly involved with tourists and sailors. This will contribute to the creation of one all-embracing system, including all entities involved in providing safety on the water for sailors and tourists. The safety system is being created mainly with regard to sailors and tourists, who will be its main beneficiaries, but naturally also local residents will profit from it, both directly and indirectly.

The system will increase the feeling of safety, shorten the time for rescue services to reach the location of an emergency situation, and will improve the image of the Great Masurian Lakes as a safe and tourist-friendly region (KLIMCZAK 2012).

Organisational structure of the system

The project and the solutions put forward in it aim at improving safety on the Great Masurian Lakes. The unit of the Masurian Voluntary Water Rescue Service, for which the system of water rescue systems on the Great Masurian Lakes was designed, has become an equal participant of the system after the law on the National Rescue System took effect. The extension of the system of water rescue stations basing on the structures of the Masurian Voluntary Water Rescue Service is warranted both by its human resources and its existing infrastructure and equipment. The service has been operating in the area for years, its personnel know the lakes and the region well, and are continuously improving their professional skills (professional development).

The Masurian Voluntary Water Rescue Service cooperates with all services involved in water rescue on the Great Masurian Lakes, i.e. with the State Fire Service, the Police, the Masurian Rescue Service, and the Ambulance Service. In accordance with legal regulations (the law on the National Rescue System) the central unit taking emergency calls will be the Poviat Rescue Centre, with whom the Masurian Voluntary Water Rescue Service will remain in constant contact (as the Headquarters of the Masurian Voluntary Water Rescue Service already does today).

The network of water rescue stations based on the structures of the Masurian Voluntary Water Rescue Service will consist of 3 all-year rescue stations, including the headquarters in Giżycko, and 6 seasonal rescue stations scattered throughout the Great Masurian Lakes (both the northern and the southern part of the lake district).

The construction of professional water rescue stations in the lake district and the improvement of the equipment of all services involved in water rescue

in the area, combined with a professional development programme for the services' personnel, will considerably improve the safety of tourists in the region. The system will also involve independent harbours, marinas and holiday resorts, which will support the rescue services providing first aid measures at the scene of an emergency.

The implementation of the comprehensive solutions set forth in the project will increase the effectiveness of rescue operations (and contribute to the reduction of lethal accidents on the water) and shorten the time for rescue teams to arrive on the scene of an emergency. The water rescue stations allow for a better surveillance of the lakes and more effective pre-emptive measures to avoid accidents.

Planned marketing measures

The aim of the project is to further the development of sailing tourism by providing for greater safety for tourists on the Great Masurian Lakes through a complex solution to the question of safety on the water.

A plan for marketing measures for a comprehensive solution to the question of safety in Masuria, including the construction of water rescue stations on the Great Masurian Lakes, was presented divided into three main elements:

– product
– promotion
– distribution.

The plan does not include any prices, as **the project is a non-profit enterprise** (not generating profits). The content of the marketing campaign was designed separately for four target groups of the system:

– local governments in the area of the Great Masurian Lakes, financial institutions;
– harbours, marinas, holiday resorts in the area of the Great Masurian Lakes
– tourists – sailors;
– local residents of the area of the Great Masurian Lakes.

Conclusion

The implementation of the *Strategy for the Development of Sailing Tourism through the Creation of a Network of Water Rescue Stations in the Area of the Great Masurian Lakes* will be successful if the measures will be well coordinated and decisions consequent. The strategy may encounter difficulties and

opposition from different social groups. Nevertheless, the measures proposed in the strategy should be carried out without compromise, while carefully monitoring developments of the market, both internal and external.

Some of the main problems that could jeopardize the implementation of the strategy are the following:

– EU funding might not be available (currently the aims and priorities of the project are being reviewed to make them fully compatible with the conditions for EU funding in the framework of the EU budget for the years 2013–2020);
– lack of funding for the participants' own contributions (water rescue services are financed by the State Treasury, which during an economic downturn may decide to cut funds for their maintenance or development);
– difficulties in deciding on the entity that will administrate the whole system and coordinate its implementation (a number of entities in the region are rivalling over who should supervise a comprehensive system to provide for safety on the water);
– insufficient funding for promoting the project and insufficient efforts of single participants to obtain organizational and financial support.

It should be pointed out that the project meets all essential criteria to qualify for subsidies from the EU, i.e. the following:

1) Eligibility criteria:

– consistence of the measures with their detailed aims;
– consistence of the measures with the project types eligible for subsidies;
– consistence with the development strategy of the voivodship;
– positive effects on horizontal objectives (environmental protection, employment policy);
– consistence with Polish and European law.

2) Additional criteria:

– measures going beyond the level of the municipal/communal territory;
– the project meets regional needs and takes into consideration market demand;
– positive effects on the region's attractiveness to tourists;
– positive effects on the preservation and creation of new jobs;
– measures can be continued after the completion of the project.

The modern and comprehensive solutions of the system aim at increasing the number of tourists visiting Masuria, increasing tourist safety, and improving tourist services to meet EU standards.

Presently the project is in the planning and financing stage. Its authors view it as a continuation of the project to create a network of eco-marinas, which is currently under construction in the region of the Great Masurian Lakes and in the area of Lake Jeziorak in the Western part of the Voivodship of Warmia and Masuria. This network of twelve eco-marinas will be a natural

starting point for the creation of a general safety system in the region. With the necessary rescue equipment added, they will be a ready-made network of water rescue stations. Once funding has been secured from EU funds and the State Treasury, the project should be implemented in the years 2013–2020.

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INFLUENCE OF SELECTED ENVIRONMENTAL FACTORS ON THE USE OF BEACHES IN THE WARMIA AND MAZURY REGION OF POLAND BY YOUNG WOMEN

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K e y w o r d s: women aged 19–20, use of beaches, environmental factors.

A b s t r a c t

The aim of the study conducted at the University of Warmia and Mazury in Olsztyn in 2011 was to assess the influence of selected environmental factors on the use of Warmia and Mazury beaches by 298 women aged 19–20. The research was carried out by a diagnostic survey method employing an anonymous questionnaire. The following environmental factors were applied in the research: the place of permanent residence, parents' education, students' monthly budget, the distance between the place of residence and the nearest lake, and the availability and quality of beaches. The research showed that in the majority of cases the applied environmental factors did not influence how often the respondents frequented Warmia and Mazury beaches. It was observed that irrespective of environmental factors most women went to the beach no more than five times a year, with significantly fewer declaring doing so 6–15 times. None of the women went to the beach more than 15 times per year.

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WPŁYW WYBRANYCH CZYNNIKÓW ŚRODOWISKOWYCH NA WYKORZYSTANIE PLAŻ WARMIŃSKO-MAZURSKICH PRZEZ MŁODE KOBIETY

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S ł o w a k l u c z o w e: kobiety w wieku 19–20 lat, wykorzystanie plaż, czynniki środowiskowe.

A b s t r a k t

Celem badań przeprowadzonych na Uniwersytecie Warmińsko-Mazurskim w Olsztynie w 2011 r. było zbadanie wpływu wybranych czynników środowiskowych na wykorzystanie plaż warmińsko-mazurskich przez 298 kobiet w wieku 19–20 lat. Zastosowano metodę sondażu diagnostycznego z wykorzystaniem anonimowego kwestionariusza ankiety. W badaniach uwzględniono następujące czynniki środowiskowe: miejsce stałego zamieszkania, wykształcenie rodziców, miesięczne środki utrzymania, odległość miejsca zamieszkania od jeziora, obecność i standard plaży przy najbliższym jeziorze. W badaniach wykazano, że w zdecydowanej większości przypadków zastosowane czynniki środowiskowe nie wpływały istotnie na wykorzystanie plaż warmińsko-mazurskich przez kobiety. Niezależnie od zastosowanych czynników środowiskowych, najwięcej spośród kobiet uczęszczających na plaże korzystało z nich do pięciu razy w ciągu roku i dużo mniej od 6 do 15 razy w ciągu roku. Żadna kobieta nie korzystała z plaż na Warmii i Mazurach więcej niż 15 razy w ciągu roku.

Introduction

Coastal areas such as beaches are considered to be one of the main national resources used for recreational purposes. Consequently, beach tourism is one of the main sources of income for countries such as Greece, Spain, Egypt, Australia, and Croatia (de DIOS et al. 2012). Thailand and other oceanic islands also fall into this category (WDID 2011). In the majority of developed countries beaches are considered to be natural resources the main function of which is to provide a place for leisure. To give an example, over ten per cent of Spain's GDP (Gross Domestic Product) comes from the tourism industry in coastal areas where the population can as much as double during the summer (de DIOS et al. 2012).

In order to attract as many tourists as possible, coastal areas are adapted and modernized to fulfill the needs of even the most demanding clients. Beach managers do their best to meet the customers' expectations, with particular

attention paid to tidiness, comfort, and esthetics of these places. The 430-km Spanish Catalan coast can serve as an example of this. There, tourism is the main industry and beach management is focused on recreational use and leisure (ARIZA et al. 2008). Overall, the standard of beaches is based mainly on the number of offered facilities and services, although other factors such as cleanliness and accessibility also play a role.

The behaviors of beach users, however, do not depend only on the standard and availability of beaches. It is well known that environmental factors, including socio-psychological ones, significantly affect human behavior (MACCALLUM and POYNTER 1995). Among others they have been linked to the level of physical activity that people engage in (EIBEN and MASCIE-TAYLOR 2004). Based on Bronfenberg's theory, these effects on human behavior can be analyzed in the context of the immediate environment, connected with home and family (e.g., parents' educational background), in the social-economic context (place of residence and monthly budget), and in the cultural context (norms and behaviors accepted by a given society) (BRONFENBRENNER 1994).

The immediate environment is connected with social factors. From the moment a child is born, it is under the influence of the family environment (BOGIN 1999). Children of parents with a higher education were shown to develop more quickly, both physically and mentally (EIBEN and PANTÓ 1988). Individuals who derive from higher class families and those of white-collar workers are on the whole more physically fit than their peers from middle class families and especially those of parents performing typical blue collar jobs such as factory workers and farmers. This stems directly from the fact that such children are better informed about the necessity and purpose of physical activity by their parents (JOPKIEWICZ and SULIGA 2008).

In the social-economic context one of the most important indicators is urbanization (EVELETH and TANNER 1990, EIBEN et al. 1996). Children from urban environments, especially large cities, have easier access to sport-recreational facilities and media (television, cinema, theatre). Monthly income is a good reflection of a given family's material status, while the actual state of wealth and consumption is indicated by income per family member (ROCHE and SUN 2003). The varied levels of income and expenses result in differences in managing the budget (LINDGREN 1976).

The cultural context concerns the influence of the social environment on personal development. Family, the local community and the even the nation modify the influence of the external environment by constructing certain social-cultural norms and behaviors specific to a given civilization (WOLAŃSKI 2005).

Aim and Scientific Context of the Study

The analysis of available literature concerning the use of Warmia and Mazury beaches and factors by which it may be influenced revealed a complete lack of such publications. Moreover, no publications on the standard of Warmia and Mazury beaches and its effect on the recreational health behaviors of the region's residents were noted.

The above presented arguments have led us to establish the following study aim: The aim of the study conducted at the University of Warmia and Mazury in Olsztyn (UWM) was to determine the influence of selected social-psychological factors on the recreational-health behaviors of women aged 19–20 expressed by the use of Warmia and Mazury beaches. The following environmental factors were accepted as the independent variables: the place of permanent residence, the parents' educational background, the students' monthly budget, the distance separating the place of residence from the nearest lake, and the presence and standard of beaches at the nearest lake. The specific behavior of female students expressed by the frequency of going to Warmia and Mazury beaches was the dependent variable. The study aim was realized by attempting to answer the following question:

Do selected social-psychological factors significantly influence the use of Warmia and Mazury beaches by 1st year female students enrolled at the University of Warmia and Mazury?

Materials and Methods

The research was conducted in 2011 on 298 first year female students attending the University of Warmia and Mazury in Olsztyn (UWM). The study group consisted specifically of 1st year female students so that the results of studies concerning beach use would expand on the series of cross-sectional studies conducted on UWM 1st year students biannually since 2000. These studies were focused primarily on the lifestyle and motor fitness of young adults beginning their university education (PODSTAWSKI 2006, 2011). In addition the present studies will be continued over the course of the students' university education as longitudinal studies. Moreover, the female students constitute the vast majority of the UWM students (approx. 70%).

All 19–20 year-old women from randomly selected groups of students were questioned. The research was carried out in compliance with prior consent from the Ethical Committee of UWM and the volunteers agreed to participate in the study. All participants were permanent residents of the Warmińsko-

-Mazurskie voivodeship. Such a group was considered homogenous and appropriate for this type of studies. The research was conducted with a diagnostic survey method using an anonymous questionnaire.

Statistics

Statistical calculations were carried out using the Statistica PL v. 10 computer program in the basic statistics module (STANISZ 2008). Descriptive statistics as well as tests of significance for the structure indicator at a significance level of $\alpha = 0.05$ were applied in the calculations and statistically significant differences occurred when the calculated p value was lower than α ($p < \alpha$). When assessing the frequency of beach use only individuals who reported going to beaches were taken into account. The formula below was used in order to calculate the structure indicator (relative frequency), which explains the division of the analyzed statistical sample into groups of subjects differentiated by values of individual features (1):

$$W_i = \frac{n_i}{N} \tag{1}$$

where:
Wi – structure indicator, ni - the number of individual components of a given group, N – the number of the whole statistical sample (RÓSZKIEWICZ 2002). For interpretation of results, the following residential categories were established: village, small town: < 20,000 inhabitants, big town: 20,000 – 50,000 inhabitants, small city: 50,000 – 100,000 inhabitants, and big city: > 100,000 inhabitants.

Results

The results of the influence of the analyzed factors, i.e., the place of permanent residence, parents' educational background, students' monthly budget, distance between the place of residence and the nearest lake, and presence and standard of beaches at the nearest lake, on the use of Warmia and Mazury beaches have been presented in Tables.

Table 1 shows the influence of the permanent place of residence on the use of beaches by UWM female students. Statistically significant differences were observed only for women residing in small towns (probability p – 0.0119) and

revealed a low number of women frequenting beaches. Statistically significant differences weren't observed for any other places of residence, where approximately half of the residences reported going to beaches, whilst the other half did not. The majority of women who frequented beaches did so no more than 5 times per year in all of the analyzed urbanization categories (villages – 61.70%, small towns – 63.64%, big towns – 52.0%, and big cities – 62.5%). Significantly fewer students went to the beach 6–15 times a year (village – 38.30%, small town – 36.36%, big town – 48.0%, and big city – 37.5%). Despite the proximity of beaches, no women reported going to the beach more than 15 times a year (Table 1).

Table 1

Influence of permanent place of residence on Warmia and Mazury beach use

Statistical parameters	Permanent place of residence									
	village		small town		big town		small city		big city	
	frequenting beaches									
	yes	no	yes	no	yes	no	yes	no	yes	no
No. of students questioned	47	35	55	78	25	30	6	5	8	9
Structure indicator	0.1577	0.1174	0.1846	0.2617	0.0839	0.1007	0.0201	0.0168	0.0268	0.0302
Probability (p)	0.0766		0.0119		0.2393		0.3823		0.4015	
Frequenting beaches	Permanent place of residence									
	village		small town		big town		small city		big city	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%
< 5 per year	29	61.70	35	63.64	13	52.00	1	16.67	5	62.50
6–15 per year	18	38.30	20	36.36	12	48.00	5	83.33	3	37.50
16–30 per year	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
30 < per year	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	47	100.0	55	100.0	25	100.0	6	100.0	8	100.0

Abbreviations: *N* – number of indicated answers, % – percentage of students, if $p < \alpha = 0.05$ – statistically significant differences

Table 2 illustrates that factors such as: the parents' educational background and the students' monthly budget did not significantly affect the use of Warmia and Mazury beaches. We can therefore conclude that 1st year female students go to beaches irrespective of their parents' educational background and available funds (Table 2).

Table 2

Influence of parents' educational background and students' monthly budget on Warmia and Mazury beach use

Statistical parameters	Mother's educational background					
	primary school		secondary school		higher education	
	frequenting beaches					
	yes	no	yes	no	yes	no
No of students questioned	16	16	86	83	49	58
Structure indicator	0.0537	0.0537	0.2886	0.2785	0.1644	0.1946
Probability (p)	0.5000		0.3922		0.1684	
Statistical parameters	Father's educational background					
	primary school		secondary school		higher education	
	frequenting beaches					
	yes	no	yes	no	yes	no
No of students questioned	15	15	73	83	53	59
Structure indicator	0.0503	0.0503	0.2450	0.2785	0.1778	0.1980
Probability (p)	0.5000		0.1761		0.2640	

Statistical parameters	Students' monthly budget							
	< 1000 zł		1000–1500 zł		1500–2000 zł		< 2000 zł	
	frequenting beaches							
	yes	no	yes	no	yes	no	yes	no
No of students questioned	87	95	48	57	5	6	0	0
Structure indicator	0.2919	0.3188	0.1611	0.1913	0.0168	0.0201	0.0000	0.000
Probability p)	0.2379		0.1666		0.3823		0.0000	

Abbreviations: if $p < \alpha = 0.05$ – statistically significant differences

Table 3 presents the results of the influence of the parents' educational background and students' monthly budget on the frequency of going to beaches in Warmia and Mazury. It was observed that irrespective of the applied social-economical factors, women most often frequented beaches up to 5 times a year (mother's education: primary school – 68.75%, secondary school – 65.75%, higher education – 53.85%; father's education: primary school – 46.67%, secondary school – 65.75%, higher education – 52.83%; students; monthly budget: < 1000 zł – 55.17%, 1000-1500 zł – 64.58%, and 1500–2000 zł – 66.67%). Much fewer female students went to beaches 6–15 times a year (mother's education: primary school – 31.25%, secondary school – 34.24%; higher education – 46.15%; father's education: primary school – 53.33%; secondary school – 34.24%, higher education – 47.17%; monthly budget: < 1000 zł – 44.83%, 1000–1500 zł – 35.42%, and 1500–2000 zł – 33.33%. None of the women reported using beaches more than 15 times a year (Table 3).

Table 3
Influence of parents' educational background and students' monthly budget on Warmia and Mazury beach use frequency

Mother's educational background						
Frequenting beaches	primary school		secondary school		higher education	
	N	%	*N*	%	*N*	%
> 5 per year	11	68.75	48	65.75	24	53.85
6–15 per year	5	31.25	25	34.24	28	46.15
16–30 per year	0	0.00	0	0.00	0	0.00
30 < per year	0	0.00	0	0.00	0	0.00
Total	16	100.00	73	100.00	52	100.00
Father's educational background						
Frequenting beaches	primary school		secondary school		higher education	
	N	%	*N*	%	*N*	%
> 5 per year	7	46.67	48	65.75	28	52.83
6–15 per year	8	53.33	25	34.24	25	47.17
16–30 per year	0	0.00	0	0.00	0	0.00
30 < per year	0	0.00	0	0.00	0	0.00
Total	15	100.00	73	100.00	53	100.00
Students' monthly budget						
Frequenting beaches	< 1000 zł		1000–1500 zł		1500–2000 zł		< 2000 zł	
	N	%	*N*	%	*N*	%	*N*	%
> 5 per year	48	55.17	31	64.58	4	66.67	0	0.00
6–15 per year	39	44.83	17	35.42	2	33.33	0	0.00
16–30 per year	0	0.00	0	0.00	0	0.00	0	0.00
30< per year	0	0.00	0	0.00	0	0.00	0	0.00
Total	87	100.00	48	100.00	6	100.00	0	0.00

Abbreviations: *N* – number of indicated answers, % – percentage of students

The analyses of Table 4 revealed that the distance between the place of permanent residence and the nearest lake significantly influenced the use of beaches but only in the case of lakes located 5–10 km away. Women who lived more than 5 km from a lake frequented beaches significantly less often then others, which may have been caused by the lack of available transport and general inconvenience. The type of beaches also significantly influenced their use. Considerably more women frequented city beaches with lifeguard services than unguarded ones, and the lack of beaches resulted in not spending time at lake (Table 4).

Table 4

Influence of distance between permanent place of residence and nearest lake as well as type of beach on Warmia and Mazury beach use

Distance to nearest beach								
Statistical parameters	to 1 km		1–2.5 km		2.5–5 km		5–10 km	
	Frequenting beaches							
	yes	no	yes	no	yes	no	yes	no
No of students questioned	22	23	58	48	49	58	9	28
Structure indicator	0.0738	0.0772	0.1946	0.1611	0.1644	0.1946	0.0302	0.0939
Probability (p)	0.4376		0.1424		0.1684		0.0006	
Presence and type of beach								
Statistical parameters	city beach (with lifeguards)		wild beach (unguarded)		no beach			
	frequenting beaches							
	yes	no	yes	no	yes	no		
No of students questioned	92	55	49	81	0	21		
Structure indicator	0.3087	0.1846	0.1644	0.2718	0	0.0705		
Probability (p)	0.0002		0.0008		0. 0000			

Abbreviations: if $p < \alpha = 0.05$ – statistically significant differences

From the analysis of Table 5 it can be said that more women residing up to 1 km and 5–10 km from lakes went to beaches 6–15 times a year significantly less often than those residing 1–5 km away. Surprisingly, not a single woman reported going to the beach more than 16 times a year. Moreover, the respondents did not go to lakes that did not have beaches. The highest number of women (83) frequented beaches 1–5 times per year; this was not dependent on the type of beach (guarded city beach – 59.78%, unguarded wild beach – 57.14%) – Table 5.

When asked to assess the standard of Warmia and Mazury beaches on a scale of 1 to 10 (with one being the poorest), the respondents' answers ranged from 1 to 7. Only the lowest standard of beaches (1) was shown to have an influence on beach use (Table 6).

Table 5

Influence of distance between permanent place of residence and nearest lake as well as type of beach on Warmia and Mazury beach use frequency

Distance to nearest beach								
Frequenting beaches	to 1 km		1–2.5 km		2.5–5 km		5–10 km	
	N	%	*N*	%	*N*	%	*N*	%
> 5 per year	10	40.00	35	60.34	34	69.39	4	44.44
6–15 per year	15	60.00	23	39.66	15	30.61	5	55.56
16–30 per year	0	0.00	0	0.00	0	0.00	0	0.00
30 < per year	0	0.00	0	0.00	0	0.00	0	0.00
Total	25	100.00	58	100.00	49	100.00	9	100.00

Presence and type of beach						
Frequenting beaches	city beach (with lifeguards)		wild beach (unguarded)		no beach	
	N	%	*N*	%	*N*	%
> 5 per year	55	59.78	28	57.14	0	0.00
6–15 per year	37	40.22	21	42.86	0	0.00
16–30 per year	0	0.00	0	0.00	0	0.00
30 < per year	0	0.00	0	0.00	0	0.00
Total	92	100.00	49	100.00	0	100.00

Abbreviations: *N* – number of indicated answers, % – percentage of students

Table 6

Influence of beach standard (on a scale of 1 to 10 pts) on Warmia and Mazury beach use

Beach standard	Statistical paremeters	No. of students questioned	Structure inducator	Probability (p)
1	frequent don't frequent	5 22	0.0168 0.0738	**0.0004**
2	frequent don't frequent	15 17	0.0503 0.0570	0.3583
3	frequent don't frequent	32 32	0.1074 0.1074	0.5000
4	frequent don't frequent	36 35	0.1208 0.1174	0.4490
5	frequent don't frequent	40 33	0.1342 0.1107	0.1908
6	frequent don't frequent	11 18	0.0369 0.0604	0.0912
7	frequent don't frequent	2 0	0.0067 0.0000	0.0785
8	frequent don't frequent	0 0	0.0000 0.0000	**0.0000**
9	frequent don't frequent	0 0	0.0000 0.0000	**0.0000**
10	frequent don't frequent	0 0	0.0000 0.0000	**0.0000**

Abbreviations: if $p < \alpha = 0.05$ – statistically significant differences

Discussion

The results of our studies have practical value as they can be applied to improve and popularize Warmia and Mazury beaches. Unfortunately, they cannot be compared to studies of other Polish authors, since no such studies concerning the use of lakeside beaches have been published. As emphasized by Breton et al, foreign studies also lack such publications and those available tend to focused on sea and ocean coasts (BRETON et al 1996). Our observations revealed that 19–20 year-old women only sporadically frequent beaches in the analyzed region, despite the fact that these objects are located in such close proximity to their permanent place of residence. One of the reasons behind such low beach attendance may be the unwillingness to do physical activity, which is directly reflected by not taking full advantage of the natural environment's potential for recreational-health purposes. Cross-sectional studies conducted biannually among 1st year university students revealed that the vast majority of women beginning their studies at the UWM limit their physical activity only to the obligatory P.E. lessons (PODSTAWSKI 2006, 2011).

Out of 10 European countries analyzed, Poland was ranked second to last in terms of its citizens' level of physical activity (6%), contrary to Finland which was ranked first (45%) (STAROSTA 2010). The level of physical activity characterizing a given society, however, doesn't have an influence on whether or not its people take advantage of the recreational potential of the natural environment. This is well illustrated by Finland which is very rich in water areas (nearly 190,000 lakes) (HEMMI 2005). The country, similarly to the Warmia and Mazury region of Poland (3000 bodies of water), "is called the land of a thousand lakes" (HIRN and MARKKANEN 1987). Moreover, Eastern Finland resembles the region analyzed in our studies not only by the abundance of lakes, but also by the relatively low income levels, and a higher (than other regions of the country) level of unemployment (ESKELINEN and FRITSCH 2006). However, the physical activity of the Finns and the favorable conditions for lake tourism aren't reflected by their use of these natural resources (KONU et al. 2010). The reason behind this, as in the case of the region analyzed in our study, may be the unfavorable weather conditions.

A factor which significantly influenced the number of 1st year female students frequenting Warmia and Mazury beaches was the type of beach. Young Polish women prefer going to city beaches which offer lifeguard services and are therefore safer, as well as offer facilities which are attractive for spending free time, e.g., café's, restaurants, and shops. City beaches are established and maintained by local governments, which supply the necessary funding and realize many programs and events such as: concerts, sailing competitions, and various types of sports training courses. A good example

of such a program is the "Active Olsztyn (Olsztyn Aktywnie)" program organized among others at the city Beach, which provides anyone who is interested with the opportunity to take part in various forms of physical activity including yoga, jogging, martial arts, etc.

Wild beaches on the other hand are often dirty and full of litter, while city beaches tend to be kept relatively clean and offer toilets and bathrooms. Among the factors influencing the use of beaches, cleanliness is said to have the strongest impact on choosing a given location (BALLANCE et al. 2000). This was confirmed by studies pertaining to the recreational use of Spanish beaches, which revealed that irrespective of the age and gender of beach users as well as beach types, adequate sanitary-hygiene conditions must be met (BRETON et al. 1996). Although not all beaches provided sanitary facilities in terms of hygiene, the ecological and chemical conditions of the Warmia and Mazury region are considered good, with the exception of the Vistula Lagoon (STOMER et al. 2011). It is also interesting to note that there are no private beaches in Poland because of a Polish law which states that every citizen has the right to walk along the lakeshore without any restrictions and the owners of properties located on the lakeside must make this possible.

Unfortunately, the Olsztyn City Beach with its "Active Olsztyn" program is an exception rather than the norm. The majority of Polish resorts in the Warmia and Mazury region are focused on making the highest possible profits while minimizing expenses. Beach development is usually restricted to meeting safety-health norms and doesn't have much in common with recreational programs. Developing such programs is not easy, as they cannot be based solely on the immediate area of beaches, but must include increasing the attractiveness of the whole recreational complex and its surroundings (GRUMBINE 1994, BIRD 1996, YEPES 2004). Doing so would enable people to make full use of the potential offered by a given beach complex. With proper management and marketing techniques (JAMES 2000, SIMM et al. 1995, HJALAGER et al. 2011), beaches in the Warmia and Mazury region can hope to reverse this negative tendency.

As mentioned earlier, beaches are one of the main components of what recreational centers have to offer. Their use however, is strongly affected by atmospheric conditions and unfortunately for our region the local weather is very uncertain and changeable (WOŚ 1999). If a beach does not offer additional attractions to entertain beachgoers during bad weather conditions it will not attract many clients. Our findings showed relatively little influence of the analyzed factors on beach use. The only factors which were shown to influence beach use were the type of beach and the distance to the nearest beach, the first of which may be connected with the attractiveness of city beaches in terms of the facilities and additional attractions they offer as well as the safety they

provide. None of the analyzed socio-economic factors appeared to affect beach use. Therefore, other factors should be taken into account, such as the above mentioned unfavorable climate, the expectations of current and potential beach users, and the availability of various recreational programs and events.

Conclusions

The analyzed environmental factors have a very weak or no influence on the use of Warmia and Mazury beaches by 19–20 year old women. The following factors were determined to partially negatively influence beach use: permanent place of residence (for small towns), the distance between the place of residence and nearest lake (5–10 km), and beach standard (lowest score – 1). Not surprisingly, the actual presence of a beach at the lakeside and its type were shown to have the strongest influence on beach use. More women frequented city beaches with lifeguarded services, than unguarded ones, and the lack of beaches resulted in women not spending time at the lakeside. The studies should be continued and their scope extended to include additional environmental factors and individual preferences, which may have a significant influence on the use of Warmia and Mazury beaches.

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THE POTENTIAL OF LAKES AND LAKE LANDSCAPE IN THE CONCEPT OF NORDIC WELLBEING

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K e y w o r d s: Lakes, lake landscape, wellbeing, tourism.

A b s t r a c t

The concept of Nordic Wellbeing was developed on a joint research project involving researchers from each of the Nordic countries. As lakes and lake landscape are dominant in Finland, the aim of this paper is to examine if lakes and lake landscapes can bring new content and added value into Nordic wellbeing tourism development. This is done by using Finnish case studies of the Nordic Wellbeing Project.

The data is collected from interviews with stakeholders of the Nordic Wellbeing Project, on participation in project activities, and on secondary sources including analyses undertaken by the laboratory areas. The interviews constitute the main data of this report.

As a conclusion, the lake tourism development in the wellness/wellbeing context is ongoing up and the future looks bright despite the great challenges of the development work in businesses but also in the implementation of the national Wellbeing Tourism Strategy.

POTENCJAŁ JEZIOR I KRAJOBRAZÓW POJEZIERZY W KONTEKŚCIE IDEI NORDYCKIEGO DOBROSTANU

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S ł o w a k l u c z o w e: jeziora, krajobraz pojezierza, dobrostan, turystyka.

A b s t r a k t

Ideę nordyckiego dobrostanu wypracowano w trakcie projektu badawczego z udziałem badaczy z krajów nordyckich. Jako że w Finlandii dominują jeziora i krajobrazy jeziorne, celem artykułu było sprawdzenie, czy jeziora i pojezierza mogą wnieść nową treść i wartość dodaną do rozwoju turystyki

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opartej na idei nordyckiego dobrostanu. Oceny tej dokonano w oparciu o badania przypadków z Finlandii włączonych do projektu „Nordycki dobrostan".

Dane zgromadzono podczas wywiadów przeprowadzonych z uczestnikami projektu „Nordycki Dobrostan" na temat uczestnictwa w działaniach projektu, a także, korzystając ze źródeł pośrednich, łącznie z analizami wykonanymi w warunkach laboratoryjnych. Podstawowe informacje zawarte w tym raporcie pochodzą z wywiadów.

Należy zauważyć ciągły rozwój turystyki w kontekście osiągania dobrej kondycji i dobrostanu uczestników oraz stwierdzić, że przyszłość rysuje się jasno, mimo wyzwań, które stawia dalszy rozwój tej gałęzi biznesu, a także realizacja krajowej Strategii rozwoju turystki dobrostanu.

Introduction

"Tourism plays a vital role in contributing to people's wellbeing" (SCHOFIELD 2004, 135 cited by KULCZYCKI and LÜCK 2009). In recent decades the popularity of Finland, Sweden, Norway, Iceland and Denmark as tourism destinations has increased (*Tourism in peripheries*..., 2007, HALL et al. 2008). Nordic countries are blessed with a significant variety of landscape types and climates, and there are many options for activities in all seasons. From the perspective of wellness and wellbeing tourism, however, the Nordic countries lack natural healing assets and tradition, which has led to a situation in which wellness and wellbeing tourism are mainly based on relaxation and include services like massage, fitness, bath and sauna (SMITH and PUCZKÓ 2009). Thus it is justified to say that the Nordic countries and their image depend on a landscape of natural beauty, adventurous activities, cultural experiences as well as good services (see e.g GENC 2010). As traditional tourism destinations are becoming more crowded, people are looking for alternatives, inspiring locations and activities (SMITH and KELLY 2006) and less crowded and densely populated areas (BJÖRK et al. 2011). DE BOTTON (2002) likewise describes how travellers are attracted to landscapes that benefit their soul by making them feel small, yet part of an infinite and universal cycle. A similar statement was made by SHELDON and PARK (2009), who say that the place in which wellness tourism occurs significantly influences the quality of the experience. Thus it is no coincidence that many wellness and wellbeing centres are located beside the ocean or on a mountain top (SMITH and PUCZKÓ 2009). To give an example, PECHLANER and FISCHER (2006) raised the significance of location in the context of Alpine wellness, while KANGAS and TUOHINO (2008) raised the lakes at the centre of wellbeing tourism in Finland as Finland can offer numerous unique tourism experiences in lake environments.

The term wellbeing was chosen to describe the context of Nordic wellness and wellbeing tourism as a result of earlier research and feedback from the field. The term is also seen as an umbrella term including a variety of aspects: *Wellbeing is a multidimensional state of being describing the existence*

of positive health of body, mind and soul. Wellbeing is an individual issue, but is manifest only in congruence with the wellbeing of the surrounding environment and community (HJALAGER et al. 2011, p. 10).

Defining Nordic wellbeing

In recent years, health, wellness and wellbeing concepts have fascinated tourism scholars in Nordic countries (e.g. BJÖRK et al. 2011, HJALAGER 2005, 2010, 2011, HJALAGER et al. 2008, HJALAGER and NORDIN 2011, HJALAGER and KONU 2011, HUIJBENS 2011, KANGAS and TUOHINO 2008, KONU et al. 2010, 2011, TUOHINO and KANGAS 2009, TUOHINO 2012). This increased interest could be seen as a reflection of changes in values and lifestyles. Terms such as quality of life, self-fulfilment, slow-life, downshifting and experiences coincide with an increased interest in beauty and health treatments, illness prevention, down-aging and self-improvement. The aging population tends to be more active, healthier, wealthier, and also to live longer (HJALAGER et al. 2011, TUOHINO et al. 2012). More consumers are travelling to improve their general wellness and health; the health and wellness tourism segment is in an early phase of growth with considerable future potential. These wellbeing tourists are willing and able to be proactive regarding their general physical and mental wellbeing, sometimes even exaggeratedly so (KORTHALS 2004, HJALAGER et al. 2011, YEOMAN 2008). An inversely related factor influencing the interest in health, wellness and wellbeing entails the downside of modern affluence (HJALAGER et al. 2011).

In response to these challenges the concept of Nordic wellbeing was developed in the joint research project which involved researchers from the universities of the five Nordic countries. The project *Nordic Wellbeing – A health tourism approach to enhance competitiveness of Nordic Tourism enterprises and destinations* (http://www.uef.fi/mot/nordic-wellbeing) was implemented in 2009 and 2010. The main aim was to draw a wider picture of what constitutes the wellbeing category of tourism in the overarching, transnational geographical context of Denmark, Finland, Iceland, Norway and Sweden. A further aim was to explore the potential utilization of special and even unique Nordic resources and advantages articulated in policy considerations for the emergence and support of a *Nordic Wellbeing* brand. Accordingly, the joint research achieved a more profound understanding of the driving forces that could lead to the successful development of coherent wellbeing tourism in the Nordic region (HJALAGER et al. 2011).

The concept building was based on the idea that the Nordic countries are favored by a significant variety of landscape types and climates, and there are many options for activities in the context of wellbeing in all seasons. From the

Finnish perspective, lakes and lake landscape (lakescape) are an essential part of the Finnish landscape. For this reason, the Nordic wellbeing concept in the Finnish context could be associated with nature, outdoor life, purity, healthy image, and values of the northern hemisphere. In future, Nordic wellbeing could be a significant profiler of the Finnish tourism business sector in European markets.

Wellbeing tourism development in Finland on strategic and practical levels

The first discussions about wellness and wellbeing tourism in the Finnish tourism industry started in 2002, when the Finnish Tourist Board recognized the importance of wellbeing tourism development (TUOHINO 2012). The first investigation of the contemporary state of Finnish wellbeing products was made in 2007 (*Hyvinvointituotteiden*... 2008). This led to the establishment of a strategy group for wellbeing tourism, and in January 2009 the new Finnish Wellbeing Tourism Strategy was launched. The strategy defines (*Development Strategy*... 2009) defines three different kinds of goals for the period 2009–2013. These are operational goals, image goals and quantitative goals. Operational goals include the implementation of terminology and theme-based thinking in the field. This, to give an example, includes the identification of core products; new product innovation in wellness/wellbeing tourism and support for common product ideas.

In the Finnish language the words corresponding to wellness and wellbeing are complex in the tourism context. Wellness tourism is usually associated with luxury products and five-star hotels while wellbeing tourism may include products and services from a wider scale, possibly pampering, activities and experiences of luxury, but is does not necessarily come from high-class hotels. In the Finnish context the concept of wellbeing tourism is more appropriate because the broader definition highlights better the Finnish understanding. In contrast to this idea, the word wellness was used in the development of a Finnish Lake Wellness Experience product (KONU et al. 2010). Behind this was the notion that the Lake Wellness Experience product is expected to include all the attributes connected to the word wellness (e.g. high quality and luxury). This interpretation is supported by YEOMAN (2008), who suggests that the future tourist is increasingly aware of luxury as a concept of fulfilment instead of materialism.

At present the wellbeing segment in Finland is booming and is among the main themes in Finnish tourism strategy. The implementation of the national

wellbeing tourism strategy is ongoing in wellbeing tourism businesses. However, the profile of Finland's wellbeing tourism can still be described as weak and unspecific despite the systematic work by the Finnish Tourism Board in recent years (TUOHINO 2012).

The development of the Lake Wellness concept sprang from the academic research idea of using the main tourism resource of Finland – the lakes. All the businesses involved in the concept development were located on lake shores (see KANGAS and TUOHINO 2008, TUOHINO and KANGAS 2009). However, at that time, the lakes were more valued as a framing landscape for outdoor activities rather than for their offering of sellable tourism products. As a result of a development process the following fundamental pillars were defined (KANGAS and TUOHINO 2008, TUOHINO and KANGAS 2009):

- spirit, mind, and self-development: relaxing excursions in the forest and lacustrine environment;
- health: Nordic walking around the lake shores or through forests, traditional and preventive treatments;
- healthy cuisine: local raw materials and freshwater fish;
- internal and external beauty: Finnish sauna, peat sauna treatment;
- relaxation and comfort: swimming in the lake, Finnish sauna experience, baths in a barrel of hot water, campfire relaxation;
- tailor-made, movement/fitness: guided tours in and on the lake, kick sledding or trip skating on frozen lakes.

The pillars included various elements taken from the ideas of the interviewees and adapted to the model of MÜLLER and LANZ KAUFMANN (2001). As well as these, the accommodation is an essential part of the Lake Wellness Concept. In Finland the Finnish Tourist Board (*Hyvinvointimatkailumökit...* 2011) has defined the criteria for so-called wellbeing accommodation in cottages.

The Lake Wellness Concept development included the ideation for the core product, namely experiencing the lake, and concept development. The various elements of the Lake Wellness Product were tested at Nordic Tourism Fairs in 2010 to obtain more customer information about the suitability of the concept for potential customers. According to the survey, potential tourists predominantly expected relaxation and comfort from their wellbeing tourism product. The second most important element was healthy food and the third health promotion and health-enhancing services. The results confirmed that taking care of oneself and relaxation are the most highly valued activities on a wellbeing holiday. According to the study, there was room for a new innovative resource based concept and Lake Wellness could be deemed a holistic response to this (TUOHINO et al. 2012).

Below this paper discusses the role of lakes in the Nordic Wellbeing Concept. This is done by using Finnish case studies of the Nordic Wellbeing Project within a theoretical framework of Nordic wellbeing and Lake Wellness concepts.

Materials and Methods

A qualitative research method was chosen. ECHTNER and RITCHIE (1993) claim that a structured questionnaire is extremely ill suited to the scrutiny of the unique, holistic components of images. There are many unstructured ways of gathering research data. This includes among others content analyses and both visual and written information, interactive individual or group interviews (JENKINS 1999, SHANI and WANG 2011). In consumer research it is possible to conduct qualitative research using open-ended questions. The research can be implemented either as a focus group interview or individual interviews (MIDDLETON and CLARKE 2001). In the present study individual interviews were chosen because this was found to be more appropriate given the resources available.

The data is based on three different kinds of materials: interviews with stakeholders in the laboratory areas of the Nordic Wellbeing Project and supplemented by data from Savonlinna Region, participation in laboratory activities, and secondary sources including analyses undertaken by the laboratory areas. However, the interviews constitute the main data of this report.

The stakeholder interviews were conducted in the laboratory areas of Nordic Wellbeing project in Jyväskylä, Vuokatti and Vaasa Regions (Figure 1) and supplemented in Savonlinna Region. In total 54 interviews were conducted during autumn 2009 and spring 2010. The interviewees were tourism and wellbeing professionals such as tourism entrepreneurs (1/3), experts (1/3) and regional developers (1/3) from the laboratory areas. The interviews took from 40 minutes to two hours.

The interviews were taped and later transcribed. The data was classified and grouped by the researchers. Grouping was based on both questions presented and keywords from respondents. In this phase the supplementary information from the laboratory areas was also taken into account.

The thematic questionnaire included questions about unique selling points, networking and cooperation in the laboratory areas, structure of the business environment (e.g. locomotive entrepreneurs, competitiveness, competition, cooperation and internationalization), sources of information and the utilization of information in their development processes, motivations, innovation factors and the understanding of the Nordic wellbeing concept and its content.

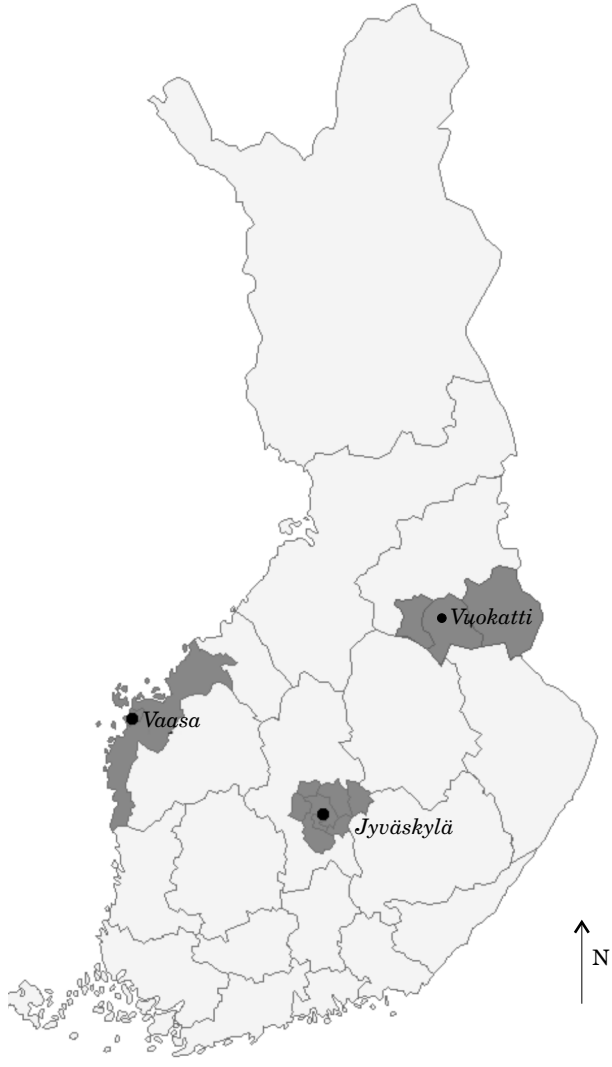

Fig. 1. Finnish laboratory areas of Nordic Wellbeing project (map made by Laura Koskinen, UEF)

Due to the nature of the joint project, the whole study was large in size. For this reason this paper presents only the results of specific issues, i.e. the Nordic Wellbeing Concept and its contents in the lake context. More detailed research questions were as follows:

– how do you see the unique selling points of your laboratory area/Nordic countries; what are the main resources of the area, about what the area is

know well, what are the factors that give added value for the region/customer, and what customers value on the region?
– Nordic Wellbeing – what does it bring to mind? What kind of features might it include, what does it describe or what would be the content of the concept?
– Nordic Wellness – what does it bring to mind? What kind of features might it include, what does it describe or what would be the content of the concept?
– Lake Wellness in the Finnish context – what does it bring to mind? What kind of features might it include, what does it describe or what would be the content of the concept?

The Nordic Wellbeing Concept and its potential for lake tourism development

Nordic Wellbeing was described from a general and comprehensive perspective, and also by specifying the tourism and tourism product context. Some of the interviewees mentioned products, services and elements that the concept may include, for instance, various activities (e.g. running, Nordic walking and hiking) and wellbeing services (e.g. massages, sauna and spa treatments). Resources that were mentioned when the unique selling points of the Nordic countries were discussed included locally produced and "clean" (Nordic) food (also including ingredients from the forests e.g. berries), nature and natural elements (e.g. lakes and forests), culture, and natural ingredients that can also be used e.g. in different treatments. In addition, infrastructure and opportunities for various fitness and sports facilities were mentioned. Some of the interviewees connected medical services to Nordic Wellbeing. Utilizing resources (nature, infrastructure, facilities etc.) in services makes it possible for customers to do different things and to participate in a variety of activities according to their own abilities and interests. Additionally, there are opportunities for various treatments and also to use technical equipment for stimulation and new challenges. All this is supported by good accommodation and catering facilities and the chance to have fun and enjoy oneself. These elements form a comprehensive package of high quality designed in the Nordic way. One interviewee hoped that the focus of products and services would have a more spiritual context in future.

The Nordic Wellbeing products and services were mentioned to be of high quality and reliable. The importance of co-operation was emphasized when product development and service packages were discussed. Accessibility and availability of services were deemed essential. The importance of customers being able to actually buy products and services at the travel destination was mentioned because it was felt that it creates trust and an image of reliability regarding the area and the products it offers.

Abstract issues were also connected to the Nordic Wellbeing concept. Nordic values such as equality, respect for others, appreciating, supporting, taking care of others and appreciating nature were mentioned several times. How these values could be connected to tourism products was also discussed. It was deemed important that when Nordic Wellbeing is discussed, the importance of nature and the Nordic way of life should be highlighted.

Nordic Wellbeing was also described as holistic wellbeing including wellbeing of mind, body and soul. Aspects of intellectuality were mentioned. Some of the interviewees felt that holistic wellbeing emanates partly from Nordic values, but also from the environment. The concept was described with adjectives such as authentic, ecological and exotic. Being together with others and having fun was also one aspect that was connected to the theme. The chance to be oneself was also emphasized. This included being in harmony with one's own body, mind and also the social or natural environment. Nordic Wellbeing and services connected to it were seen as a chance to balance individuals' stress and stress factors thereby improving their wellbeing. Wellbeing was thought to be achieved if the individual has an active role in taking care him/herself either physically and/or mentally. In the Nordic contexts holistic wellbeing was seen to come from the different Nordic environments and unique features and resources of the Nordic countries.

Sauna was seen as the most celebrated wellbeing and wellness service of the Nordic countries. One of the interviewees commented that there is a sauna in almost every wellness centre in Europe: "Well it is sauna. It is probably it. And is it Swedish sauna or Finnish sauna, well that's the question". (F4S, free translation by the author). She said that even though it was not always clear if it was Finnish or Swedish sauna, it was connected to the Nordic countries.

Many of the interviewees approached the Nordic Wellbeing concept by describing the end state that people will achieve by using the services and products of the concept. The main aim was to help customers to get the feeling of wellbeing. It was also noted that this was very subjective and that it is challenging to provide the prerequisites that make the feeling possible for everyone – it cannot be achieved by offering the same products and services to everyone. The feeling of wellbeing was seen to come from a clear mind, a clean and healthy body, clean and pure nature, fresh air, and from interaction with nature.

Some of the interviewees approached the concept more generally, taking a more social perspective. In this respect the role and wellbeing of local people was considerable. It was deemed important that the region should also provide good life for local people. These ideas and issues were connected to the discussion about the welfare state, and to mental, environmental, social and community wellbeing and welfare.

One of the interviewees felt that there are no clear images for the Nordic countries, Scandinavia or Finland as wellbeing destinations. It was mentioned that a shared understanding of the Nordic Wellbeing and Nordic Wellness concepts was needed. This was considered important if and when products and services are provided and marketed under the themes. However, one of the interviewees said that it was not clear what concept should be used. There was also criticism; only one concept should be used to avoid confusion. It is not possible to brand things and issues connected to the wellbeing and wellness of the Nordic countries if there is no shared understanding on what concept should be used.

To be more specific, the following sub-sections discuss the lakes, lake landscapes and their potential within the Nordic wellbeing concept.

Lake Wellness and its potential within the Nordic wellbeing concept

The interviewees contemplated the Lake Wellness concept from different angles. First of all, the great potential of the concept was recognized. The concept could offer new product development potential as well as new ideas for the development work. The connection with nature and the potential for wellbeing tourism were deemed one of the main issues. Some interviewees perceived Lake Wellness as a non-motorized, non-technological based concept.

The connection to nature became evident in comments focusing on hiking and trekking in lake environments as well as national parks near shorelines. In this context seasonality issues were also taken into account; lake tourism could be both winter tourism utilizing ice and snow and summer tourism e.g. with rowing boats. Rowing was mentioned as an example of an activity which offers peacefulness and experiences. More broadly, the Lake Wellness concept was deemed a nature-based experience making people feel well and offering multidimensional experiences. A spiritual approach was also mentioned as well as flow experiences. Lake Wellness was furthermore a matter of transcending one's own limitations or something exotic for foreigners. With a touch of luxury the concept was deemed to be closer to the continental European understanding of wellness.

However, many respondents recognized the challenges the concept will face in the future. The potential for Lake Wellness in volume was estimated to be rather small. On the other hand, the concept was seen to be undervalued in Finland compared to businesses located on lake shores.

Unique selling points and the added value of the lakes for wellbeing tourism

As unique selling points the respondents mentioned first of all the lake landscape itself and its beauty. The uniqueness of the natural scenery together with good services close to the lakes and their greater utilization were mentioned as an important issue in the future. Values connected to nature and nature friendliness were described through attributes like peacefulness, safety, cleanliness or individuality.

Unique selling points were also evaluated from the perspective of future potential. Lakes and lakescapes were seen as attractive factors for foreigners. On the other hand the potentiality of lakes and lakescapes was evaluated from the recreational perspective. Lakes and lakescapes could offer an ideal environment for hobbies, leisure and work.

It was challenging for some interviewees to define what aspects and attributes give added value for tourists in the Nordic countries. Many of the interviewees mentioned nature as a unique attribute, but later started to think about what actually makes this natural environment so special, and gives added value for tourists. Keeping in mind the idea of strengthening the image of the Nordic countries as a wellbeing destination they began to consider the wholesomeness of forest berries and the health benefits of exercising in forest areas.

Conclusions

To summarize, most of the interviewees found that the resources connected to the environment and natural surroundings, Nordic values and the human-nature relationship were the core of the framework for Nordic Wellbeing products and services. These were also things that to a certain extent impart content and unique characteristics to diverse wellbeing tourism products, services and activities offered in the Nordic countries. The considered necessary end-state for customers was a feeling of wellbeing realized through holistic wellbeing experiences. The interviews show that the majority of the respondents prefer the Nordic Wellbeing concept because Nordic Wellness products and services are seen in many cases to be part of the wider Nordic Wellbeing Concept.

The potential of the Lake Wellness Concept was also seen. With a touch of luxury the concept was deemed closer to the continental European conception of wellness. However, the potential volume of Lake Wellness was estimated to be rather small and to face many challenges in future development phases. On

the other hand the concept was considered to be undervalued as in Finland many tourism businesses are located on lake shores or at least lakes are easily accessible.

Discussion

The aim of this article was to examine if Nordic wellbeing concept and lakes and lake landscapes can imbue Nordic wellbeing tourism development with new content and added value. This was done using Finnish case studies of the Nordic wellbeing project.

It became fairly obvious that Finland has very good core resources and attractions. However, some of the resources, e.g. lakes and lake landscape, are not utilized efficiently and there so far no clear profile of wellbeing in the laboratory areas from a tourism perspective.

The Nordic wellbeing tourism product is typically oriented towards nature and outdoor experience and enjoyment combined with achievement, healthy local food, local culture and purity of nature, water and air. In the future it will be necessary to identify the unique selling points of each destination and utilize these more efficiently in product and service development processes. Implementation also entails the allocation of tangible and intangible resources.

The potentiality of lakes and lakescapes was also seen within the Nordic Wellbeing Concept. In addition, Lake Wellness as a more specific concept was deemed to have future potential. However, the concept was seen probably more as a niche product for certain markets, although the potential was recognized. It should be noted that lakes and lakescapes are not only undervalued as wellbeing tourism resources, but also in a broader sense in Finnish nature-based tourism resource.

And how should we proceed in future? Right now the Nordic Wellbeing Concept is closely connected to two spin-off projects. SaimaaLife (www.saimaalife.com) is a lifestyle blog about finding a balance and happiness in a woman's life. It is also a place to hear about other women's ways to be well and thoughts about balance in life and happiness. It offers inspiration and simple ways for natural wellbeing. SaimaaLife is all about quality of life, relaxed attitude, real food, creating one's own way of life, deriving wellbeing from nature and from all things natural. All the activities are built around the blog. Holistic wellbeing, naturalness, learning and happiness are the pervasive themes in the blog. Right now the blogger is building her short-term business plan around the blog for the following four years. As the process in its early stages, the focus is currently on the target group of the blog, and on the forthcoming service concepts and services. Nature and lakescape are in

a significant role in the blog. The long-term aim is to build business activities round the blog.

Travel and Relax – developing wellbeing tourism in the Vaasa Region is another spin-off project of Nordic Wellbeing, and is based on the findings of the Vaasa laboratory area. According to the results, Vaasa Region and its local nature and culture, as well as fitness training and exercise should be highlighted as the main themes of the area in developing wellbeing tourism in the region. The main focus of the project is to build a multi-disciplinary network, to create new innovative product development work and to promote availability and accessibility of wellbeing tourism services. Travel and Relax -project started in April 2012 and will last until December 2013.

To summarize, the lake tourism development in the wellness/wellbeing context in both the Finnish and Nordic contexts is operational up and the future is bright despite the great challenges in the development work in businesses but also in the implementation of the national Wellbeing Tourism Strategy.

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VERTICAL DISTRIBUTION AND ABUNDANCE OF PELAGIC FISH IN TWO DEEP STRATIFIED LAKES IN LATVIA*

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K e y w o r d s: hydroacoustics, Lake Svente, Lake Dridzis, fish density, vertical distribution of fish.

A b s t r a c t

Vertical distribution and abundance of pelagic fish were studied in two deep and stratified lakes in south-eastern Latvia. Features of vertical distribution and abundance of fish were studied using hydroacoustic methods. Acoustic data were collected by a BioSonics DT-X digital echosounder operating at the frequency of 200 kHz. The results showed significant differences in acoustic estimates of fish density between day and night surveys. The vertical distribution of fish was markedly heterogeneous in Lake Svente and Lake Dridzis during the day and night. The characteristics of vertical distribution and abundance of fish were different between the two lakes. Spatial segregation of larger and smaller fish was observed in Lake Svente during the day.

ROZKŁAD PIONOWY I LICZEBNOŚĆ RYB W JEZIORACH SVENTE I DRIDZIS NA ŁOTWIE

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S ł o w a k l u c z o w e: hydroakustyka, Jezioro Svente, jezioro Dridzis, zagęszczenie ryb, rozkład pionowy ryb.

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Abstrakt

Badano rozkład pionowy oraz liczebność ryb w dwóch głębokich, stratyfikowanych jeziorach w południowo-wschodniej części Łotwy. Użyto metod hydroakustycznych. Dane akustyczne gromadzono za pomocą cyfrowej echosondy BioSonics DT-X ustawionej na częstotliwość fal 200 kHz.

Wyniki badań wskazują na występowanie istotnych różnic w szacunkowych ocenach akustycznych zagęszczenia ryb między pomiarami w nocy i w dzień. Pionowy rozkład ryb był znacząco niejednorodny podczas dnia i nocy w jeziorach Svente i Dridzis. Cechy charakterystyczne opisujące rozkład pionowy i liczebność ryb były odmienne w dwóch badanych jeziorach. W Jeziorze Svente zaobserwowano segregację przestrzenną większych i mniejszych ryb występującą podczas dnia.

Introduction

Lakes are an important group of freshwater habitats, which people generally consider attractive. The Water Framework Directive requires all member states of the European Union to achieve a sound ecological status of surface waters as defined by different groups of biota (European Commission 2000). Understanding of freshwater ecosystem functions is important for effective lake management. However, the spatial distribution of fish in water ecosystems is a complex issue. There are external and internal factors that determine the spatial distribution of fish populations. These factors influence migration, feeding, predator avoidance, reproduction and habitat selection of fish. Traditionally, the environmental background is mentioned as a major factor that correlates with the spatial heterogeneity of fish (LAEVASTU and HAYES 1981, PLANQUE et al. 2011). Abiotic factors especially strongly shape vertical gradients in deep lakes (ŚWIERZOWSKI 2001, EILER and EILER 2004). It is assumed also that the pattern of space use is a complex result of individual species making decisions based on the trade-off between foraging behaviour and predation risk (ROJAS and OJEDA 2010). Light regime is one of the important factors that contribute to vertical and horizontal migrations of fish. Thus, it is assumed that the vertical distribution of fish populations in the lake is unstable through the time (ŚWIERZOWSKI 2001, ŚWIERZOWSKI 2003, DRAŠÍK et al. 2009). The main objective of this study was to evaluate vertical distribution and abundance of fish in two deep lakes in south-eastern Latvia, taking into account vertical gradients of physicochemical parameters, acoustic fish size, and diel cycle.

Materials and Methods

The lakes are located in the south-east of Latvia. Lake Dridzis (55°58'N, 27°17'E) is the deepest lake of Latvia (maximum depth 63 m, mean depth 12.8 m) and its surface area is 7.5 km^2. The lake lies in the Lake Dridzis Nature

Park. Lake Svente (55°51'N, 26°21'E) is a relatively deep, slightly eutrophic lake of 7.35 km^2 in surface area. The lake is situated in the region called Augshzeme and its surroundings make a complex area of protected landscapes (POIKANE et al. 2001, BRAKOVSKA and ŠKUTE 2007). The mean depth of the lake is approximately 7.7 m and the maximum depth 38 m. The northern part of the lake is 20–35 m deep and has a strongly marked depression (35 m). Lake Svente is the ninth deepest lakes in Latvia (BRAKOVSKA and ŠKUTE 2007). Both lakes are popular tourists sites, also attracting many fishermen.

According to the fisheries data on Lake Dridzis, almost 50% of the lake's fish fauna consisted of roach (*Rutilus rutilus*), bream (*Abramis brama*), and tench (*Tinca tinca*). Predators were represented by pike (*Esox lucius*) (24%) and perch (*Perca fluviatilis*) (23%) (*Fisheries Logbooks of Lake Dridzis* 1998). Almost 70% of the fish fauna of Lake Svente consisted of roach (*Rutilus rutilus*) and tench (*Tinca tinca*), whereas predators were represented by perch (*Perca fluviatilis*) (9%) and pike (*Esox lucius*) (13%). Also present, although in low abundances, were bream (*Abramis brama*) and carp (*Carassius carassius*) (*Fisheries Logbooks of Lake Svente* 2001).

Acoustic backscattering data were collected by a BioSonics DT-X digital echosounder operating at the frequency of 200 kHz, split-beam 6.8° transducer and a pulse duration of 0.4 msec. The device was calibrated by the standard sphere method (FOOTE et al. 1987). The hydroacoustic technique has an obvious advantage of being non-lethal and allows for acquiring high-resolution spatio-temporal data with a relatively small sampling effort (SIMMONDS and MACLENNAN 2005). Fish were sampled on the same line transect both during the day (1:00 PM) and night (1:00 AM) in each lake in August 2011. Line transects were situated in the deepest parts of the lakes. The total length of a transect in each lake was approximately 1000 m. The transducer of the echosounder was placed 0.5 m below the surface at the back of the boat and tilted slightly downward. The boat speed was maintained at 2 m sec^{-1}. The hydroacoustic acquisition threshold was set at – 90 dB and the ping rate was 5 per second. Hydroacoustic and positional data were visualized and continuously stored on a Getac M230 portable computer running the BioSonics Acquisition® program (version 6.0). Physicochemical parameters of the water column (water temperature, concentration of dissolved oxygen, pH, and concentration of chlorophyll- α) were measured consequently at the deepest locations of transects by a calibrated HATCH™ DS5 multi-parameter probe, which allowed for the data capture every 1 m from the lake bottom to the surface.

Raw acoustic data were imported to Echoview® (version 4.9) software. Hydroacustic data were calibrated and echograms were scrutinized to exclude unwanted reverberation and echo traces in the water column that were not fish. Sound speed and absorption coefficients were calculated in Visual Acquisition®

and entered in Echoview® to find out the effects of temperature and salinity on the achieved acoustic data (HAGGINBOTTOM et al. 2009). Hydroacustic data of the transect were divided vertically into 5 m depth zones, and fish density was calculated in each strata. Fish density was obtained using the echo integration method. The target strength (TS) and volume back scattering strength (Sv) thresholds used in the analysis were -64 dB and -70 dB, accordingly (PARKER-STETTER et al. 2009). Values of the target strength were generated in Echoview® for single targets within each analysis cell identified by the split-beam single target detection algorithm (HAGGINBOTTOM et al. 2009). The target strength (TS) frequency distributions were compared between the epilimnion and hypolimnion. These two zones of the water column were defined with respect to the thermocline in both lakes.

Data of the physicochemical parameters were exported from the HATCH™ DS5 multi-parameter probe to the Microsoft Excel® software for visualization and further analysis.

The data on fish densities were first checked for normality and homogeneity of variances, using Kolmogorov's and Bartlett's tests. Analysis of variance (ANOVA) tested the time and depth effect on fish density estimates. Prior to ANOVA testing, square root transformation was applied to variables (MCDONALD 2009). All statistical tests were considered significant at the 0.05 significance level. Data analyses were performed using SPSS® (version 11.5.0).

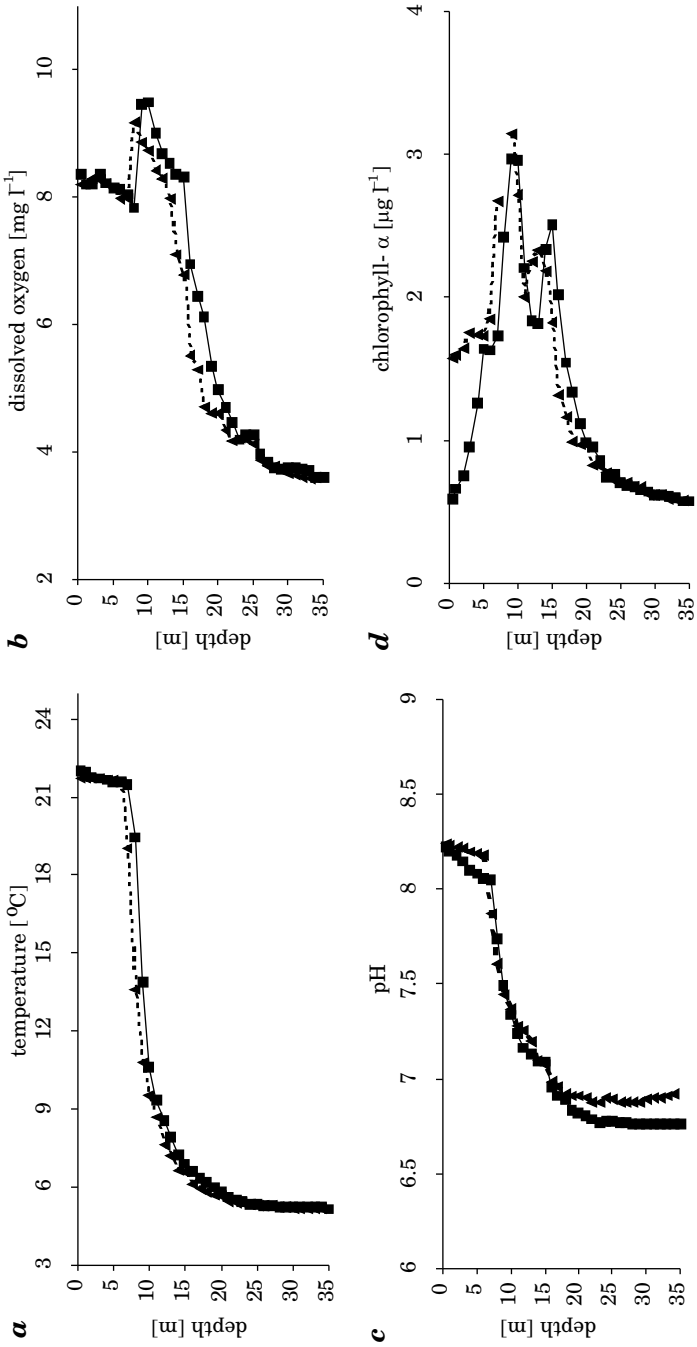
Results and Discussion

Consistent with our expectations, the profiles of physicochemical parameters were found to be relatively uniform in the temporal dimension, but obviously varied in the spatial dimension. The values of water temperature varied from 5.15°C at the bottom to 22°C at the surface, dramatically decreasing at the depth of 6–12 m. The thermocline in Lake Svente was observed at this depth (Figure 1 a). The pH profiles were similar to the temperature profiles. The values of pH varied from 6.8 at the bottom to 8.2 at the surface (Figure 1 c). The values of chlorophyll- α concentration varied from 0.6 $\mu g\ l^{-1}$ to 3.1 $\mu g\ l^{-1}$ at the depth of 10 m (Figure 1 d). The highest values of dissolved oxygen were observed at the depth of the thermocline. Marked depletion of dissolved oxygen concentration was seen in the hypolimnion of Lake Svente (Figure 1 b). Statistical analysis indicated that the estimated fish density differed between day and night surveys (ANOVA, $P < 0.05$) in the 5 m depth zones of Lake Svente, except for the 30–35 m depth zone (ANOVA, $P = 0.975$). This difference was especially pronounced in the upper part of the water column (Figure 2 a). The results showed that fish were not distributed evenly along the

vertical gradient during the day (ANOVA, $P < 0.05$) and during the night (ANOVA, $P < 0.05$). The 0–10 m depth zone of Lake Svente was the most densely populated at night. Nevertheless, the highest fish density during the daytime was observed in the deepest part of the hypolimnion. The values of fish density varied from 0.23 ind. · 1000 m^{-3} to 55 ind. · 1000 m^{-3} during the daytime and from 24 ind. · 1000 m^{-3} to 146 ind. · 1000 m^{-3} during the night. The target strength data implicitly provide information on the fish size. The values of target strength in Lake Svente varied from -62.5 dB to -20.5 dB. It should be noted that smaller fish were mostly represented in the epilimnion during the daytime, whereas larger fish occupied the hypolimnion (Figure 3 a). However, spatial segregation of larger and smaller fish was not so marked during the night in Lake Svente (Figure 3 b).

In lake Dridzis values of water temperature varied from 4.7°C at the bottom to 20.6°C at the surface, decreasing abruptly at the depth of 5–10 m (Figure 1 e). The values of pH varied from 7 at the bottom to 8 at the surface. The values of chlorophyll- α concentration varied from 0.8 μg l^{-1} to 2.6 μg l^{-1}, (Figure 1 h). Profiles of dissolved oxygen concentration showed that the hypolimnion of Lake Dridzis was sufficiently oxygenated. However, an abrupt decrease of dissolved oxygen concentration from 8.2 mg l^{-1} to 5.8 mg l^{-1} was observed at the depth of 5–10 m (Figure 1 f). The results showed that the values of fish density differed between day and night surveys (ANOVA, $P < 0.05$) in all depth zones of Lake Dridzis, except for the 45–50 m depth zone (ANOVA, $P = 0.459$). It should be noted that the depth zones below 35 m were almost uninhabited regardless of the time of day (Figure 2 b). Fish density estimates differed across 5 m depth zones both during the day (ANOVA, $P < 0.05$) and night (ANOVA, $P < 0.05$). The highest fish density was observed in the 5–10 m depth zone both during the day and night. The values of fish density in Lake Dridzis varied from 0.1 ind. · 1000 m^{-3} to 53 ind. · 1000 m^{-3} during the daytime and from 0.2 ind. · 1000 m^{-3} to 155 ind. · 1000 m^{-3} during the night. The patterns of target strength distributions did not show marked differences in vertical distribution of smaller and larger fish in Lake Dridzis (Figure 3 c, d).

The results showed that both lakes were strongly stratified in August. The summer stratification of water was observed in Lake Svente and Lake Dridzis during previous surveys and during several surveys in other lakes in this region, similar in depth (BRAKOVSKA and ŠKUTE 2007, JUREVIČS 2008). The vertical profiles of dissolved oxygen markedly differed between the lakes below the depth of 6 m. These opposite patterns of dissolved oxygen distribution could be explained by different trophic levels of the lakes. The metalimnetic peak of chlorophyll- α concentration could be explained by the marked presence of phytoplankton at this depth. Thus, abiotic factors showed spatial variations strongly influenced by the water stratification. However, light


a
temperature [°C]
depth [m]
b
dissolved oxygen [mg l⁻¹]
depth [m]
c
pH
depth [m]
d
chlorophyll- α [µg l⁻¹]
depth [m]

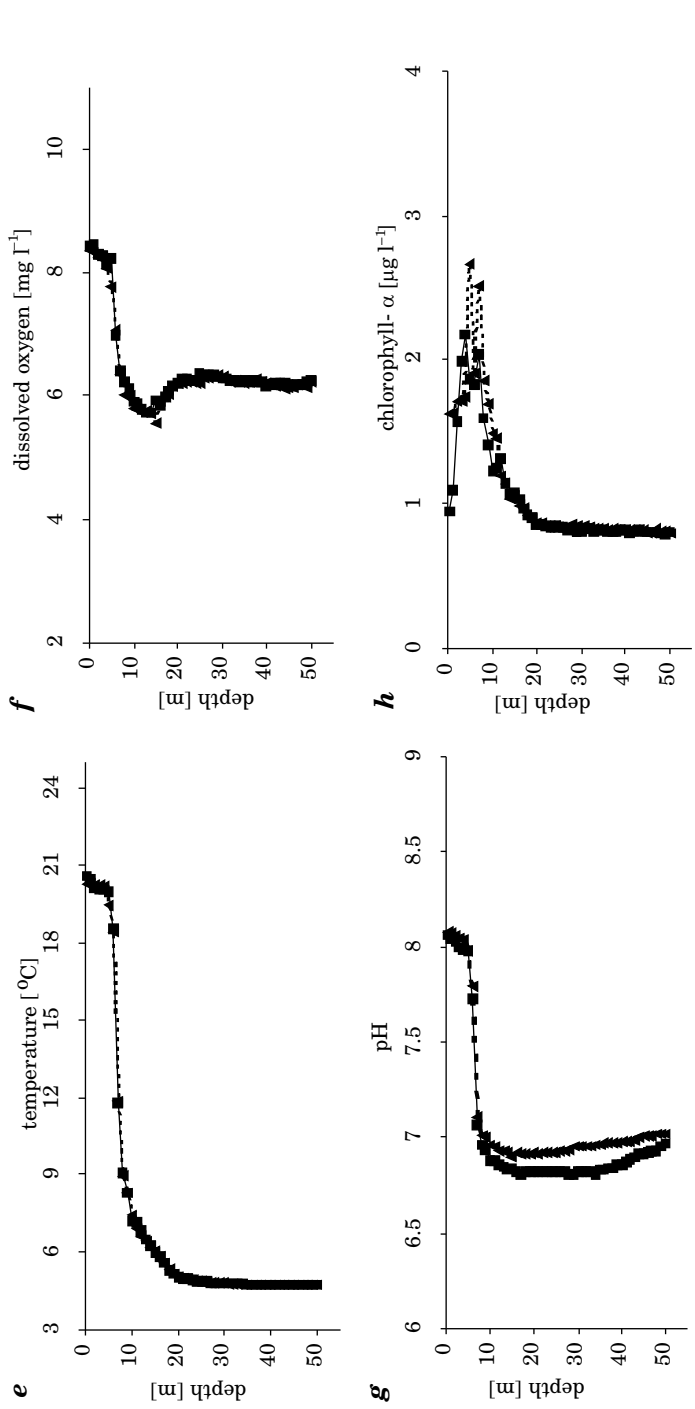


Fig. 1. Profiles of the water temperature, dissolved oxygen concentration, pH and chlorophyll- α concentration in Lake Svente (*a–d*) and Lake Dridzis (*e–h*) for each of the two sampling periods

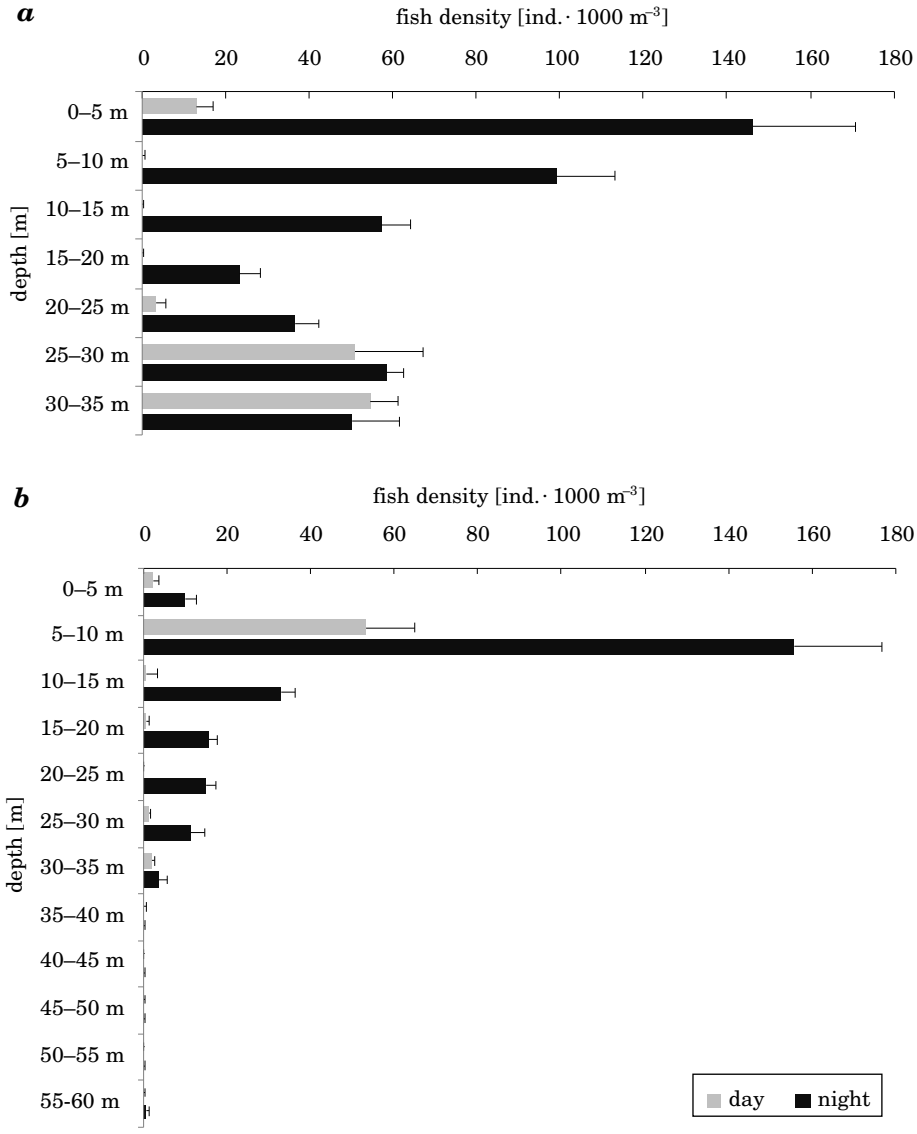


Fig. 2. Mean (+SE) volumetric fish density in Lake Svente (*a*) and Lake Dridzis (*b*) for each of the two sampling periods

intensity was one of the unmeasured changeable factors that should also be taken into account. A relatively high fish density at night in both lakes could have been caused by the horizontal migration of fish to a certain part of the lake or it may have just reflected the movement of fish from the onshore zone into the open water during the night. However, results of this study could not

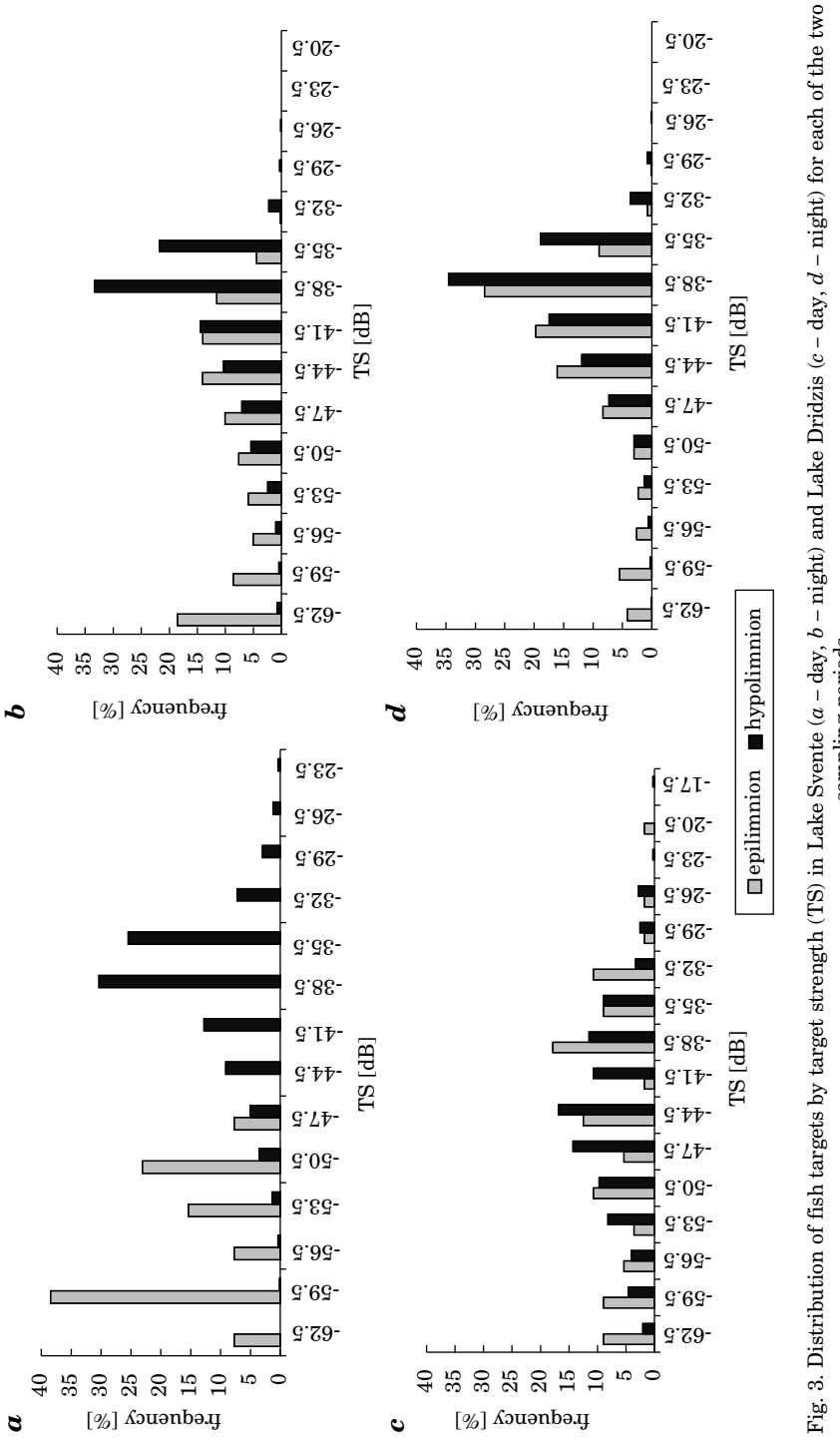


Fig. 3. Distribution of fish targets by target strength (TS) in Lake Svente (*a* – day, *b* – night) and Lake Dridzis (*c* – day, *d* – night) for each of the two sampling periods

sufficiently confirm or reject these assumptions because we had no data about the spatial distribution of fish across the whole lake. An analogous situation of increased fish density in the open water at night was described by MASSON et al. (2001), ŚWIERZOWSKI (2003), EILER and EILER (2004). This pattern of spatio-temporal distribution confirmed a significant time effect on the acoustic estimates of fish abundance in the open water (ŚWIERZOWSKI 2001). Consistent with our expectations and similar studies, fish were not distributed evenly along the vertical gradient in both lakes (DEMBIŃSKI 1971, EILER and EILER 2004, BRIEDIS 2011). Moreover, the characteristics of vertical distribution of fish differed between the lakes. In contrast to Lake Svente, the deepest part of the hypolimnion in Lake Dridzis was almost uninhabited. A significant impact of water temperature and dissolved oxygen concentration on spatial location of fish has been emphasized (EILER and EILER 2004, DOROSZCZYK 2007). The hypolimnion of Lake Dridzis, however, was sufficiently oxygenated. Therefore, the low fish density in the corresponding depth could not be explained by scarcity of oxygen. It should be noted, that Lake Dridzis is much deeper than Lake Svente. Therefore Lake Dridzis has a larger dark hypolimnion zone. Thus, such an important abiotic condition as light regime could probably limit the preferred fish habitat in the hypolimnion of Lake Dridzis. The 5–10 m depth zone of Lake Dridzis was most abundantly inhabited regardless the time of the day. This stratum of the water column approximately corresponded to the metalimnion. The peak of chlorophyll- α concentration was found at that depth in Lake Dridzis. We assumed that it implicitly indicated possible relationships between phytoplankton, zooplankton and fish in Lake Dridzis. The fish density in the metalimnion and upper hypolimnion in Lake Svente at night decreased with increasing depth (Figure 2). Thus, the patterns of vertical distribution of fish in Lake Svente during the night partially could be associated with the water temperature (DEMBIŃSKI 1971). The spatial segregation of larger and smaller fish in Lake Svente during the day could be explained by the predator-prey interactions, taking into account the light regime (SIH 2005, ROJAS and OJEDA 2010). Unfortunately, the hydroacoustic technique does not allow identification of fish species. Thus, this assumption could not be fully confirmed.

Conclusions

The vertical distribution of fish was markedly heterogeneous in Lake Svente and Lake Dridzis during the day and night. The significant time effect on the acoustic estimates of fish abundance was evident in the open water of both lakes. The results of this study indicated that, despite the similar

geographic location and origin of the lakes, certain differences are possible in vertical distribution and abundance of fish. Profiles of physicochemical parameters were found to be relatively uniform in the temporal dimension. Therefore, the spatio-temporal heterogeneity of vertical distribution of fish could not be fully explained by the measured physicochemical parameters. The scale and methods of this study allow for determination of characteristics of the vertical distribution and abundance of fish in both lakes. However, further studies are needed to elucidate reasons for particular vertical distribution patterns.

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THE NUTRITIONAL VALUE OF SELECTED SPECIES OF FISH FROM LAKE AND FISH FARM OF NORTH-EASTERN POLAND

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K e y w o r d s: fish, chemical composition, fatty acids.

A b s t r a c t

The objective of this study has been to determine the chemical composition of fish which are used to make traditional dishes in Warmia and Mazury. The material for our analyses consisted of lake fish (roach, tench, pike, vendace, burbot) and cultured fish (carp) from north-eastern Poland. The highest protein content was found in muscles of vendace (19.2 ÷ 21.9%) and roach (20.5%), and the lowest one – in fillets from the carp reared in cooling water (15.7 ÷ 16.6%). The content of fat in meat of the carp from cooling waters was typical for fish (9.3 ÷ 12.4%). In contrast, lake fish (roach, tench, pike, vendace and burbot) were classified as lean fish.

The results showed the highest content of unsaturated fatty acids in muscles of burbot (82.8%) and the lowest one – in roach fillets (71.7%). Burbot meat was characterized by the highest share of n-3 PUFA acids (25.0%), including eicosapentaenoic (7.9%) and docosahexaenoic (11.5%) acids.

Our investigations have verified the assumption that the nutritional value of fish is affected by species-specific traits, environmental conditions and aquaculture techniques.

WARTOŚĆ ODŻYWCZA WYBRANYCH GATUNKÓW RYB Z PÓŁNOCNO-WSCHODNIEJ POLSKI

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K e y w o r d s: ryby, skład chemiczny, kwasy tłuszczowe.

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Abstrakt

Celem badań było określenie składu biochemicznego ryb, z których przyrządzane potrawy należą do tradycyjnych produktów regionalnych Warmii i Mazur. Materiał badawczy stanowiły ryby jeziorowe (płoć, lin, szczupak, sielawa, miętus) oraz ryby hodowlane (karp) z terenu północno-wschodniej Polski. Najwyższą zawartość białka stwierdzono w mięśniach sielawy (19,2 ÷ 21,9%) i płoci (20,5%), a najniższą w filetach karpia z wód pochłodniczych (15,7 ÷ 16,6%). Zawartość tłuszczu w mięsie karpia z wód pochłodniczych była charakterystyczna dla ryb tłustych (9,3–12,4%). Natomiast ryby jeziorowe (płoć, lin, szczupak, sielawa, miętus) zaliczono do ryb chudych.

Uzyskane wyniki badań wskazały najwyższą zawartość kwasów tłuszczowych nienasyconych w mięśniach miętusa (82,8%), a najniższą w filetach płoci (71,7%). Mięso miętusa charakteryzowało się najwyższym udziałem kwasów PUFA n-3 (25,0%), w tym kwasów eikozapentaenowego (7,9%) i dokozaheksaenowego (11,5%).

W przeprowadzonych badaniach potwierdzono tezę, że na wartość odżywczą ryb wpływają m.in. cechy gatunkowe, środowiskowe oraz technika chowu.

Introduction

Since prehistoric times, water bodies, both marine and inland (lakes and rivers) have been one of the basic sources of food for people (CIOS 2007, MAKOWIECKI 2003). North-eastern Poland is no exception and its residents used to eat large amounts of fish from Masurian lakes and rivers, from Vistula Lagoon and from the Baltic Sea (OSTOJSKI and WOLSKI 2006). Today, increasingly more often, people look for products typical of a given region.

Development of regional products is listed as one of the aims in development strategies of different European regions (RADZYMIŃSKA 2007). Taking advantage of regional products, including fish dishes (GĄTARSKA at al. 2009, RADZYMIŃSKA et al. 2009), is also becoming important for the growth of tourism in Warmia and Mazury. Fish are not just a regional product but also a true 'treasure trove' of valuable nutrients, because fish meat is a source of value-rich and easily digestible protein, which is 90% assimilable in the human digestive tract (BRZOZOWSKA 1998, SIKORSKI 1997a).

Fish meat is characterized by differentiated fat content, which ranges – depending on a fish species – from 0.2 to 40% (SIKORSKI 1997b, KOŁAKOWSKA and KOŁAKOWSKI 2001). This fat contains long-chain, polyunsaturated omega-3 fatty acids, valuable for human health, and especially eicosapentaenoic and docosahexaenoic acids, practically speaking available to people only in fish. These acids produce a variety of beneficial effects on the human body, e.g. they alleviate symptoms of inflammatory diseases, are essential for the good development of the brain and help maintain proper functions of the brain and the organ of vision (UAUY and DANGOUR 2006).

One of the most significant effects produced by omega-3 fatty acids concerns the development and functions of the nervous system (BURDGE 1998). Omega-3 acids support learning processes, improve concentration and relieve

aggression in children and are extremely important in prevention of cardiovascular diseases (NESS et al. 2002, KOLANOWSKI 2007, KOLANOWSKI and POWIERŻA 2008). Moreover, they reduce the risk of contracting cancer (CARROL 1996).

According to American Heart Association (Lichtenstein at al. 2006) and The America Dietetic of Canada (KRIS-ETHERTON at al. 2007) daily consumption of EPA and DHA should be between 0.5 to 1.0 g.

For nutrition, it is extremely important that fish contain fat-soluble vitamins, especially A and D as well as group B vitamins (GAWĘDZKI and HRYNIEWIECKI 2005).

Fish meat is certainly a better source of such elements as phosphorus, potassium or magnesium than slaughter animal meat. With respect to micronutrients, such elements as iron, copper, iodine, selenium, chromium and fluoride, by being present in considerable amounts in fish meat, attract special attention (BORUCKA and WIECZOREK 2003, POLAK-JUSZCZAK 2005).

The nutritional value of fish is shaped by several factors, e.g. the fish species and size, environmental conditions, type of ingested food (by wild fish) and aquaculture techniques (cultured fish).

The purpose of this study has been to determine the biochemical composition of selected fish species, which are used to make traditional fish dishes in the region of Warmia and Mazury in Poland.

Material and Methods

The material consisted of lake fish (roach, tench, pike, vendace, burbot), found in catches on open waters, and cultured fish (carp) from north-eastern Poland. Vendace was captured in Wigry Lake; roach, vendace, tench and pike were caught in Hańcza Lake; cultured carp originated from the fish farms in Bartołty Wielkie and cage placed in cooling water in Ostrołęka. The carp from the Fish Farm in Bartołty Wielkie received wheat as supplementary fed, and in the Fish Farm in Ostrołęka, the carp were fed granulated feed. Fish were caught in September.

The content of the basic chemical components (dry matter, total protein, crude fat, crude ash) in muscles of the examined fish was determined with the Weende method (AOAC 1996). Dry matter was determined by drying in an oven at 105°C for 24 h. Crude protein was determined by Kjeldahl's method and crude fat by Soxhlet's method. Crude fat content was extracted from the sample in anhydrous ethyl ether, crude ash by combustion at 550°C in a muffle furnace for 24 h. The determinations of the crude protein and fat, moisture and crude ash, were carried out at the Laboratory of Department of Nutrition Animals and Feed Science.

Quantitative and qualitative analyses of fatty acids were performed after muscle fat was cold-extracted (FOLCH et al. 1957). Seperation of fatty acids was conducted with the gas chromatography method using Hewlett Packard 6890 with a flame – ionising detector (FID), on a 30 m 0.32 mm internal diameter capillary column (Chair of Commodity Science and Food Analysis University of Warmia and Mazury in Olsztyn).

Results

The content of the basic chemical components in muscles of the examined fish was varied and depended on the fish species and size, and on the habitat in which they lived (Table 1). The highest total protein content was found in muscles of vendace (19.2 ÷ 21.9%) and roach (20.5%). Muscles of tench and pike were characterized by a lower protein content (19.1 and 18.6%, respectively), and the lowest level of this component was found in fillets of the carp cultured in cooling water (15.7 ÷ 16.6%).

Table 1

Chemical composition of muscle selected species of fish from north-eastern Poland

Species of fish	Components [%]			
	dry matter	crude protein	crude fat	crude ash
Vendace H	25.8	21.9	2.6	1.2
Vendace W	21.8	19.2	1.4	1.0
Burbot	19.6	17,9	0.4	1.1
Roach	22.8	20.5	0,9	1.2
Tench	21.1	19.1	0.6	1.2
Pike	21.0	18.6	0.8	1.4
Carp O	27.9	16.60	9.3	1.8
Carp O1	30.2	15.7	12.4	1.9
Carp B	26.5	17.78	6.8	1.7
Carp B1	26.7	18.0	6.9	1.6

vendace H – fish caught in Hańcza Lake; vendace W – fish caught in Wigry Lake; carp O – fish (body weight 1000–1500 g) from cooling water in Ostrołęka; carp O1 – fish (body weight 1500–2000 g) from cooling water in Ostrołęka; carp B – fish(body weight 1000–1500 g) from Fish Farm in Bartołty Wielkie; carp B1 – fish (body weight 1500–2000 g) from Fish Farm in Bartołty Wielkie

The highest fat content was determined in muscles of the carp from cooling water (9.3 ÷ 12.4%), much less- in the carp from Fish Farm in Bartołty Wielkie (6.8 ÷ 6.9%). The percentage of fat did not exceed 1% in muscles of roach, tench and pike (Table 1). The lowest fat content was found in burbot meat (0.4%).

The content of crude ash in muscles of the analyzed fish ranged from 1.0 to 1.9% The highest content of this component was determined in muscles of the carp from cooling water (1.8 ÷ 1.9%), slightly less – in the carp cultured in an earthen fish pond. The lowest content of crude ash, from 1.0 to 1.4%, was detected in muscles of the fish captured in natural habitats.

The share of particular fatty acids was differentiated depending on the fish species and habitat (Figures 1–3). Our analysis of the profile of fatty acids showed that the highest percentage of mono- and polyunsaturated acids occurred in muscles of burbot (82.8%), and the lowest – in muscles of roach (71.7%). A much higher percentage of unsaturated acids was determined in fat of vendace (74.0 ÷ 77.6%), pike (75.6%) and tench (73.4%). In muscles of the carp kept in cooling waters contained a higher percentage (75.2 ÷ 75.7%) of unsaturated acids relative to the carp reared in earthen fish ponds (73.2 ÷ 73.3%).

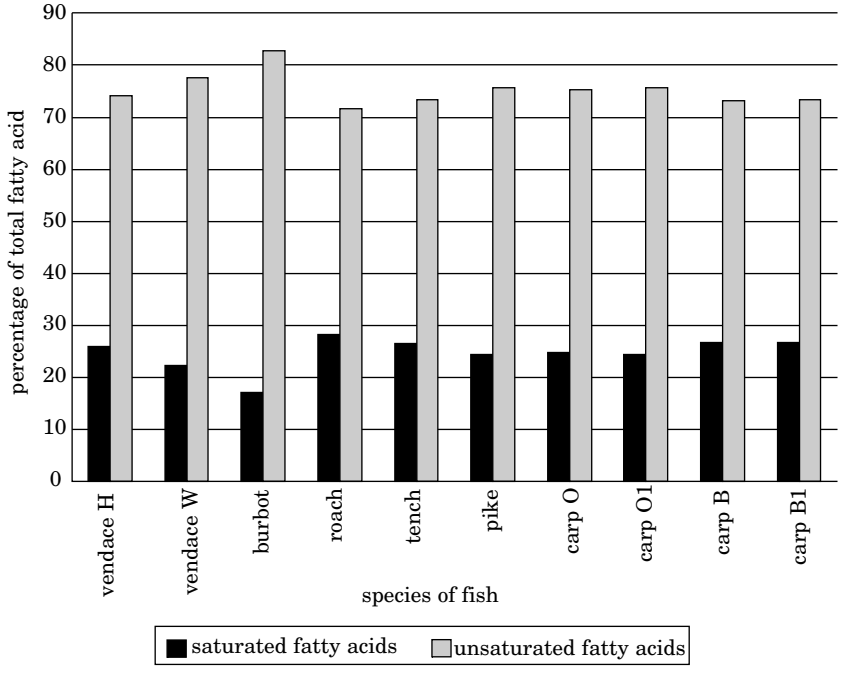

Fig. 1. Fatty acids composition [%] of muscle selected species of fish from north-eastern Poland

The percentage of n-3 PUFA acids was the highest in burbot meat (25.0%), including eicosapentaenoic acid (7.9%) and docosahexaenoic acid (11.5%). Much less of omega 3 acids was found in fat of vendance (17.3 ÷ 18.4%), roach (14.2%), tench (11.9%) and pike (11.4%).

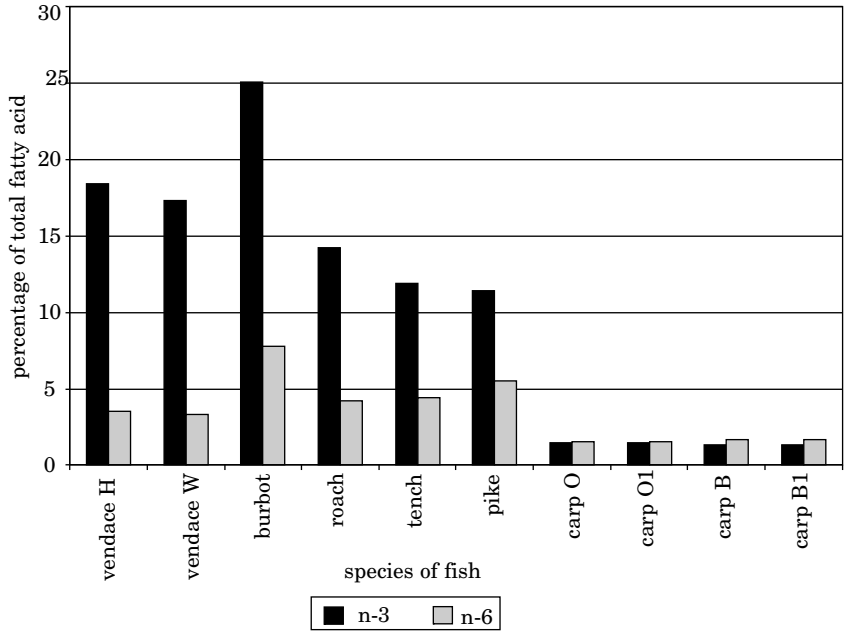

Fig. 2. Percentage share of essential polyunsaturated fatty acids n-3 and n-6 in muscle of selected species of fish from north-eastern Poland

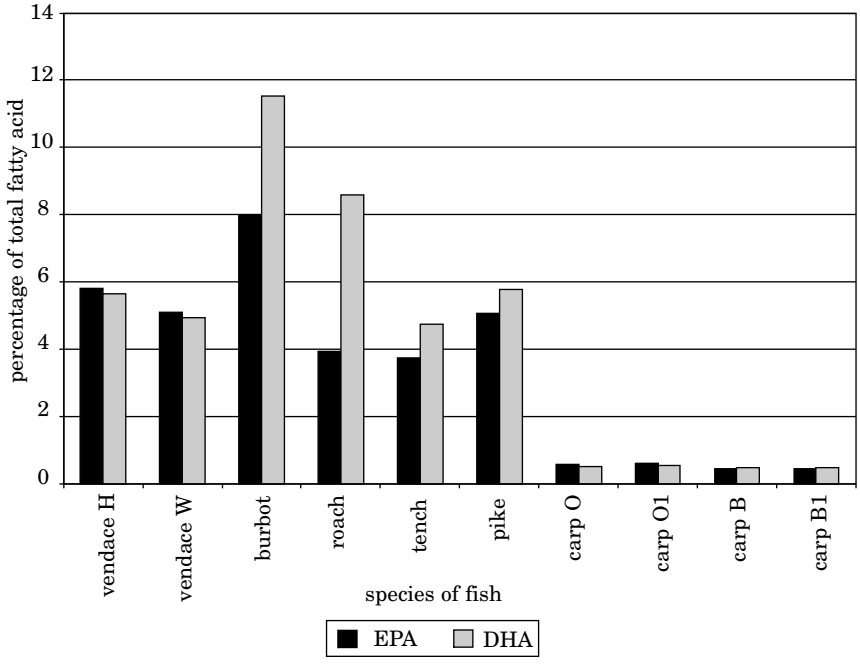

Fig. 3. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) content in muscle of selected species of fish from north-eastern Poland

Fat in the muscles of carp was characterized by the lowest percentage of these acids (1.3 ÷ 1.4%). It is noteworthy that also the level of EPA and DHA acids was the lowest in carp fat (0.5 ÷ 0.6%).

The highest percentage of omega-6 polyunsaturated fatty acids was found in burbot muscles (7.8%); a much lower percentage of this acid occurred in the muscle fat of pike (5.5%), tench (4.4%) and roach (4.2%). The fat from carp, irrespective of where the fish were reared, had the lowest content of omega-6 acids (1.3 ÷ 1.5%) – Figure 2.

The nutritional value of fish also depends on the n-3 to n-6 acid ratio. The determined values of this ratio are shown in Figure 4. The highest ratio of these two groups of acids was found in fat of the vendance from Wigry Lake (1:5.3); it was slightly lower in fat of the whitefish captured from Hańcza Lake. The lowest ratio was detected in fat of cultured carp (from 1:0.8 to 1:1).

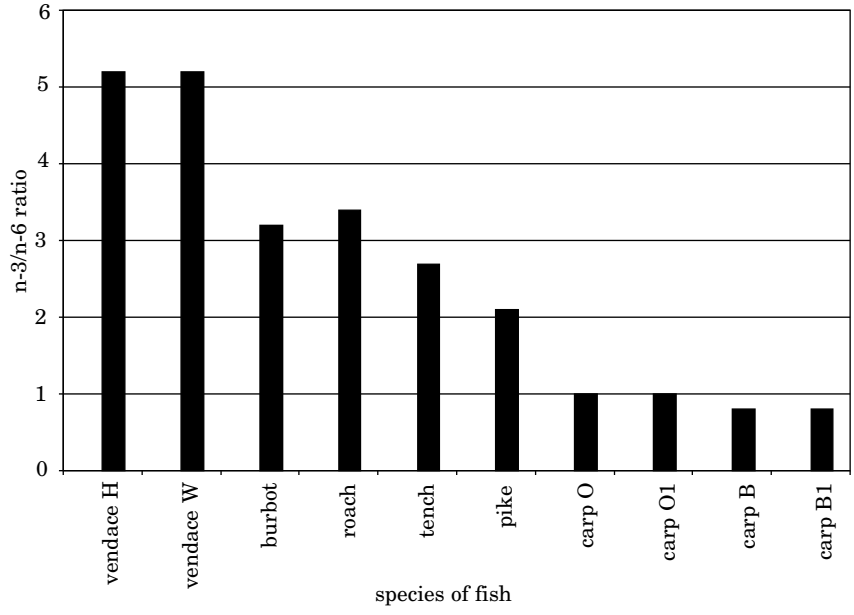

Fig. 4. Polyunsaturated acids n-3/n-6 ratio in muscle of selected species of fish from north-eastern Poland

Discussion

The results of our analyses, as presented above, reveal high variation in the content of particular nutrients in fish meat (Table 1, Figures 1–3). In meat of the vendace from Hańcza Lake, the level of total protein was higher than in meat of the vendace from Wigry Lake. Likewise, the content of crude fat and crude ash in the vendace from Hańcza Lake was higher than in the vendace

from Wigry Lake. It can be suspected that these differences were a result of the different trophic status of both lakes. Our data are different from the information reported by ZIĘCIK and ZAMOJSKI (1964), who examined vendace captured from Wydryńskie Lake, and found 17.8% of crude protein and 1.4 ÷ 1.5 of crude fat.

In the analysed meat of tench, the total protein content (19.1%) was similar and that of crude fat (0.6%) lower than in meat of tench captured from Legińskie Lake (ZIĘCIK and SŁAWIŃSKI 1965). On the other hand, the meat of burbot contained four-fold less fat (0.4%) than in burbot the Rogalica River, in north-western Poland (KOŁAKOWSKA at al. 2000).

Muscles of the carp from the earthen fish pond in Bartołty Wielkie were characterized by a higher total protein and lower crude fat content than found in carp from the cage fish farm located in cooling water in Ostrołęka (Table 1). The differences in total protein in the muscles of carp B and carp B1 could have been an effect of very good feeding conditions in the earthen ponds. In turn, the higher fat content in carp O and carp O1 (9.3 ÷ 12.4%) was most probably due to the feeding of carp with granulated feed and a higher water temperature, which stimulated higher feed intake and led to fat accumulation in muscles. The results obtained in our study were close to the ones reported by WIELOPOLSKA at al. (2003), i.e. 9.3 ÷ 14.4%. It should be emphasized that larger carp, weighing 1.5 ÷ 2 kg, had more fat than smaller ones (1.0 ÷ 1.5 kg).

The results achieved during our research enable us to conclude that fish originating from Polish lakes can be classified as lean ones (*Ryby i przetwory rybne*... PN-A-86770: 1999). It has also been proven that meat of wild fish contains much less lipids than meat of cultured fish (Table 1).

Crude fat content of muscle for vendace, burbot, roach, tench, pike and carp was lower in comparison with results obtained by BIENKIEWICZ at al. (2008). Presumbly, such significant differences were methodology dependent for crude fat content estimation, especially for common using Soxhlet's metod (in this work) and Bligh and Dyer's method applied by BIENKIEWICZ at al. (2008).

Nonetheless, the health-promoting value of fish meat depends primarily on the presence of polyunsaturated fatty acids, and especially eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids. Our analysis of the profile of fatty acids revealed that the highest percentage of polyunsaturated fatty acids appeared in fat of burbot (Figure 1). In addition, the composition of omega-3 acids in this fish had the highest per cent share of EPA and DHA (Figure 3). Our comparison of the content of fatty acids in muscles of roach and burbot with the results obtained by KOŁAKOWSKA at al. (2000) enabled us to conclude that the fish caught in Hańcza Lake were characterized by a higher content of PUFA acids than fish from other lakes in north-eastern Poland. The level of

unsaturated fatty acids in fat of anlysed fishes was significantly different in comparison to values described by BIENKIEWICZ at al. (2008). Only in case of carp, originated from aftercooling water farming, values were similar and ca 2% lower than values obtained for carp farmed in classical pond system.

Fishes such as vendace, tench, roach, burbot and pike originated from north-east lakes of Poland revealed higher nutritive value in relation to n-3 PUFA content in comparison with popular and marketing preferable fishes in Poland such as: oilfish, nile perch and pangasiid catfish (POLAK-JUSZCZAK 2007).

Conclusions

The results indicate that fish (vendace, tench, roach, burbot, pike) from lakes in north-eastern Poland, compared to fish from fish farms, are characterized by a higher content of protein and a much lower level of fat. The profile of fatty acids clearly demonstrates that burbot, vendace, roach and tench contained much more of the dietary valuable polyunsaturated fatty acids than the analysed carp. Fish caught in lakes contained large quantities of EPA and DHA, which are an essential component of human diet.

The present study confirmed the assumption that the nutritional value of fish is affected by such factors as the fish species and size, the habitat and aquaculture techniques.

Wild fish in Warmia and Mazury, caught from lakes in north-eastern Poland, are a valuable element of our diet and should be promoted as regional products. In the context of the nutritional value of fish and the culinary history, fish prepared according to the traditional, regional kitchen in Warmia and Mazury (for example, vendace smoked over specific types of hardwood, or tench in cream sauce) should become permanent elements of the traditional regional cuisine and receive the same protection as analogous traditional dishes and food products from Poland and other European Union countries.

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