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Address
ul. Jana Heweliusza 14
10-718 Olsztyn-Kortowo, Poland
tel.: +48 89 523-36-61
fax: +48 89 523-34-38
e-mail: wydawca@uwm.edu.pl

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TABLE OF CONTENTS

Agriculture

Biology

Humans and Environment

SPIS TREŚCI

Nauka o żywności i żywieniu

POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 28(1): 7–16, Y. 2013

EFFECT OF ITALIAN RYEGRASS (*LOLIUM MULTIFLORUM* LAM.) GROWN AS AN INTERCROP ON MORPHOLOGICAL TRAITS OF SPRING BARLEY (*HORDEUM VULGARE* L.) UNDER WATER DEFICIT STRESS*

Marta K. Kostrzewska, Kinga Treder, Magdalena Jastrzębska, Maria Wanic

Department of Agriculture Systems
University Warmia and Mazury in Olsztyn

K e y w o r d s: spring barley, morphological traits, Italian ryegrass, water.

A b s t r a c t

A pot experiment, set up in an additive design, was run in order to assess the effect of Italian ryegrass on morphological traits of spring barley at different phases of its development under optimal and 50% lower soil moisture content. The following traits were measured: plant height, number of developed leaves per plant, length of ears, number of grains in an ear and length of roots. The assessment was completed during five development phases of barley (the BBCH scale): emergence (10–13), tillering (22–25), stem elongation (33–37), heading (52–55) and ripening (87–91). In 2009–2011, 3 cycles of the experiment were completed. It has been shown that Italian ryegrass did not have any significant negative effect on the morphology of spring barley's aerial organs, although it retarded the development of roots during emergence, as reflected by their length. Water supply differentiated demonstrably the rate of growth and development of crops. Its deficit restrained the growth of spring barley throughout the whole growing season. Besides, shortage of water was responsible for a smaller number of leaves and shoots on plants, shorter ears and less numerous grains in an ear. The presence of Italian ryegrass as an intercrop, in comparison with a spring barley pure stand, did not exacerbate the negative impact of water shortage on the morphological traits of this cereal.

Address: Marta K. Kostrzewska, University Warmia and Mazury in Olsztyn, Plac Łódzki 3, 10-718 Olsztyn, Poland, phone +48 (89) 523 37 91, e-mail: marta.kostrzewska@uwm.edu.pl
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WPŁYW ŻYCICY WIELOKWIATOWEJ (*LOLIUM MULTIFLORUM* LAM.) JAKO WSIEWKI NA CECHY MORFOLOGICZNE JĘCZMIENIA JAREGO (*HORDEUM VULGARE* L.) W WARUNKACH STRESU WODNEGO

Marta K. Kostrzewska, Kinga Treder, Magdalena Jastrzębska, Maria Wanic

Katedra Systemów Rolniczych
Uniwersytet Warmińsko-Mazurski w Olsztynie

S ł o w a k l u c z o w e: jęczmień jary, charakterystyka morfologiczna, życica wielokwiatowa, woda.

A b s t r a k t

W doświadczeniu wazonowym, założonym według schematu addytywnego, oceniano wpływ życicy wielokwiatowej na cechy morfologiczne jęczmienia jarego w różnych fazach jego rozwoju w warunkach optymalnego i zmniejszonego o 50% uwilgotnienia materiału glebowego. Badania obejmowały pomiary: wysokości roślin i liczby rozwiniętych liści na roślinie, długości kłosów, liczby zawiązanych ziaren w kłosie oraz długości korzeni. Ocenę przeprowadzano w pięciu fazach rozwojowych jęczmienia (skala BBCH): wschody (10–13), krzewienie (22–25), strzelanie w źdźbło (33–37), kłoszenie (52–55) i dojrzewanie (87–91). W latach 2009–2011 zrealizowano 3 cykle doświadczenia. Wykazano, że życica nie miała istotnego ujemnego wpływu na morfologię części nadziemnych jęczmienia jarego, jednak podczas wschodów osłabiała rozwój korzeni wyrażony ich długością. Czynnikiem silnie różnicującym tempo wzrostu i rozwoju roślin była dawka wody. Jej niedobór ograniczał wzrost jęczmienia jarego przez cały okres jego wegetacji, a ponadto redukował liczbę liści i pędów oraz powodował skrócenie kłosa i zmniejszenie liczby ziaren w kłosie. Obecność życicy wielokwiatowej jako wsiewki, w relacji do siewu czystego jęczmienia jarego, nie pogłębiała negatywnego oddziaływania niedoboru wody na cechy morfologiczne tego zboża.

Introduction

Currently, intercrops are less important as a source of animal feed, but their role as a factor enriching soil with organic matter gains in importance owing to improved physiochemical properties of soil and the biotic condition of the whole environment. The structure of grown intercrops is dominated by stubble-field catch crops. Intercrops sown between a main crop are far less common (JASKULSKA and GAŁĘZEWSKI 2009). There is a wealth of references discussing the multifaceted functions of intercrops, for example review papers by SONGIN (1998) and ANDRZEJEWSKA (1999) and more recent articles by GALON et al. (2011), JASTRZĘBSKA (2009), KOSTRZEWSKA et al. (2011), PAŁYS et al. (2009), PAWŁOWSKI and WOŹNIAK (2000), SOBKOWICZ (2009), WANIC et al. (2012), etc.

Legumes and grasses are recommended as intercrops, either as pure stands or mixed with winter or spring cereals. Italian ryegrass belongs to grass species sown as intercrops in cereal fields, including spring barley. However, in dry years, Italian ryegrass can heavily compete with a cereal crop for water (WANIC

et al. 2006), which may cause a lower yield of the protective crop. The yielding success of a mixture components and catch crop has been frequently documented in the literature (JASKULSKI 2004, KURASZKIEWICZ 2004, PŁAZA and CEGLAREK 2004, PŁAZA et al. 2010, WOŹNIAK 2000). Other consequences of the competition between crops and intercrops are changes in the rhythm of development of plants, their altered density, fecundity and morphology, but articles dealing with these questions are rarer (CRALLE et al. 2003, SOBKOWICZ 2003, YACHI and LOREAU 2007). The purpose of this study has been to evaluate the effect of Italian ryegrass on morphology of spring barley at different phases of its development and under different soil moisture conditions.

Materials and Methods

The research was based on a strict pot experiment carried out at the Greenhouse Laboratory of the Faculty of Biology and Biotechnology, at the University of Warmia nad Mazury in Olsztyn. In 2009–2011, three cycles of the experiment were run. The evaluated plant was a hull-less cultivar of spring barley called Rastik.

The experimental factors:

First order – stand type: pure stand (C) and in a mixture with Italian ryegrass (M),

Second order – water supply to plants: sufficient to satisfy the requirements (W) and less by 50% (N).

The soil material was collected from the arable horizon of typical brown soil developed from weak loamy sand. The soil was slightly acid in reaction, contained 1.22–1.91% of humus and was moderately abundant in phosphorus, potassium and magnesium. One week before sowing, each pot was filled with 8 kg of soil material, which had been mixed with mineral fertilizers in the following amounts (pure component in g per pot^{-1}): 0.5 N (urea), 0.2 P (monopotassium phosphate), 0.45 K (potassium sulphate).

The total amount of water supplied to plants during the whole growing season was 17,000 cm^3 per pot in the optimum water supply variant and half of this amount, i.e. 8,500 cm^3 per pot in treatments with water deficit. The optimum amount of water had been established based on a preliminary experiment, in which soil moisture content, water evaporation from soil, transpiration from plants and water content in plants had been measured. During the plant growing season, water supply was varied depending on the development phase of the crops and soil moisture content.

The experiment was set up in an additive design, with four replicates (SEMERE and FROUD-WILLIMAS 2001). Eighteen germinating spring barley kernels were planted in each pot as well as 18 kernels of Italian ryegrass in pots

with a mixed stand. Kernels were placed in soil 3 cm deep, at even distance from one another, using a template for that purpose.

Throughout the whole experiment, the ambient temperature in the laboratory was maintained at 20–22°C. In order to induce vernalization, the temperature was lowered to 6–8°C for 9 days when plants were in the full emergence period.

The morphological traits of spring barley were measured on five dates corresponding to five development phases of this cereals in a pure stand and under optimal soil moisture content, i.e. (on the BBCH scale) emergence (10–13), tillering (22–25), stem elongation (33–37), heading (52–55) and ripening phase (87–91). The measurements comprised height of plants, number of stems per plant, number of developed leaves per plant, and starting from the tillering phase, length of ears and number of grains in an ear. Because it was difficult to sort out roots of the protective crop and intercrop, the measurements of the root system included only the length of the longest root from each plant at the emergence phase.

The results in the tables are means for the three cycles of the experiment. The results from the experiment in a totally randomized design underwent statistical processing by analysis of variance and differences between treatments were estimated using Duncan's test. In all statistical analyses, the level of confidence was set at $p=0.05$.

Results

The stand type did not have any significant effect on height of spring barley plants at any of the analyzed plant development stages (Table 1). The lower water supply, however, significantly limited the growth of barley throughout the whole growing season. As a result, differences in plant height between pots with insufficient and optimal soil moisture content ranged from 4 cm (at emergence) to nearly 18 cm (at heading stage). The experiment has also shown that plant water supply had significant influence on the plant height irrespective of the stand type. When supplied with sufficient amounts of water, barley plants, whether sown as pure stand or mixture, were higher throughout the whole growing season than under water shortage conditions (differences statistically confirmed). This negative effect of water shortage on barley growth deepened at the end of the growing season.

The number of barley shoots at the analyzed development phases was similar for both stand types (Table 2). Less water in soil, however, significantly depressed the formation of lateral stems. Under water deficit in soil, barley plants sporadically grew non-productive lateral shoots, which dried out prema-

Table 1

Height of spring barley plants [cm]

Source of variability	Treatment	Spring barley development phases				
		emergence	tillering	stem elongation	heading	ripeness
Stand type	C	26.2^a	42.0^a	47.1^a	51.9^a	54.0^a
	M	25.2^a	42.1^a	46.8^a	51.4^a	52.7^a
Plant water supply	W	27.8^a	48.2^a	55.8^a	59.0^a	59.0^a
	N	23.6^b	35.9^b	38.1^b	44.2^b	47.7^b
Interaction of factors	C – W	28.7^a	47.6^a	56.2^a	59.6^a	61.2^a
	C – N	23.7^b	36.4^b	37.9^b	44.1^b	46.8^c
	M – W	26.9^a	48.8^a	55.3^a	58.4^a	56.7^{ab}
	M – N	23.5^b	35.3^b	38.2^b	44.3^b	48.6^{bc}

C – pure stand, M – mixed with Italian ryegrass, W – water supply satisfying requirements, N – water supply less by 50%

a, b, c – homogenous groups: values marked with the same letter within particular factors or their interactions do not differ significantly at $p = 0.05$

Table 2

Number of spring barley stems, stems plant^{-1}

Source of variability	Treatment	Spring barley development phases			
		tillering	stem elongation	heading	ripeness
Stand type	C*	1.5^a	1.6^a	1.6^a	1.7^a
	M	1.4^a	1.5^a	1.3^a	1.4^a
Plant water supply	W	1.7^a	1.9^a	1.6^a	1.6^a
	N	1.2^b	1.2^b	1.3^b	1.4^a
Interaction of factors	C – W	1.7^a	1.9^a	1.7^a	1.8^a
	C – N	1.2^b	1.2^b	1.4^{ab}	1.5^a
	M – W	1.7^a	1.8^a	1.5^a	1.4^a
	M – N	1.1^b	1.1^b	1.1^b	1.3^a

* key cf. the Table 1

turely. Until the heading phase, spring barley grown in pots with an optimal water dose produced significantly more shoots than plants grown on less moist soil. More extensive tillering of barley was observed in both pure and mixed stands.

The number of leaves on spring barley plants was similar in pure and mixed stands (Table 3). No differences were noticed during the whole vegetative season. However, this trait was significantly differentiated by the amount of water available to plants. From emergence to stem elongation, significantly fewer assimilatory organs were found on plants growing under water deficit than in treatments with an optimum water supply. However, the proportions

Table 3

Number of spring barley leaves, leaves plant^{-1}

Source of variability	Treatment	Spring barley development phases				
		emergence	tillering	stem elongation	heading	ripeness
Stand type	C*	2.8^{a}	5.7^{a}	7.7^{a}	6.7^{a}	7.1^{a}
	M	2.9^{a}	5.7^{a}	7.7^{a}	6.8^{a}	7.3^{a}
Plant water supply	W	3.1^{a}	6.8^{a}	9.2^{a}	5.9^{b}	6.3^{b}
	N	2.6^{b}	4.6^{b}	6.2^{b}	7.6^{a}	8.1^{a}
Interaction of factors	C – W	3.0^{ab}	6.6^{a}	9.0^{a}	5.8^{b}	6.4^{b}
	C – N	2.6^{b}	4.8^{b}	6.3^{b}	7.6^{a}	7.8^{a}
	M – W	3.1^{a}	6.9^{a}	9.3^{a}	5.9^{b}	6.2^{b}
	M – N	2.6^{b}	4.4^{b}	6.1^{b}	7.6^{a}	8.3^{a}

* key cf. the Table 1

were reverse during the two subsequent phases, i.e. heading and ripening. When analyzing the interactions between the examined factors, it was found out that during emergence significantly more water was held in leaves of barley grown in a mixed stand and with optimum water supply than in pots with insufficient soil moisture. During the tillering and stem elongation phases, water deficit in soil made barley plants form significantly fewer assimilatory organs (2–3 leaves fewer) in both stand types compared to barley cultivated on moist soil. During the two final phases, the situation was opposite: irrespective of the stand type, the treatments poorer in water produced barley plants with more leaves (differences statistically verified) than the pots in which soil was moist enough to sustain good development of the plants. This was most probably a consequence of the different barley development rates induced by different water availability; under the lower water supply, the consecutive development phases began with a delay. At the same time, when the soil moisture content was optimal, lower leaves on barley plants began to wilt.

The length of barley ears did not depend on the stand type (Table 4). Reducing the water supply to half the optimal level resulted in the formation of shorter ears, but this effect was significant only during the heading phase. The response of barley to water deficit consisted of a significant reduction in the number of grains (by about 8 to 4 grains) compared to the pots with an optimal water supply. Our analysis of the interactions between the factors did not reveal significant differences in the values of this trait, but when barley plants received as much water in soil as required, a tendency towards a higher number of grains in barley ears, both grown in a pure stand or mixture with Italian ryegrass, was observed.

Table 4

Length of ear [cm] and number of grains per ear

Source of variability	Treatment	Spring barley development phases		
		heading	ripeness	
		length of ear		number of grains
Stand type	C	6.1^a	5.2^a	5.9^a
	M	5.9^a	5.1^a	6.2^a
Plant water supply	W	7.0^a	5.7^a	7.9^a
	N	5.0^b	4.7^a	4.2^b
Interaction of factors	C – W	7.0^a	5.8^a	8.0^a
	C – N	5.1^b	4.6^a	3.7^a
	M – W	6.9^a	5.3^a	7.7^a
	M – N	4.8^b	4.8^a	4.7^a

* key cf. the Table 1

In the early growth, spring barley grown as a pure stand produced significantly longer roots (by an average of 3 cm for the three cycles of the experiment) than barley grown in a mixture with Italian ryegrass (Table 5). No significant effect of the soil moisture content of this trait was demonstrated. Our analysis of the interaction between the factors showed that during the emergence phase significantly longer roots were formed by barley growing alone under water deficit conditions than mixed with Italian ryegrass irrespective of the water supply.

Table 5

Length of spring barley roots [cm]

Source of variability	Treatment	Emergence
Stand type	C	14.9^a
	M	12.0^b
Plant water supply	W	13.0^a
	N	13.9^a
Interaction of factors	C – W	14.0^{ab}
	C – N	15.8^a
	M – W	12.0^b
	M – N	11.9^b

* key cf. the Table 1

Discussion

Competition is one of the major ecological processes present in nature. It shapes the dynamics, composition and structure of biocenoses. Bleasdeale (after CONNOLLY et al. 2001) defines competition as a phenomenon which results in a depressed or retarded growth of one or both competing plants and modification of their exterior shape relative to plants growing separately.

The response consisting of mutual interactions between components in a sowing mixture is expressed through changes in the development of not only aerial parts (height, surface area of leaves) but also root systems (length of roots). In this study, Italian ryegrass was not indicated to have caused an effect on the morphology of aerial organs of barley, but its presence resulted in shorter barley roots. However, GALON et al. (2011) concluded that although Italian ryegrass does not limit the height of barley, it can be highly competitive towards this cereal, reducing its tillering, surface area of leaves and accumulation of dry matter. Similar results were obtained by IGNACZAK (1995), who demonstrated less extensive tillering of a protective crop (barley) grown together with Westerwold ryegrass. According to CRALLE et al. (2003), the extent of mutual reactions between components of a sowing mixture depends on the proportions of plants of particular species sown on a field and on the soil's abundance in nutrients. PŁAZA and CEGLAREK (2004) claim that Italian ryegrass sown as an intercrop acts positively on barley only when mixed with papilionaceous plants, and the positive influence consists of improved density of ears before harvest, more grains per ear and higher weight of 1000 grains of barley.

Sensitivity of barley to variable moisture content in soil is a species-specific trait (WIELGO and DZIAMBA 2000, MARTYNIAK 2001). In this study, water deficit was shown to produce typically a significant negative effect on the examined spring barley traits from emergence to full grain ripeness. As stated by MARTYNIAK (2001), the response of barley to water deficit in the early vegetative season is weak, but any water shortage occurring at the early heading phase may cause the highest yield losses. Our results are highly congruent with the data reported by SAMARAH et al. (2009), who noticed depressed plant height and worse yield structure components (e.g. number of ears per plant and grains per ear, lower 1000 grains weight) in barley grown under water deficit stress in both laboratory and field experiments. Also, PŁAZA and CEGLAREK (2004) demonstrated significantly inferior yield characteristics of barley grown alone under precipitation shortage during the vegetative season, but showed a positive effect of intercrops such as mixed legumes and Italian ryegrass on yields of the protective crop, also in dry years. According to WIELGO and DZIAMBA (2000), when soil is less wet, crops grow shorter and produce shorter ears, whether or not grown in the presence of Italian ryegrass. Additionally, the number of ears and leaves as well as number of grains per ear decline, which means that the presence of Italian ryegrass as the intercrop did not matter in this respect under water deficit conditions. WANIC et al. (2006), who traced changes in the water content in soil cropped with spring barley and Italian ryegrass during a whole plant growing season concluded that the grass is too competitive towards barley during the stem elongation phase of this cereal.

Conclusions

1. The stand type did not have any effect on the morphology of aerial parts of spring barley, such as plant height, number of stems and number of leaves per plant, length of an ear and its content of grains.

2. Depressed water supply reduced the height of barley plants, number of leaves and shoots, length of an ear and number of grains in an ear.

3. Italian ryegrass as an intercrop in spring barley did not exacerbate the negative effect of water deficit on development of barley.

4. During the emergence phase of spring barley, the presence of Italian ryegrass had a negative effect on length of barley roots.

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INFLUENCE OF COMPETITIVE INTERACTIONS BETWEEN SPRING BARLEY (*HORDEUM VULGARE* L.) AND ITALIAN RYEGRASS (*LOLIUM MULTIFLORUM* LAM) ON ACCUMULATION OF BIOMASS AND GROWTH RATE OF PLANTS DEPENDING ON WATER DOSES*

Maria Wanic, Marta K. Kostrzewska, Magdalena Jastrzębska, Kinga Treder

Department of Agricultural Systems
University of Warmia and Mazury in Olsztyn

K e y w o r d s: competition, spring barley, Italian ryegrass, water, biomass.

A b s t r a c t

Competitive interaction between spring barley and Italian ryegrass was investigated in the pot experiment. It was evaluated on the base of the dry mass accumulation in over-the-ground parts and roots. The factors of the experiment were: 1. method of sowing the plants – pure crop and mixed crop (with identical share of both components), 2. supply of plants with water – optimal dose (of 17000 cm^3 during vegetation period) and decreased by 50% as compared to it (8500 cm^3).

Examinations were conducted during the following spring barley development stages (BBCH): leaf development (10–13), tillering (22–25), stem elongation (33–37), inflorescence emergence (52–55) and ripening (87–91). It was shown that both species under the influence of competitive interactions developed lower over-the-ground mass than in pure crop. Barley had stronger negative influence on Italian ryegrass than the other way round. The decreased water dose increased the competitive influences of the grass on the cereal during the stem elongation and inflorescence emergence stages. The accumulation of over-the-ground biomass of Italian ryegrass in the mixed crop was lower than in pure crop during the entire vegetation period. From the stem elongation stage, larger differences between sowing methods occurred in the object with lower water supplies while they were equalised during the remaining period. In case of the mixed crop, the roots of both species were developed poorer than in pure crop without the differentiating influence of water doses. Under the influence of joint cultivation, a slowdown in biomass accumulation during the period between tillering and inflorescence emergence occurred in case of barley while in Italian ryegrass that slowdown occurred from leaf development until inflorescence emergence. The crop growth rate did not depend on the water dose supplied.

Address: Maria Wanic, University of Warmia and Mazury, pl. Łódzki 3, 10-718 Olsztyn, Poland, phone: +48 (89) 523 48 39, e-mail: mwanic@uwm.edu.pl
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WPŁYW ODDZIAŁYWAŃ KONKURENCYJNYCH MIĘDZY JĘCZMIENIEM JARYM (*HORDEUM VULGARE* L.) I ŻYCICĄ WIELKOKWIATOWĄ (*LOLIUM MULTIFORUM* LAM) NA AKUMULACJĘ BIOMASY I TEMPO WZROSTU ROŚLIN W ZALEŻNOŚCI OD DAWEK WODY

Maria Wanic, Marta K. Kostrzewska, Magdalena Jastrzębska, Kinga Treder

Katedra systemów rolniczych
Uniwersytet Warmińsko-Mazurski w Olsztynie

S ł o w a k l u c z o w e: konkurencja, jęczmień jary, życica wielkokwiatowa, woda, biomasa.

A b s t r a k t

W doświadczeniu wazonowym badano oddziaływania konkurencyjne między jęczmieniem jarym i życicą wielokwiatową. Oceniano je na podstawie akumulacji suchej masy w częściach nadziemnych i korzeniach. Czynnikami doświadczenia były: 1. sposoby siewu roślin – w siewie czystym oraz w mieszance (o jednakowym udziale obu komponentów), 2. zaopatrzenie roślin w wodę – dawka optymalna (wynosząca w okresie wegetacji 17 000 cm^3) oraz obniżona w stosunku do niej o 50% (8500 cm^3). Badania wykonywano w fazach rozwojowych jęczmienia jarego (BBCH): wschody (10–13), krzewienie (22–25), strzelanie w źdźbło (33–37), kłoszenie (52–55) i dojrzewanie (87–91). Wykazano, że oba gatunki pod wpływem oddziaływań konkurencyjnych wykształciły mniejszą masę nadziemną niż w siewie czystym. Jęczmień wywierał silniejszy ujemny wpływ na życicę niż odwrotnie. Zmniejszona dawka wody nasilała oddziaływania konkurencyjne trawy na zboże w fazach strzelania w źdźbło i kłoszenia. Akumulacja nadziemnej biomasy życicy wielokwiatowej w mieszance była mniejsza niż w siewie czystym w całym okresie wegetacji. Do fazy strzelania w źdźbło większe różnice między sposobami siewu wystąpiły w obiekcie uboższym w wodę, a potem się wyrównały. W mieszance korzenie obu gatunków były słabiej wykształcone niż w siewie czystym, bez różnicującego wpływu dawek wody. Pod wpływem wspólnej uprawy u jęczmienia nastąpiło spowolnienie tempa gromadzenia biomasy w okresie między krzewieniem i kłoszeniem, a u życicy od wschodów do kłoszenia. Szybkość wzrostu łanu obu gatunków nie zależała od wielkości dawki wody.

Introduction

The beneficial influence of intercrops on the soil environment, sanitary status of standing crop and productivity of crops caused that they have become the inseparable component in organic farming also recommended in integrated farming (DOLTRA, OLESEN 2013, JASKULSKA, GAŁĘZEWSKI 2009, JASKULSKI, JASKULSKA 2006, KOSTRZEWSKA et al. 2011). Various species of plants can be sown as intercrops and various forms of them can be cultivated. Sown intercrops represent one of the forms. For the majority of vegetation period they grow together with the protected crop and after its harvest, they remain in the field until late autumn and next they are ploughed as green fertiliser or harvested for forage. Nevertheless, it should be taken into account that the intercrops may compete with the main crop for the environmental factors, particularly water, light and biogens contributing finally to the lower yields of the main crop (HAUGGAARD-NIELSEN et al. 2001). Theoretically, that competition

can commence already during the initial period of vegetation and continue, with diversified intensity, until its end. The intensity of that process depends on the choice of species, their densities and the environment factors.

Italian ryegrass is one of the species used frequently as intercrop sown with cereals including spring barley. Its positive influence on the barley yield manifests, however, during the years of moderate or abundant rainfalls. During the dry seasons, the intercrop becomes a strong competitor for water for the cereal (WANIC et al. 2006). Hence, the research hypothesis was formulated assuming that shortage of water may intensify the competitive influences between spring barley and Italian ryegrass. Verification of that hypothesis was conducted on the base of the pot experiment aimed at evaluation of the competitive influences between those species under conditions of abundance and shortage of water on accumulation of biomass in over-the-ground parts and roots of the plants during the entire period of their vegetation.

Materials and Methods

The studies were conducted on the base of the closed pot experiment performed at the Greenhouse Laboratory of the Faculty of Biology and Biotechnology, University of Warmia and Mazury in Olsztyn. Three cycles of the experiment were carried out. The first continued from 18.03 until 30.06.2009, the second from 15.03 until 05.07.2010 and the third from 18.04 until 22.07.2011. Spring barley (*Hordeum vulgare*) – naked grain cultivar *Rastik* and Italian ryegrass (*Lolium multiflorum* LAM) – *Gaza* cultivar were the subject of evaluation.

The light typical brown soil formed of low clay sand with dusty sand in subsoil formed the medium for the experiment. It was characterised by slightly acid reaction, 0.71–1.11% organic carbon content and moderate abundance with phosphorus, potassium and magnesia. The soil with whichpots were filled was collected from the layer of up to 25 cm deep.

The factors of the experiment were:

I – plants sowing method: pure crop (C) and mixed crop (M),

II – water supply: dose consistent with the demand of the crops and dose decreased to 50% of it.

In case of the object with optimal water supply, the quantity of that component supplied to the plants during the vegetation season per pot was 17000 cm^3 while the decreased quantity (less by a half) was 8500 cm^3. During the vegetation period, the water dose was diversified depending on the development stage of the crops and soil humidity. The "optimal" water dose was determined on the base of the test experiment in which measurements of the soil humidity, transpiration and water content in plants were taken.

The experiment was established according to the additive model in which the number of plants in the mixed crop is the sum of the numbers of plants in pure crop sowing (SEMERE, FROUD-WILLIAMS 2001). In total, each round of the experiment consisted of 120 Kick-Brauckmann pots: 3 sowing methods (pure barley, pure Italian ryegrass and together in mixed crop) x 2 levels of water supplies to the plants x 5 development stages x 4 repetitions. Each pot 22 cm in diameter and 28 cm deep was filled, one week before sowing of plants, with 8 kg of soil applying once mineral fertilisation at the dose of pure components ($g \cdot pot^{-1}$): N – 0.5 (in the form of urea), P – 0.2 (monopotassium phosphate), K – 0.45 (potassium sulphate).

In each pot, 18 germinating seedlings of barley or Italian ryegrass or in case of the mix 18 germinating seedlings of barley and 18 germinating seedlings of Italian ryegrass were sown. Using patterns, they were positioned in equal distances from one another on the surface of the soil medium and then then immersed in it to the depth of 3 cm. The pots containing barley, Italian ryegrass and the mixed crop were isolated from each other using partitions of aluminium film.

During almost the entire duration of the experiment, the air temperature at the laboratory was maintained within 20–22°C. To allow the plants going through the full vernalisation process, during the peak of leaf development stage the temperature was decreased to 6–8°C for the period of 9 days. Soil medium humidity measurements were taken daily (using the Easy Test device by the Institute of Agrophysics in Lublin).

The competitive influences between species were examined during five periods determined by the development rhythm of spring barley as pure crop growing under conditions of optimal water supply during the BBCH stages of leaf development (10–13), tillering (22–25), stem elongation (33–37), inflorescence emergence (52–55) and ripening (87–91).

Every year, when spring barley reached the appropriate development phase, all plants were removed from pots projected for that stage, roots were separated from over-the-ground parts from which, according to the development stage the leaves, stems and heads were separated (in case of barley only as in case of ryegrass they were not developed). The separated parts of plants were dried to air-dry mass and weighted. Based on the yields of over-the-ground dry mass the computations of standing crop growth rate were made using the following formula (PIETKIEWICZ 1985, RADFORD 1967):

$$CGR = \frac{dWc}{dt} \cdot \frac{1}{P}$$

where:
CGR – crop growth rate,
dWc – crop biomass increase (g dry mass),
dt – period of time during which the increase occurred,
P – pot surface (m^2).

The results were processed statistically by applying the variance analysis method for the system of factors at the error probability of $\alpha = 0.05$, applying the *Statistica* software. Statistics were computed for each growth phase and individual plant parts separately. Duncan's test was applied for evaluation of differences between objects.

Results

The over-the-ground biomass of spring barley increased until the inflorescence emergence phase and then during the ripening phase it was reduced (by 7.6% as compared to the inflorescence emergence phase; Table 1). The factors of the experiment diversified the biomass across the entire vegetation period. Plants growing in mixed crop with Italian ryegrass were characterised by significantly lower mass than those from pure crop (except for mixed sowing during barley tillering when only the tendency for obtaining lower productivity was recorded). The largest differences between the methods of sowing appeared at the inflorescence emergence stage when the yield of the over-the-ground mass of that cereal growing together with ryegrass was lower by 22.2% than in pure crop. Limitation of mass increase of that crop in the mixed crop as compared to pure crop at the stem elongation phase was more pronounced in the leaves than in the stems. During the inflorescence emergence stage, it was more pronounced in case of the leaves and heads than in the stems. During the ripening stage, it concerned mainly the yield of grains as the mass of stems, leaves and heads did not show significant diversification resulting from the method of sowing.

In case of optimal water dose, plants of spring barley developed higher mass than in case of the decreased water availability. The favourable influence of the water dose was the most pronounced at the stem elongation stage. The productivity of plants at that object was in average more than 2.5 times higher than of those growing under conditions of water shortage. During the final period of vegetation, as a consequence of the decreasing demand of barley concerning water, the influence of water doses proved to be smaller. Water shortage during the stem elongation phase decreased the growth of stems the most while during the phases of inflorescence emergence and ripening – the growth of heads.

Table 1

Dry mass of over the ground parts of spring barley ($g \cdot pot^{-1}$)

Development phase (BBCH)	Parts of plants	Higher water dose			Lower water dose			Average		
		Sowing method								
		*C**	*M**	average	*C*	*M*	average	*C*	*M*	average
Leaf development (10–13)	leaves	0.94^{a}	0.80^{b}	0.87^{a}	0.75^{b}	0.63^{c}	0.69^{b}	0.85^{a}	0.72^{b}	0.79
Tillering (22–25)	leaves	5.26^{a}	4.73^{a}	5.00^{a}	2.68^{b}	2.35^{b}	2.52^{b}	3.97^{a}	3.54^{a}	3.76
Stem elongation (33–37)	stems	8.15^{a}	7.41^{b}	7.78^{a}	3.02^{c}	2.38^{d}	2.70^{b}	5.59^{a}	4.90^{b}	5.25
	leaves	6.21^{a}	4.97^{b}	5.59^{a}	2.83^{c}	2.19^{d}	2.51^{b}	4.52^{a}	3.58^{b}	4.05
	total	14.36^{a}	12.38^{b}	13.37^{a}	5.85^{c}	4.57^{d}	5.21^{b}	10.11^{a}	8.48^{b}	9.30
Inflorescence emergence (52–55)	stems	9.08^{a}	7.95^{b}	8.52^{a}	4.39^{c}	3.16^{d}	3.78^{b}	6.74^{a}	5.56^{b}	6.15
	leaves	7.07^{a}	4.93^{b}	6.00^{a}	4.15^{c}	3.39^{d}	3.77^{b}	5.61^{a}	4.16^{b}	4.89
	heads	2.83^{a}	2.22^{b}	2.53^{a}	0.96^{c}	0.52^{d}	0.74^{b}	1.90^{a}	1.37^{b}	1.64
	total	18.98^{a}	15.10^{b}	17.05^{a}	9.50^{c}	7.07^{d}	8.29^{b}	14.25^{a}	11.09^{b}	12.67
Ripening (87–91)	stems	6.43^{a}	6.22^{a}	6.33^{a}	5.77^{a}	4.14^{b}	4.96^{b}	6.10^{a}	5.18^{a}	5.64
	leaves	5.07^{a}	4.72^{a}	4.90^{a}	3.76^{b}	3.35^{b}	3.56^{b}	4.42^{a}	4.04^{a}	4.23
	heads, including grain	2.94^{a} 2.34^{a}	$1.98^{a,b}$ 1.84^{b}	2.46^{a} 2.09^{a}	1.38^{a} 1.25^{c}	1.09^{b} 1.01^{c}	1.24^{a} 1.13^{b}	2.15^{a} 1.80^{a}	1.54^{a} 1.43^{b}	1.85 1.62
	total	14.44^{a}	12.92^{b}	13.67^{a}	10.91^{c}	8.58^{d}	9.76^{b}	12.68^{a}	10.76^{b}	11.71

*C – pure crop, M – mixed crop

a, b, c, d – homogenous groups: values marked with the same letter within the individual factors or their combined influence do not differ significantly at $p = 0.05$

The ryegrass growing together with barley limited the mass increase of the over-the-ground parts of barley in similar way on both objects with different soil humidity during the phases of leaf formation and inflorescence emergence. During stem elongation and ripening, its negative influence was more pronounced under conditions of water shortage. During the stem elongation phase, the difference between the mixed crop and pure crop at the object with the water dose lower by a half relative to the needs of barley was 21.9% while in case of optimal water supply that difference was 13.8%. During ripening, those differences were 21.4% and 10.5% respectively. During the tillering stage, the sowing method did not diversify the biomass of that cereal significantly in case of both moisture levels. Analysis of the individual parts of barley showed that mixed sowing limited growth of its stems significantly more at the object offering lower availability of water. During leaf formation and stem elongation, the difference in the mass of leaves between the mixed and pure crop at both water doses was similar and during inflorescence emergence cultivation of both species together limited growth of the leaves more in pots watered with more quantity of water. During the phases of tillering and ripening, the sowing

method was without influence on the mass of leaves at both objects. During the inflorescence emergence stage, larger differences in the mass of heads between sowing methods were encountered on the object with the lower water dose while at the ripening stage the relations were the opposite. Joint cultivation of species in combination with the lower water dose did not diversify the grain shapeliness while in combination with the higher water dose it confirmed the advantage of pure crop over the mixed crop cultivation.

Over-the-ground mass of Italian ryegrass increased until the end of the experiment duration and changed under the influence of the experiment factors more evidently than spring barley (Table 2). The cereal had negative influence on the grass already from the beginning of vegetation. The reaction of ryegrass to the presence of barley became more pronounced at the phase of inflorescence emergence when the dry mass yield was 72.3% lower than in pure crop. At the end of vegetation, the difference between the mixed crop and pure crop decreased slightly (to 63.6%). During the stem elongation and inflorescence emergence phases, barley had stronger negative influence on the mass of ryegrass stems than the leaves and during ripening, it limited their growth to a similar extent.

Under water shortage conditions, ryegrass generates significantly less dry mass than when optimal water supply was assured during the entire vegetation period. During leaf emergence, at the object with lower water supply, its

Table 2

Dry mass of over the ground parts of Italian ryegrass ($g \cdot pot^{-1}$)

Development phase (BBCH)	Parts of plants	Higher water dose			Lower water dose			Average		
		sowing method								
		*C**	*M**	average	*C*	*M*	average	*C*	*M*	average
Leaf development (10–13)	leaves	0.15^a	0.14^b	0.14^a	0.11^c	0.10^c	0.11^b	0.13^a	0.12^b	0.13
Tillering (22–25)	leaves	2.55^a	1.17^b	1.86^a	1.03^c	0.40^d	0.72^b	1.79^a	0.79^b	1.29
Stem elongation (33–37)	stems	4.18^a	0.79^c	2.49^a	1.39^b	0.44^d	0.95^b	2.79^a	0.61^b	1.71
	leaves	3.97^a	2.00^c	2.99^a	2.82^b	0.84^d	2.57^b	3.40^a	1.42^b	2.41
	total	8.15^a	2.79^c	5.47^a	4.21^b	1.28^c	3.52^b	6.19^a	2.04^b	4.12
Inflorescence emergence (52–55)	stems	7.74^a	1.88^c	4.81^a	3.55^b	0.90^d	2.23^b	5.65^a	1.39^b	3.52
	leaves	13.11^a	3.91^c	8.51^a	6.98^b	2.00^d	4.49^b	10.05^a	2.96^b	6.51
	total	20.85^a	5.79^c	13.32^a	10.53^b	2.90^d	6.72^b	15.70^a	4.35^b	10.03
Ripening (87–91)	stems	7.61^a	2.62^c	5.15^a	3.44^b	1.32^d	2.38^b	5.53^a	1.97^b	3.75
	leaves	15.02^a	5.53^c	10.28^a	8.80^b	3.21^d	6.01^b	11.91^a	4.37^b	8.14
	total	22.63^a	8.15^c	15.40^a	12.24^b	4.53^d	8.39^b	17.44^a	6.34^b	11.89

*C – pure crop, M – mixed crop

a, *b*, *c*, *d* – homogenous groups: values marked with the same letter within the individual factors or their combined influence do not differ significantly at $p = 0.05$

productivity was lower than at the object with abundant water supply by over 20%, and during the tillering stage the difference was over 60%. That difference decreased during the stem elongation phase (to 36%) to increase again during further vegetation (to almost 50%. Lowered water availability limited mass increase of stems more than that of the leaves, particularly during the barley stem elongation phase.

Until the barley stem elongation phase, the negative influence of mixed sowing was slightly more pronounced at the object less abundant with water. During the remaining phases of vegetation, the water dose had no influence on the size of differences between the sowing methods. At stem elongation phase, in the mixed crop, higher water dose limited the mass of ryegrass more than the lower water dose. In case of the leaves, the relations were the opposite. During the other periods, the size of differences between sowing methods in dry mass of stems and leaves was similar.

Under the influence of competition, barley and ryegrass also developed poorer roots (Table 3). In case of the mixed crop, their combined mass was lower than the combined mass of the roots of both species from pure crop. During the individual phases the differences were as follows: leaf formation (by 33.9%), stem elongation (by 41.5%) inflorescence emergence (by 42.1%) and ripening (by 44.8%). No significant differences were observed during barley tillering only.

Table 3

Dry mass of spring barley and Italian ryegrass roots in pure and mixed crop ($g \cdot pot^{-1}$)

Barley development stage (BBCH)	Plant	Water dose		
		higher	lower	average
Leaf development (10–13)	barley (*C**)	0.54	0.54	0.54
	Italian ryegrass (*C*)	0.05	0.04	0.05
	barley + Italian ryegrass (*M**)	0.33	0.44	0.39
	average	0.31	0.34	0.33
Tillering (22–25)	barley (*C*)	1.76	0.95	1.36
	Italian ryegrass (*C*)	0.67	0.49	0.58
	barley + Italian ryegrass (*M*)	2.41	1.41	1.91
	average	1.61	0.95	1.28
Stem elongation (33–37)	barley (*C*)	3.06	1.67	2.37
	Italian ryegrass (*C*)	2.39	1.65	2.02
	barley + Italian ryegrass (*M*)	3.01	2.13	2.57
	average	2.82	1.82	2.32
Inflorescence emergence (52–55)	barley (*C*)	2.09	1.75	1.92
	Italian ryegrass (*C*)	6.75	3.62	5.19
	barley + Italian ryegrass (*M*)	4.79	3.45	4.12
	average	4.54	2.94	3.74
Ripening (87–91)	barley (*C*)	1.80	0.94	1.37
	Italian ryegrass (*C*)	5.63	3.58	4.61
	barley + Italian ryegrass (*M*)	4.06	2.54	3.30
	average	3.83	2.35	3.09

*C – pure crop, M – mixed crop

The water dose did not diversify the mass of roots during the plants leaf formation phase. However, already during tillering its influence became visible. In average, for the sowing methods, decreasing its supply resulted in 41.0% limitation in roots mass increase. During the stem elongation phase those differences decreased to 35.5% and they remained at a similar level until the end of vegetation.

Mixed sowing was more limiting to dry mass accumulation in the roots of both species during the leaf development stage at the objects more abundant with water. During further development phases, water doses had similar influence on the size of the differences in the mass of roots between sowing methods.

Spring barley achieved the fastest crop growth rate (CGR) in the over-the-ground parts during the tillering-stem elongation interphase (Table 4). For the sowing methods and water doses it averages 0,49 $g \cdot day \cdot pot^{-1}$. Between inflorescence emergence and ripening, however, the reduction of it was detected. No influence of sowing method on crop growth rate between leaf formation and tillering was found. It became visible during the later period where in the mixed crop significantly slower rate of growth was recorded; in relation to pure crop it was: from tillering until stem elongation 18.5% and from stem elongation until inflorescence emergence 37.5%. At the end of vegetation, the differences between sowing methods were levelled.

The halved water dose decreased growth of barley field during the entire period of its vegetation. It was the most pronounced between tillering and stem elongation phase.

Table 4

Spring barley field growth rate ($g \cdot day \cdot pot^{-1}$)

Development stage	Sowing method	Water dose		
		higher	lower	average
Leaf development – tillering	pure	0.27^{a}	0.12^{b}	0.20^{a}
	mixed	0.25^{a}	0.10^{b}	0.18^{a}
	average	0.26^{a}	0.11^{b}	0.19
Tillering – stem elongation	pure	0.79^{a}	0.28^{b}	0.54^{a}
	mixed	0.67^{a}	0.20^{b}	0.44^{b}
	average	0.73^{a}	0.24^{b}	0.49
Stem elongation – inflorescence emergence	pure	0.18^{a}	$0.14^{a,b}$	0.16^{a}
	mixed	0.11^{b}	0.09^{b}	0.10^{b}
	average	0.15^{a}	$0.12^{a,b}$	0.13
Inflorescence emergence – ripening	pure	-0.17^{b}	0.06^{a}	-0.06^{a}
	mixed	-0.08^{b}	0.09^{a}	-0.01^{a}
	average	-0.13^{b}	0.08^{a}	–0.03

a, *b* – homogenous groups: values marked with the same letter within the individual factors or their combined influence do not differ significantly at $p = 0.05$

During almost the entire vegetation period, the doses of water had no significant influence on the size of differences in dry mass accumulation rates caused by sowing methods. Only during the stem elongation – inflorescence emergence interphase at the object more abundant in water, barley cultivated as pure crop accumulated biomass faster than in the mix with ryegrass.

Over-the-ground mass of Italian ryegrass, similar to spring barley, increased the fastest between tillering and stem elongation and the slowest between inflorescence emergence and ripening (Table 5). Significantly lower crop growth rate was determined in the mixed crop during the period from barley leaf development until inflorescence emergence. The average for water doses daily dry mass increases were lower there than in pure crop by from 54.5% to 80.9%. At the end of the vegetation period, the higher dry mass accumulation rate was determined in case of the mixed crop.

Table 5

Italian ryegrass field growth rate ($g \cdot day \cdot pot^{-1}$)

Development stage	Sowing method	Water dose		
		higher	lower	average
Leaf development – tillering	pure	$0{,}16^{a}$	$0{,}05^{b,c}$	$0{,}11^{a}$
	mixed	$0{,}07^{b}$	$0{,}02^{c}$	$0{,}05^{b}$
	average	$0{,}11^{a}$	$0{,}04^{b}$	0,08
Tillering – stem elongation	pure	$0{,}66^{a}$	$0{,}28^{b}$	$0{,}47^{a}$
	mixed	$0{,}10^{c}$	$0{,}08^{c}$	$0{,}09^{b}$
	average	$0{,}38^{a}$	$0{,}18^{b}$	0,28
Stem elogation – inflorescence emergence	pure	$0{,}39^{a}$	$0{,}24^{b}$	$0{,}32^{a}$
	mixed	$0{,}13^{c}$	$0{,}06^{d}$	$0{,}10^{b}$
	average	$0{,}26^{a}$	$0{,}15^{b}$	0,21
Inflorescence emergence – ripening	pure	$0{,}04^{a}$	$0{,}04^{a}$	$0{,}04^{a}$
	mixed	$0{,}06^{a}$	$0{,}04^{a}$	$0{,}05^{b}$
	average	$0{,}05^{a}$	$0{,}04^{a}$	0,05

a, b, c – homogenous groups: values marked with the same letter within the individual factors or their combined influence do not differ significantly at $p = 0.05$

The lower water dose decreased the ryegrass growth rate until the barley inflorescence emergence phase, particularly during the initial period of vegetation. With the passage of time, the influence of water shortage was decreasing. Water doses were without significance for the size of differences between sowing methods.

Discussion

It has been shown in own studies that in the mixed crop spring barley and Italian ryegrass developed lower over-the-ground biomass than in case of pure crop sowing and Italian ryegrass showed stronger negative reaction to that sowing method. This is similar to the results obtained by SOBKOWICZ (2003), SOBKOWICZ and PODGÓRSKA-LESIAK (2009) and TREDER et al. (2008), who show that spring barley is the species with strong negative influence on other species. According to MOLLA and SHARAIHA (2010), SOBKOWICZ (2003) and SOBKOWICZ and PODGÓRSKA-LESIAK (2009), domination of barley results from its fast initial growth rate causing uptake of biogens from the soil and relatively short vegetation period. Different opinions are presented by GALON et al. (2011), KÄNKÄNEN and ERIKSSON (2007) and RAHETLAH et al. (2013). Their studies indicate that *Lolium multiflorum* is a strong competitor for both spring barley and other species. In own studies, the negative influence of the mixed crop components on dry mass accumulation in their over-the-ground parts increased until the barley inflorescence emergence phase and then, at the end of vegetation, it weakened. Also, SATORRE and SNAYDON (1992) showed that the highest intensity of competitive influences between cereals and *Avena fatua* occurs during the Zadoks periods from 30 until 70, which is reflected to a large extent in the here-presented experiment. On the other hand, the studies by LAMB at al. (2007) indicate that the negative effects of joint cultivation manifest more clearly in younger plants than in those with advanced vegetation. BULSON et al. (1997), MICHALSKA et al. (2008), SOBKOWICZ (2003) and TREDER et al. (2008) inform about weakening of the negative mutual influences of species at the end of vegetation. The quoted authors also link it to the different maturing times of the components. At the final stage of vegetation of one of the species, its life needs become small which causes that the available pool of growth factors is used mainly by the second species.

The sowing method not only diversified the total volume of over-the-ground biomass of barley and ryegrass but also its structure. In spring barley, during almost the entire period of vegetation, the largest limitation in dry mass accumulation was found in the leaves and the smallest in the stems, which is consistent with the results by TREDER et al. (2008). Only during ripening, biomass accumulation in the leaves, stems and heads did not show any significant correlation with the sowing method. Also, SOBKOWICZ (2003) did not record changes in biomass accumulation in the individual over-the-ground parts of plants under the influence of mixed sowing. In case of the mixed crop, in case of Italian ryegrass the lower than in pure crop yield of dry mass was found for both the stems and the leaves. The size of the difference between sowing methods in case of those parts of plants depended on the development

phase. The studies by LUCERO et al. (2002) showed no influence of mixed sowing of *Trifolium repens* with *Lolium perenne* on the mass of leaves developed by that grass as well as its positive influence on shapeliness of its stems. In the analysed experiment, in case of the mix, the total mass of the roots of both species was lower than in pure crop by ca. 40%. Similar scale of clover and ryegrass roots reduction was recorded by LUCERO et al. (2002). Also TREDER et al. (2008), studying the process of competition between spring wheat and spring barley found out a decrease in the mass of roots of both those cereals. The size of that decrease was similar to that of the over-the-ground parts.

In of own studies, in case of mixed crop, the water dose decreased by half in relation to the need of plants increased the competitive influence of ryegrass on barley during the phases of stem elongation and inflorescence emergence and that of barley on ryegrass from leaf development to stem elongation. During the other periods of joint vegetation, water doses had no influence on the size of differences in dry mass between the sowing methods. There are differences of opinions in the literature as concerns the influence of water doses on productivity of plants in case of mixed crops. LUCERO et al. (2000), investigating competition between *Trifolium repens* and *Lolium perenne* showed that in both species dry mass increases were the smaller the higher the deficit of the water was. Consistency with the above is shown by the studies of SEMERE and FROUD-WILLIAMS (2001), which showed that under conditions of drought the competitive influence of peas on maze was more intensive than in case of water excess. Decrease in competition with the increase of soil humidity was also found by MOLLA and SHARAIHA (2010). WRIGHT et al. (1999), investigating the process of competition between two cultivars of wheat and *Sinapis arvensis* showed that the cereal was more competitive than the weed on the dry soil than on the moist soil. TSIALTAS et al. (2001) in turn showed that species growing in mixed meadow communities make more effective use of the water taken from the soil and the competition among them is less fierce. Similar conclusions can be found in the work by LAMB et al. (2007). A different opinion is presented by KOLB et al. (2002), who proved that water deficit decreases the force of mutual influence of barley and ryegrass. A still different opinion is presented by CASPER and JACKSON (1997), who claim that in dry ecosystems there is no intensified competition for water between plants. WANIC et al. (2006), investigating changes in the water level in soil under spring barley and Italian ryegrass showed that the grass became a strong competitor for water to barley at the stem elongation phase of the cereal, which shows consistency with the presented results.

Conclusions

1. In the mixed crop, spring barley and Italian ryegrass developed lower over-the-ground dry mass than in the pure crop. Italian ryegrass showed stronger reaction to joint cultivation.

2. Mixed sowing on the object supplied with a dose of water lower by a half than the needs of the plants limited spring barley over-the-ground biomass growth during the phases of stem elongation and inflorescence emergence, and of Italian ryegrass from leaf development to stem elongation more that optimal water supply.

3. Among the analysed over-the-ground parts of spring barley, leaves and heads showed stronger negative reaction to cultivation in mixed crop while the stems showed weaker negative reaction.

4. Mixed sowing had the most limiting influence on dry mass accumulation in the leaves of ryegrass during the barley stem elongation stage, in its stems during the inflorescence emergence phase and proportionally in the stems and leaves during ripening.

5. The mass of roots of both species in the mixed crop was smaller than in pure crop without the diversifying influence of water doses.

6. In the mixed crop, spring barley had the lower rate of biomass accumulation during the period between tillering and inflorescence emergence. In case of Italian ryegrass, the lower rates were recorded from leaf development until inflorescence emergence without the diversifying influence of the water doses.

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STRUCTURE VARIABILITY OF *CHARA TOMENTOSA L.* SPECIMEN ON STANDS OF DIVERSE HABITAT CONDITIONS

Ewa Hirsz-Siwicka

Chamber of Natural Sciences
Sopot High School

K e y w o r d s: ecology of stoneworts, structure of population, *Chara tomentosa*, Pojezierze Mazurskie.

A b s t r a c t

Chara tomentosa is a species placed on the red list of endangered algae in Poland. However, its ecology is still barely known. The aim of the study was to advance this knowledge through determination of the variability of *Chara tomentosa* specimen between the stands of varied habitat properties. The structure of the specimen was tested in six lake populations of *Chara tomentosa* in Pojezierze Mazurskie (Mazurskie Lake District). A total length and biomass of the specimen as well as its habit and reproductive potential were determined in each of them. In the habitats rich in calcium, nitrogen and phosphorus, long (52–74 cm), of high biomass (0.6–1.2 g), extensively branched (2 branches on average) specimens of high reproductive potential (1.5–3.2 generative branches) occurred. Whereas, in the habitats poorer in the said elements small (29–42 cm), light (0.5 g) usually weakly branched specimens of low reproductive potential (0.5 generative branches) occurred.

ZMIENNOŚĆ STRUKTURY OSOBNIKA *CHARA TOMENTOSA* L. NA STANOWISKACH O ZRÓŻNICOWANYCH WARUNKACH SIEDLISKOWYCH

Ewa Hirsz-Siwicka

Katedra Nauk Przyrodniczych
Sopocka Szkoła Wyższa

S ł o w a k l u c z o w e: ekologia ramienic, struktura populacji, *Chara tomentosa*, Pojezierze Mazurskie.

Address: Ewa Hirsz-Siwicka, Sopot High School, ul. Rzemieślnicza 5, 81-855 Sopot, Poland, phone: +48 (58) 550 78 80, e-mail: ewahirsz@vp.pl

Abstrakt

Chara tomentosa jest gatunkiem umieszczonym na czerwonej liście glonów zagrożonych w Polsce, jednak jego ekologia jest nadal słabo poznana. Celem pracy było pogłębienie tej wiedzy poprzez określenie zmienności cech osobnika *Chara tomentosa* między stanowiskami o zróżnicowanych właściwościach siedliskowych. Strukturę osobnika zbadano w 6 jeziornych populacjach *Chara tomentosa* na Pojezierzu Mazurskim. W każdej z nich określono całkowitą długość i biomasę osobnika oraz jego pokrój i potencjał reprodukcyjny. Na siedliskach bogatych w wapń azot i fosfor występowały długie (52–74 cm), o wysokiej masie (0,6–1,2 g), mocno rozgałęzione (średnio 2 odgałęzienia) osobniki o silnym potencjale reprodukcyjnym (1,5–3,2 odgałęzień generatywnych), natomiast na siedliskach uboższych w te pierwiastki były one niewielkie (29–42 cm), lekkie (0,5 g), zazwyczaj słabo rozgałęzione i o słabym potencjale reprodukcyjnym (0,5 odgałęzień generatywnych) okazy.

Introduction

As a consequence of a negative influence of habitat factors, extinction of many charetea is reported. A high content of phosphorus (FORSBERG 1964, KOHLER et al. 1971) or light deficiency (BLINDOW 1988, 1992a, 1992b, COOPS and DOEF 1996) is believed to be one of the causes. Extinction of charetea has been noticed, inter alia, in Sweden (BLINDOW 1991), Finland (RINTANEN 1996), Holand (SIMONS and NAT 1996) and in Poland, where e.g. in Lake Mikołajskie, phytomass of charophyta in comparison to biomass of remaining macrophytes decreased from 60% in 1963 to 24% in 1980 and in the years 1980–1990, charophyta were completely eliminated (OZIMEK 1992).

Undoubtedly, a number of endangered species from *Characeae* of the same colony reflects inconvenient conditions of life for charophyta. All 33 taxa found in Poland (DĄMBSKA 1964, RINGER 1972) are on the red list of endangered algae (SIEMIŃSKA 2006). *Chara tomentosa* L. 1753 is one of them. Earlier, it was a taxon of an undetermined group of risk (SIEMIŃSKA 1992), currently is included in the group of rare species (SIEMIŃSKA 2006). However, there is insufficient information on this topic.

Thus, it is worth to advance the knowledge on this subject, inter alia, by determining optimal habitat conditions for development of this species. They may be depicted on the basis of individual variability of *Chara tomentosa* (MIGULA 1898, 1900, DĄMBSKA, KARPIŃSKI 1954, DĄMBSKA 1964, KRAUSE 1976, 1997). According to FALIŃSKA (1974, 1996) and ANDRZEJEWSKA (1983) diversity of individuals within one species results from the influence of abiotic and biotic environment (or it may be genetically influenced). Thus, it is a good indication of living conditions of the population.

Methods of experiments

Methods of experiments on the structure of a specimen

Field experiments were held in August in 2001 in the following lakes: Neliwa Lake (53° 22' N; 19° 52' E), Jełguń Lake (53° 39' N; 20° 32' E), Majcz Wielki Lake (53° 47' N; 21° 27' E), Krutyńskie Lake (53° 42' N; 21° 25' E) and in 2002 in Redykajny Lake (53° 49' N; 20° 25' E) and Kołowin Lake (53° 44' N; 21° 24' E). In each of the lakes, one stand was selected in the sites, where species *Chara tomentosa* occurred and formed a large, well visible patch in the environment[1].

In the first half of August, within the range of one population, five samples of plants of 0.1 m2 surface area were taken at random at the depth of 0.5 m. From among the above 5 samples, 6 specimens of *Chara tomentosa* were selected during species segregation (6 specimens * 5 samples = 30 individuals from a particular population) in order to examine individual properties (length, dry biomass and habit). Their total length and length of the third internode of a pseudo-stem (from the bottom of a thallus) and size of the longest pseudo-leaf growing out of the third internode were measured when dry. Next, stoneworts were dried in the temperature of 105°C for 3 hours. After drying, the biomass of the whole specimen was determined with accuracy up to 0.01 g. The habit was estimated on the basis of two above-mentioned properties: length of an internode and a pseudo-leaf as well as the number of long branches (over 5 cm). Number of branches with reproductive organs (oogonia and antheridia) was an additional feature taken into consideration.

Methods of experiments on habitat conditions

The analyses of habitat conditions of the researched stands were carried out in August 2001 and 2002. One surface sample of a 5-centimetres layer of sediments was taken from the best-developed area of population of *Chara tomentosa* from each lake, on the basis of which, properties of over-sedimentary water were determined. The samples of sediments were taken with the use of a tube sampler Kajak type of 52 mm diameter.

Over-sedimentary water was obtained by decanting a layer of water over sediments. In this water, nitrogen (nitrate and total), phosphorus (phosphatic and total) as well as calcium were determined. The analyses were carried out according to the methods set out by HERMANOWICZ et al. (1998). Calcium was

[1] permit number: OŚR/OIII/6638/67/00, OŚR/OIII/6636/69/01.

measured by the use of sodium versenate compared to calcite. Nitrate nitrogen was determined with phenol-disulphonic acid (435 nm), Kjeldahl nitrogen – with the distillation method; total nitrogen was calculated as a sum of Kjeldahl and nitrate nitrogen. Phosphoric phosphorus was determined with ammonium molybdenum and tin chloride(II) (650 nm); total phosphorus – was determined after mineralization with sulphur acid and amonium persulfate.

Statistical analysis of research results

Statistical analysis of the collected material was carried out with the use of Statistica 6.0 application.

Substantial hypothesis on significance of diversity of *Chara tomentosa* specimens in regard of length, dry biomass, habit and reproductive potential between the lakes, was verified by a non-parametric equivalent of analysis of variation – that is by Kruskal-Wallis test and next by a non-parametric U test (Mann Whitney) at the significance level calculated from Bonferroni correction $\alpha = \alpha/m$, where m = number of compared samples (ŁOMNICKI 1995, STANISZ 1998).

Relation between properties of a specimen and chemical properties of water was expressed by the use of Spearman correlation coefficient at the level of significance $p < 0.05$ (GUILFORD 1960, ŁOMNICKI 1995, STANISZ 1998).

Results

Chemical properties of water

The tested stands were characterised by different habitat conditions. In Kołowin, Jełguń and Neliwa lakes higher concentration of calcium in water (approx. 49–71 mg dm^{-3}) than in the remaining water bodies (under 45 mg dm^{-3}) was reported. The first group of lakes was also characterised by a slightly higher content of biogenic elements, especially total nitrogen (0.96–1.43 mg dm^{-3}). On the basis of these differences, two types of water reservoirs were distinguished. The first one including Kołowin Lake, Jełguń Lake, Neliwa Lake characterised by a higher concentration of calcium and bio genes and the second, including Majcz Wielki Lake, Krutyńskie Lake and Redykajny Lake, where the content of the tested elements was slightly higher (Table 1).

Table 1

Chemical properties of water on the experimental stands

Specification	Calcium [mg dm^{-3}]	P-PO_4 [mg dm^{-3}]	Total P [mg dm^{-3}]	N-NO_3 [mg dm^{-3}]	Total N [mg dm^{-3}]
Kołowin Lake	71.4	n.r.	0.10	0.10	1.22
Jełguń Lake	48.6	n.r.	0.25	0.14	1.43
Neliwa Lake	61.4	n.r.	0.25	0.14	0.96
Majcz W. Lake	45.0	n.r.	0.11	0.08	0.86
Krutyńskie Lake	42.8	n.r.	0.10	0.10	0.94
Redykajny Lake	35.0	n.r.	0.09	0.05	0.94

n.r. – not reported

Plant material

Diverse architecture of *Chara tomentosa* specimen as well as its reproductive potential between local populations was analysed in the study.

In case of dry biomass, the highest average values (0.6–1.2 g) are reported among specimens from Kołowin Lake, Jełguń Lake and Neliwa Lake; slightly lighter specimens, on average 0.5 g, occur in the remaining water bodies (Figure 1). Differences, which are statistically significant are visible between the above-mentioned two groups of lakes (Mann-Whitney U test, $p<0{,}001$) – Figure 1.

In regard of the number of long branches, stoneworts are less diverse. Specimens with the highest plant mass from Kołowin Lake, Jełguń Lake and Neliwa Lake, as well as Krutyńskie Lake average have 2 branches (Figure 1). In the remaining two water bodies, specimens have only one branch or do not have any (Figure 1). Differences, which are statistically significant, are visible between the above-mentioned two groups of lakes (Mann-Whitney U test, $p<0.001$).

The strongest stoneworts with the highest biomass have the longest thalli (on average 52–74 cm) of long internodes (on average 7.2–7.6 cm) and pseudo-leaves (on average 3–4 cm) in Kołowin Lake, Jełguń Lake and Neliwa Lake. Stoneworts occurring in three remaining reservoirs, that is Krutyńskie Lake, Majcz W. Lake and Redykajny Lake, have the lowest values among the researched length properties. Their pseudo-stems reach 29–42 cm on average, an internode does not exceed 5.5 cm and pseudo-leaves approximately 2 cm (Figure 2). Statistical differences become visible between the length of particular properties of a specimen from two above-mentioned groups of reservoirs (U Mann-Whitney test, $p<0.001$).

The most impressive stoneworts, which form populations in Kołowin Lake, Jełguń Lake and Neliwa Lake have the biggest number of branches with reproductive organs (1.5–3.2 branches on average). Specimens from Redykajny

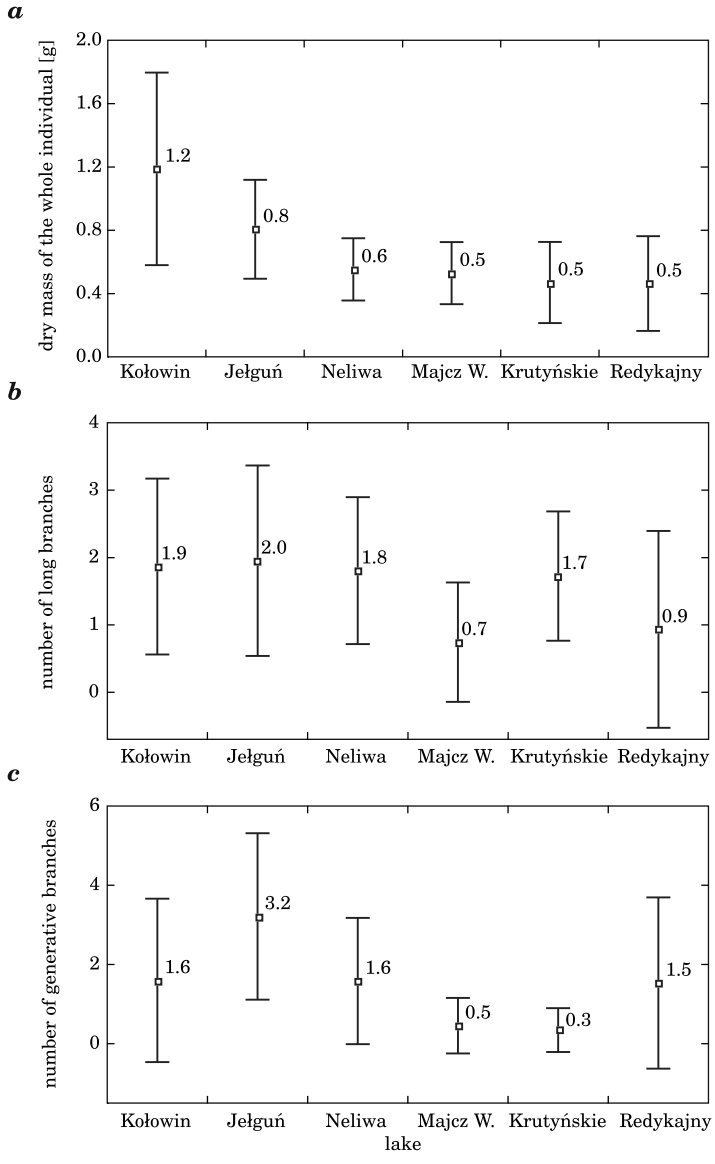

Fig. 1. Diversity of plant biomass, habit and reproductive potential *Chara tomentosa* specimen

Lake are similar in regard of the above. Thalli from remaining populations occurring in Krutyńskie Lake and Majcz W. Lake have considerably less generative branches (on average less than 0.5 branch) – Figure 1. Significant statistical differences occur between the above-mentioned values (U Mann-Whitney test, $p<0.001$).

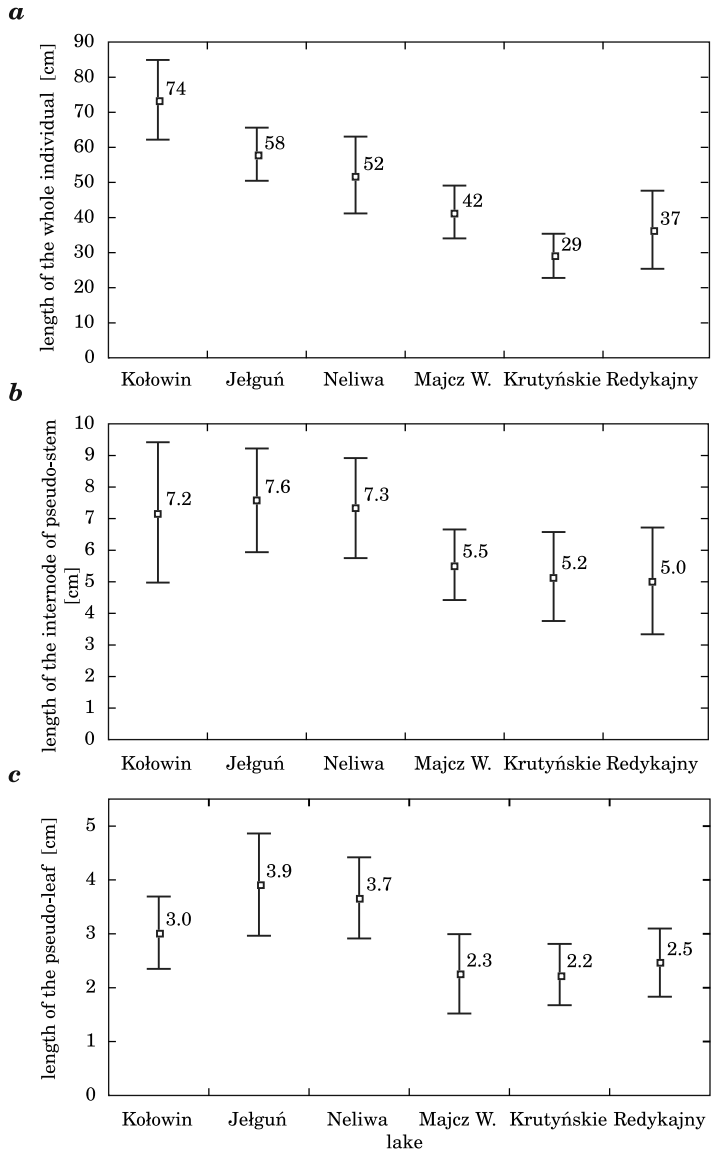

Fig. 2. Diversity of properties lenght of *Chara tomentosa* specimen

When considering values of all examined properties and degree of their relationship, it may be stated that branched thalli of the highest biomass the longest pseudo-stems, their internodes as well as pseudo-leaves and usually of the strongest reproductive potential, occur in the populations of Kołowin Lake, Jełguń Lake and Neliwa Lake. Shorter and lighter specimens, with lower number of branches and lower number of generative branches are reported

mainly in the populations of Krutyńskie Lake, Majcz W. Lake and Redykajny Lake (Figure 1, 2).

Undoubtedly, diverse habitat conditions, which occur in the researched stands influence the variability of structure of *Chara tomentosa* specimen. These places are characterised mainly by different chemical composition of water within a patch (Table 1). It mainly concerns concentration of calcium, nitrogen and phosphorus. These properties are related to different degrees with the properties of the researched taxa.

Dry biomass, length and degree of branching of a specimen prove significantly statistical correlations with calcium occurring in water. These relations are of an average strength (Spearman test rs = 0.26–0.76, $p<0.05$). The above properties of a stonewort are correlated similarly (Spearman test rs = 0.32–0.66, $p<0.05$) with all tested forms of nitrogen occurring in water, whereas considerably weaker with phosphorus (Spearman test rs = 0.11–0.26, $p«0.05$) – Table 2. All these correlations are directly proportional. Thus, relatively long specimens of considerable dry biomass and strongly branched thalli occur on the stands rich in calcium and in biogenic elements (N, P). Such specimens grow in Kołowin Lake, Jełguń Lake and Neliwa Lake. Lower, less branched specimens of low biomass occur on the stands of lower content of calcium and phosphorus as well as nitrogen (Table 1 and Figure 1, Table 2 and Figure 2).

Table 2

Relations between properties of *Chara tomentosa* specimen and chemical properties of water

Specification	Spearman's rank correlation Marked correlations are essential with $p < 0.05$		
	t.l.	d.m.	n. of b.
Calcium	0.76	0.45	0.26
Total P	0.26	0.11	0.18
$N\text{-}NO_3$	0.55	0.32	0.35
Total N	0.66	0.44	0.32

t.l. – total length of individual
d.m. – dry mass of the whole individual
n. of b. – number of long branches

Discussion

Chara tomentosa specimens from particular local populations considerably differ with the size structure. Long, "heavy", intensely branched stoneworts occur most frequently in populations from stands rich in nitrogen, phosphorus and calcium (Kołowin, Jełguń, Neliwa lakes) while short, light, weakly branched specimens grow on the habitats of slightly poorer content of the said elements (Majcz W., Krutyń, Redykajny lakes). Abiotic and biotic environ-

ment, which influence the speed of growth and development of a plant may affect the variability of the specimen within the species as FALIŃSKA (1974, 1983, 1990, 1996, 2002) and ANDRZEJEWSKA (1983) suggest. Thus, specimens living in the conditions which fully satisfy their life requirements are bigger and their architecture is more complicated as in case of the first group of the researched stands, whereas, populations occurring in inconvenient environmental conditions are basically formed by smaller, less developed specimens, what may be noticed in the second group of water bodies. Diversity of the structure of a specimen's size affected by diverse environmental conditions is known from SYMONIDES research (1974) based on *Spergula vernalis*. Specimens of this taxon are of small sizes on barren, dune sands and of considerably bigger proportions on the soils rich in water and humus. *Myosotis palustris* (FALIŃSKA 1979) attain considerable sizes in advantageous conditions of life as well.

Among "heavy" *Chara tomentosa* specimens, which form populations in Kołowin, Jełguń and Neliwa lakes, high reproductive potential is reported as well. Home range and nutritional requirements, as well as participating in reproduction depend on biomass of a specimen (ANDRZEJEWSKA, FALIŃSKA 1983). Thus, the more biomass plant organisms collect the bigger chances they have to propagate (FALIŃSKA 2002). It is also confirmed by the research on stoneworts conducted by BONIS et al. (1993) as well as GRILLAS and BATTEDOU (1998), which concern relations between weight of plants and the number of propagules produced by it.

Stands, on which *Chara tomentosa* populations occur, show similarities in relation to the water hardness and its reaction, while they are characterised by different calcium and biogenic elements content (nitrogen, phosphorus). Two last factors may influence the individual variability of the researched species. Therefore, correlations between the amount of calcium, phosphorus and nitrogen and particular properties of stoneworts were determined in own researches. During research on these relations, it must be considered that the analysis of habitats was carried out in the peak of the growing season and some of the above-mentioned elements had been already collected from water or sediments by developing stoneworts. Thus, the presented correlations may be slightly weaker than real.

In habitats of hard water, calcium cations often accompany hydrogen carbonate anions, which are the main source of inorganic carbon in the process of photosynthesis at submerged macrophytes (LÖWENHAUPT 1956, SMART, BARKO 1986, KUFEL, KUFEL 2002). Moreover, stoneworts prove higher relationship with hydrogen carbonates than vascular plants. An experiment carried out by VAN DEN BERG et al. illustrates it very well (2002). In this experiment, *Chara aspera* proved considerably higher speed of photosynthesis

in a wide range of hydrogen carbonates concentration than *Potamogenton pectinatus*. Therefore, on the "hard" water stand, richer in calcium (Kołowin, Jełguń, Neliwa lakes) stoneworts show higher speed of photosynthesis and simultaneously high plant biomass. Additionally, their "weight" increases with the increase of thallus inlay with calcium carbonate (calcite), which precipitates during uptake of carbon by plants in the process of photosynthesis (VAN DEN BERG et al. 2002).

Phosphorus content in water is positively correlated with properties of *Chara tomentosa* specimen, thus, the higher concentration of this element the better developed the specimen is. FORSBERG'S research (1964) does not confirm it, as he believes that phosphorus limits development of stoneworts. HUTCHINSON (1975), as well, states that this group of plants develops the best in waters of low content of this element. However, the experiment carried out by BLINDOW (1988) on two species of stoneworts: *Chara hispida* and *Chara tomentosa* does not show a negative influence of phosphorus on their growth even at the concentration of 1000 $\mu g\ l^{-1}$. Moreover, no disturbances in the development of *Chara connivens* and *Chara major* at the concentration of phosphoric phosphorus within the range of 9–1009 $\mu g\ l^{-1}$ was reported (SIMONS et al. 1994). What is more, KRÓLIKOWSKA (1997) reported the highest biomass of *Chara tomentosa* and *Chara aculeolata* in Łuknajno Lake, in the places frequently visited by swans. Water fertilized by droppings of these birds may stimulate growth of plants biomass even when their biomass is decreased by preying. Thus, high concentration of phosphorus, in this case, positively influences development of *Chara tomentosa* specimen.

Properties of the researched taxon, in relation to nitrogen forms, show similar relation. The highest nitrate nitrogen concentration the biggest specimens are reported. Partially, it is confirmed by research results carried out in Dutch lake Botshol, where the concentration of nitrate nitrogen within the range 5.3–20.3 $g\ l^{-1}$ triggers development of *Chara connivens* and *Chara major* (SIMONS et al. 1994).

Conclusion

Long and strongly branched specimens of high biomass and strong reproductive potential occur in the habitats rich in calcium, nitrogen and phosphorus. Shorter, lighter, often not branched specimens grow in the places poorer in the above-mentioned elements.

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DEGRADATION OF THE RECREATIONAL FUNCTIONS OF URBAN LAKE: A PRELIMINARY EVALUATION OF WATER TURBIDITY AND LIGHT AVAILABILITY (STRZESZYŃSKIE LAKE, WESTERN POLAND)*

Tomasz Joniak, Natalia Jakubowska, Elżbieta Szeląg-Wasielewska

Department of Water Protection
Adam Mickiewicz University in Poznań

K e y w o r d s: urban lake, turbidity, water opalescence, water bloom, vertical availability of PAR.

A b s t r a c t

Turbidity, as an optical property describing water clarity, is a measure of the degree to which water loses its transparency due to the presence of suspended solids, including phytoplankton and dissolved substances. Lake Strzeszyńskie was regarded as the clearest lake in Poznań (western Poland) for many years. In July 2011 first time in the history of lake the watering place was closed due to picocyanobacteria bloom and high water turbidity. The subject of paper was the preliminary assessment of changes the vertical propagation and availability of PAR, turbidity and content of OAS in the lake before and at the time of phytoplankton bloom. To comparison were taken sample from a peak of summer season of 2009 and 2011, respectively. Large changes in depths of photic zone in both periods were stated as well as reducing of euphotic zone and increase the darker disphotic zone. Picocyanophyceae bloom and high light scattering caused by high content of OAS in surface layer resulted in visible effect of the water opalescence.

DEGRADACJA FUNKCJI REKREACYJNYCH MIEJSKIEGO JEZIORA: WSTĘPNA OCENA MĘTNOŚCI WODY I DOSTĘPNOŚCI ŚWIATŁA (JEZIORO STRZESZYŃSKIE, ZACHODNIA POLSKA)

Tomasz Joniak, Natalia Jakubowska, Elżbieta Szeląg-Wasielewska

Zakład Ochrony Wód
Uniwersytet im. A. Mickiewicza w Poznaniu

S ł o w a k l u c z o w e: jezioro miejskie, mętność, opalizacja, zakwit wody, dostępność promieniowania fotosyntetycznie aktywnego.

Tomasz Joniak, Adam Mickiewicz University, ul. Umultowska 89, 61-614 Poznań, Poland, phone: +48 (61) 829 57 80, e-mail: tjoniak@amu.edu.pl
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Abstrakt

Mętność wody, jako cecha optyczna opisująca przejrzystość wody, jest miarą stopnia zanieczyszczenia wody przez zawiesiny (w tym fitoplankton) oraz substancje rozpuszczone. Jezioro Strzeszyńskie było przez wiele lat uważane za najczystsze w Poznaniu. Tymczasem nieoczekiwanie w lipcu 2011 r. pierwszy raz w historii wprowadzono zakaz kąpieli w tym jeziorze z powodu masowego zakwitu sinic pikoplanktonowych i wysokiej mętności wody. Przedmiotem badań była wstępna ocena zmian pionowego gradientu i dostępności promieniowania fotosyntetycznie aktywnego oraz mętności wody i koncentracji substancji optycznie aktywnych w okresie przed zakwitem i w jego trakcie. Zestawiono odpowiednio okres szczytu sezonu letniego roku 2009 i 2011. Stwierdzono duże różnice całkowitego zasięgu światła. W stosunku do roku 2009 w 2011 nastąpiła znacząca zmiana struktury strefy prześwietlonej z redukcją zasięgu strefy eufotycznej i wzrostem zasięgu strefy dysfotycznej. Masowy zakwit pikoplanktonowych sinic i silne rozpraszanie światła spowodowane nagromadzeniem substancji optycznie aktywnych w warstwie powierzchniowej wywołały efekt bardzo silnej opalizacji wody.

Introduction

Lakes are very attractive components of urban landscape but in order to serve their function well they need to have good water quality. The anthropogenic transformation of the catchment area may accelerate the nutrient and organic substances enrichment of waters, particularly in strongly changed urban landscape (KUCZYŃSKA-KIPPEN and JONIAK 2010). During the last century a major problem of inland water bodies has been the increase of turbidity and other optical features of water (i.e. opalescence, green colour) as a result of increase water pollution. Water turbidity is caused by many types of dissolved and suspended substances such as silt, clay, tripton, organic and mineral compounds, plankton and other (DAVIES-COLLEY and SMITH 2001). Turbidity is highly variable in aquatic systems mainly due to differentiation of water body depth and surface (HOWICK and WILHM 1985). The major sources of inorganic turbidity are runoff, shoreline erosion, and resuspension of bottom sediments under influence of water movement across the surface of the sediments (BLOESCH 1995). The main source of organic turbidity is a seasonal change in algal development, and major phytoplankton blooms in few eutrophicated waterbodies (GALLEGOS and JORDAN 2002, YE and CAI 2012).

According to APHA (1998) turbidity is the "optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample" – in lake to the greater depth. Universally believed, that turbidity is a main cause of reduction the depth of light penetration (depth of photic zone). However, this theme it's a great simplifying, because as turbidity is considered almost all what is suspended in water, and a lesser degree with dissolved substances. Meanwhile, as show the practice the increasing of water bodies eutrophication or humification causes increase the concentration of dissolved components for example algal-bacterial colloids and gels. In that

situation we can observe water opalescence. This phenomenon (often neglected) causes a strong absorption of light. In view of the above, lower values of dissolved organic compounds increase the probability of deeper light transmission. In natural waters dissolved compounds and humic substances, as end product of decaying organic matter may impart also a brown or other colour to water (FORSBERG 1992, JONIAK 2007). There is evidence that human activity with different way leading to increased turbidity in aquatic systems. The aim of this study was preliminary evaluation of water turbidity, light conditions and content of optically active components in the lake before and at the time of phytoplankton bloom. Our main purpose was to draw attention to the problem of lake degradation and its implications for the recreational use.

Material and Methods

Strzeszyńskie Lake is of glacial origin located in the northwestern part of the Poznań. It is a dimictic lake with an area of 34.9 ha, maximum depth of 17.6 m and mean depth of 8.2 m. The direct catchment of lake is 133 ha of which approx. 61% comprises forests, 20% is arable land, and 16% is meadows (FISHER et al. 2012). The lake is fed by stream Rów Złotnicki (total length 3.5 km). The stream drains of agricultural area and partially area of the village Suchy Las. The lake is the source of the Bogdanka River.

For decades it has been one of Poznań's most popular recreational lakes used for bathing and swimming. A recreational resort is located at the lake, including a large guarded bathing area (grassy beach) and a hotel-restaurant complex with full water-sewage infrastructure. In summer the bathing site is visited by several thousand people per day. Research on the trophic state of lake using the phytoplankton community structure has been conducted from 1978 onward (SZELĄG-WASIELEWSKA 2006). Up to year 2011 the situation that bathing had to be prohibited due to the excessive algae bloom in the lake has never occurred. In July of this year the bathing area had to be closed because of the excessive cyanobacteria bloom and high turbidity was stated.

Sampling and field measurements in the lake were carried out in July 2009 and in July 2011. *In situ* on the station in the deepest place were measured temperature and oxygen content with the use of the multiparameter sonde (YSI 556 MPS) and water turbidity (nephelometrically, Eutech Instr. TN-100) in the whole water column, at 1 m intervals. Water samples for laboratory analysis were taken from subsurface layer (0.5 m) and from some depths in euphotic zone. In laboratory was measured total suspended solids TSS (after filtration through GF/F filter, gravimetrical method), inherent water colour (in water after filtration through GF/F filter, visual method after

HERMANOWICZ et al. 1999), amount of coloured dissolved organic matter (CDOM, characterized by beam attenuation coefficient of membrane 0.45 μm filtered water at 380 nm, measured by Cadas 200 UV-VIS spectrophotometer) (PAAVEL et al. 2008), and chlorophyll *a* (ISO 10260). Biological samples of autotrophic picoplankton (APP) were taken in both study periods from subsurface layer and preserved immediately in 50 ml or 100 ml sterile bottles with buffered formaldehyde. Samples were concentrated on polycarbonate black filters (0.2 μm pore size) at a low vacuum pressure. Microscopic analyses were conducted under an epifluorescence microscope. APP was classified as prokaryotic or eukaryotic on the basis of autofluorescence colour, shape and size of cells (MACISAAC and STOCKNER 1993).

True depth of illuminated zone (TDIZ, sum of euphotic and disphotic zone) was measured *in situ* using the spherical quantum sensor LI-193SA with LI-1400 Datalogger (LI-COR Corporation, Lincoln, Nebraska, USA). The spherical sensor expands the range of underwater study of light as it enables the measurement of total radiation from range 400–700 nm. The bottom border of the euphotic zone is the depth reached by 1.0% of light penetrating the water surface, and disphotic zone by 0.1%. Incident irradiance was measured in the air above surface of water, then in the subsurface layer and later in the water column at 0.5 m intervals. A vertical attenuation coefficient of PAR was calculated by regressing log-transformed light with depth (KIRK 1994) separately for sub-surface layer (K_{dSubs}) and euphotic zone (K_{dZeu}). Water transparency was measured using Secchi disk (white, diameter 30 cm). According to CARLSON (1977), "Secchi depth should only be used if there are no better methods available" for the assessment of the depth of water penetration by light. This suggests the possibility of using visible light quantum sensors. Trophic status was evaluated based on CARLSON (1977) classification. Statistic calculations were made with Statistica 8.0 software.

Results and Discussion

In July 2009 Strzeszyńskie Lake was mesotrophic (TSI_{Chl} = 49, TSI_{TP} = 41, TSI_{SD} = 44) whereas in 2011 eutrophic (54, 54, 53, respectively). In the first period the trophic state was mainly determined by chlorophyll, constituting the basis for the trophic classification. This variable is the most accurate in predicting algal biomass, and more reliable than phosphorus and Secchi depth (CARLSON 1977). In earlier research the fluctuations in trophic state was reported. Phytoplankton studies have shown that in first year of lake investigation (1978) among indicator taxa of algae over 64% were oligo- or mesotrophic, whereas in end of 90th over 51% were eutrophic. On basis of the maximal summer phytoplankton biomass in the first period lake may be

classified as mesotrophic and in the second as meso-eutrophic (SZELĄG-WASIELEWSKA 2006). Unfavourable, changes in July 2011 included not only an increase in the trophy, but also change in the relationships between TSI variables, suggesting stronger influence of algae on light attenuation.

Thermal conditions of water in both periods were similar – epilimnion ranged to 4 m (Figure 1). The content of dissolved oxygen in epilimnion and upper part of metalimnion was very high (>10 mg l^{-1} O_2), while below 9 m in 2009 and 7 m in 2011 the permanent oxygen deficit (anoxia) was registered (and strong smell of H_2S was sensed). The deterioration of oxygen conditions resulted in summer fish death. In 2009 the turbidity was low in whole water column but significantly higher in 2011. In the euphotic zone, a significant increase was observed at the boundary of epilimnion and metalimnion, whereas in the metalimnion the turbidity was low. The second increase of turbidity was recorded in the hypolimnion where H_2S occurred. Surplus of hydrogen sulphide gas in lake water can lead to strong water opalescence and high turbidity (SNOEYINK and JENKINS 1980). Between compared periods the statistical analysis revealed high and significant differentiation of turbidity (*t*-test, $t = -16.60$, $p < 0.000$, $n = 16$) and CDOM ($t = -12.57$, $p < 0.012$, $n = 16$). Relatively lower and weaker differences in case of water colour ($t = -2.32$, $p < 0.048$, $n = 16$), TSS ($t = -2.52$, $p < 0.045$, $n = 16$) and chlorophyll ($t = -2.53$, $p < 0.035$, $n = 16$) was stated.

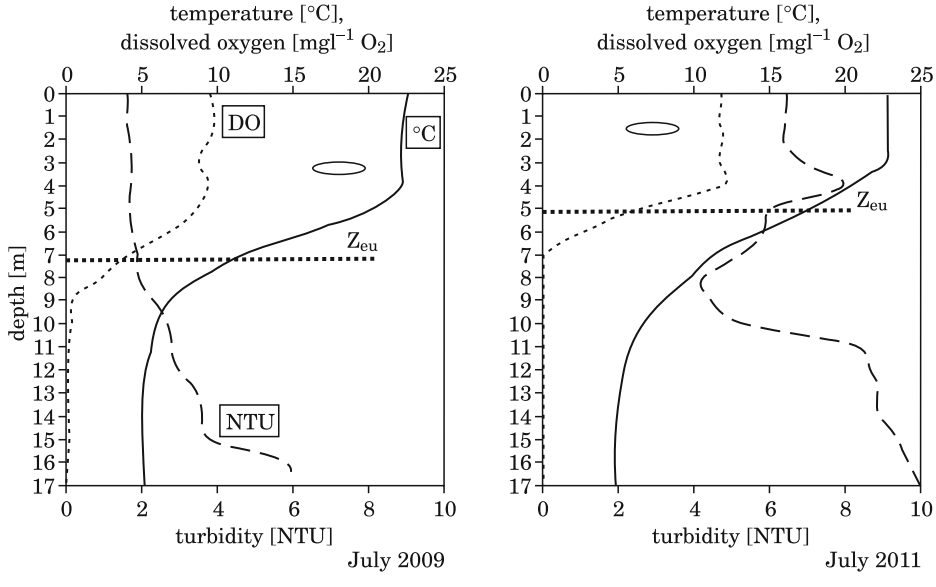

Fig. 1. Vertical profile of temperature (°C), dissolved oxygen (DO) and turbidity of water (NTU) in relation to depth of euphotic zone (Zeu) and Secchi depth in study period (white ellipse = Secchi depth)

Weather conditions were stable during both times of study with 20% of cloudiness and light wind causing only a ripple on the water. During measurement in July of 2009 cloudiness was caused by *Cirrus* and in 2011 by *Cumulus* clouds. PAR irradiance in air above surface of lake (PAR_{Air}) and in the subsurface layer (PAR_{SubI}) was higher in 2011, but depth of photic zone was smaller (Table 1). According to MATUSZKO (2009) at sun height >50° neither of the types of cloudiness cause significant changes in insolation. The study revealed that as result of covering the sun with translucent Cirrus clouds, minimum PAR dispersion occurs which increases the albedo. Other situation is in the case, when the sun is covered by vertical clouds which enable unrestricted radiation penetration only when the sun is not covered.

Table 1

Comparison of the PAR irradiance in air (PAR_{Air}), and at subsurface layer (PAR_{SubI}) in relation to solar elevation, albedo, true depth of illuminated zone (TDIZ) and diffuse attenuation coefficients of subsurface layer ($K_{d\ Subs}$) and euphotic zone ($K_{d\ Zeu}$). In down part of Table average values of OAS in subsurface and euphotic zone in both study periods

Parameter	Time	2009	2011
PAR_{Air} [µmol s^{-1} m^{-2}]	–	2300	2680
PAR_{SubI} [µmol s^{-1} m^{-2}]	–	2060	2500
Solar elevation [°]	–	57.5	54.9
Albedo [%]	–	10.4	6.7
TDIZ [m]	–	8.9	8.0
K_{dSubs} [m^{-1}]	–	0.18	0.37
K_{dZeu} [m]	–	0.59	0.78
TSS [mg l^{-1}]	Subs	4.25	7.1
	Zeu	5.30	8.9
Turbidity [NTU]	Subs	1.64	6.40
	Zeu	1.73	7.12
Chlorophyll [µg l^{-1}]	Subs	3.2	7.2
	Zeu	5.7	12.2
Water colour [mg Pt l^{-1}]	Subs	3.0	4.0
	Zeu	3.4	4.0
a_f (380) [m^{-1}]	Subs	0.4	0.8
	Zeu	0.4	0.9

The increase of water trophy and concentration of OAS during *Cyanophyceae* bloom caused a significant change in vertical gradient of PAR and availability of light in water column. The ranges of zones with various light intensity (euphotic and disphotic zone) developed differently than in July 2009. The analysis of vertical variability of the diffuse attenuation coefficient for downwelling irradiance (K_d) in the first period showed low values in subsurface layer and in deep waters (Table 1). Statistical analysis revealed a significant differentiation of K_d values in vertical profile of lake between both

periods (t = –2.85, p < 0.011, n = 18). In July 2009 PAR was transmitted deeper, and penetrated the lake's waters almost up to 9 m. During algal bloom the K_d in the subsurface layer doubled. In result, the euphotic zone was shallower and the disphotic zone was deeper (Figure 2). Therefore, substantial changes in the features of the light climate caused a decrease in TDIZ thickness by less than 1 m. However, the comparison of Secchi depth showed an almost twice larger difference (Figure 1).

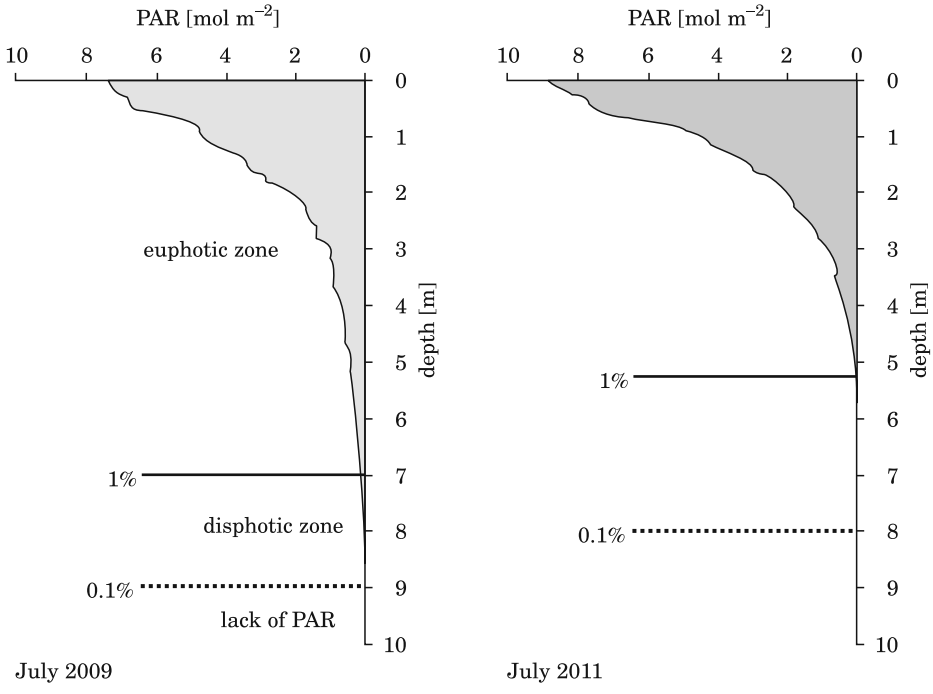

Fig. 2. Vertical distribution of PAR in lake during study periods (solid line – border of euphotic zone, dashed line – border of disphotic zone)

In July 2011 the abundance of algae in the surface layer was so high that it had a form of water bloom. Because it was the bloom of cyanobacteria the bathing site was closed, and bathing in the lake was forbidden. We are not aware of any records of algal blooms in lake before 2011. The bloom was constituted by picocyanobacteria (P-cy) from genera *Aphanocapsa* and *Aphanothece*. In 2009, their density in the surface layer reached 420 thous. cells ml^{-1}, and in 2011 it was higher by more than 200 thous. cells ml^{-1}. Earlier studies revealed that the smallest size fraction of organisms, i.e. autotrophic picoplankton (APP) (< 2 μm) is the main component of the lake phytoplankton

(SZELĄG-WASIELEWSKA 2006). Throughout the vegetation season in APP picocyanobacteria dominate over eukaryotic picoplankton, in particular in terms of biomass (SZELĄG-WASIELEWSKA 2004). High P-cy frequency in the surface layer is related to light intensity as well as light spectrum, considered a major axis of niche differentiation in P-cy communities (STOMP et al. 2004). The consequence of high cell concentration was strong scattering of sunlight and water opalescence (result of excretion of organic substances) which caused high light utilization and low water transparency. Similar states, but with clearly higher reduction of photic zone were noted in lakes of higher trophy, where the strong light scattering and absorption in shallow subsurface layer (a type of microstratification) was related to a strong bloom of larger species of blue-green algae (SOBCZYŃSKI et al. 2012). The value of the turbidity reading is influenced by both APP, belonging to phytoplankton with size >0.1 μm, and dissolved organic and mineral substances (size <0.45 μm) (BILOTTA and BRAZIER 2008).

To sum up it should be said that the water turbidity caused by strong bloom of picocyanobacteria in the examined lake had a very bad effect on its recreational function. Probably the main component of turbidity and barrier limiting the light transmission into the water were bacterial colloid suspensions or gels released in abundance by plankton, frequently forming layers of varied thickness. The excess of organic compounds results in the opalescence of surface water similar to that observed in the deoxygenated near-bottom waters rich in H_2S.

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EFFECTS OF AROMATIC PLANT EXTRACTS AND MAJOR TERPENOID CONSTITUENTS ON FEEDING ACTIVITY OF THE HORSE-CHESTNUT LEAF MINER *CAMERARIA OHRIDELLA* DESCHKA & DIMIĆ 1986*

***Bożena Kordan*[1], *Agnieszka Kosewska*[1], *Antoni Szumny*[2], *Czesław Wawrzeńczyk*[2], *Beata Gabryś*[3]**

[1] Department of Phytopathology and Entomology
University of Warmia and Mazury in Olsztyn
[2] Department of Chemistry
Wrocław University of Environmental and Life Sciences in Wrocław
[3] Department of Botany and Ecology
University of Zielona Góra in Zielona Góra

K e y w o r d s: antifeedants, feeding stimulants, β-aescin, thymol, *Cameraria ohridella*.

A b s t r a c t

Chemical control of the horse-chestnut leaf miner *Cameraria ohridella* is limited to microinjections that injure trees, for air pesticide spraying is not recommended in urban areas. Alternative methods, e.g., the use of antifeedants to control and/or prevent the *C. ohridella* infestations are searched for. The aim of the present study was to assess the effect of selected aromatic plant extracts and their major terpenoid constituents on the feeding of *C. ohridella* larvae. We found that an extract of *Solidago canadensis* was attractant, the extracts of *Tanacetum vulgare* and *Heracleum mantegazzianum* were potentially attractant, *Pimpinella anisum*, *Carum carvi, Syzygium aromaticum*, *Thuja occidentalis*, *Origanum majorana* were inactive, and *Thymus vulgaris, Satureja hortensis, Rosmarinus officinalis* were potentially deterrent. β-Pinene, geraniol, linalool, and *p*-cymene were attractant, γ-terpinene and linalool were potentially attractant, h-terpinene, terpinolene, and camphene were inactive, bornyl acetate and α-pinene – potentially deterrent, and thymol was deterrent. Complex plant extracts against *C. ohridella* larvae are less active than pure compounds. The horse chestnut characteristic saponin β-aescin appeared a feeding stimulant for *C. ohridella*.

Address: Bożena Kordan, University of Warmia and Mazury in Olsztyn, ul. Romana Prawocheńskiego 17, 10-957 Olsztyn, Poland, phone: +48 (89) 523 37 81, e-mail: bozena.kordan@uwm.edu.pl

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WPŁYW OLEJKÓW ETERYCZNYCH ROŚLIN AROMATYCZNYCH ORAZ ICH NAJWAŻNIEJSZYCH SKŁADNIKÓW TERPENOIDOWYCH NA ŻEROWANIE SZROTÓWKA KASZTANOWCOWIACZKA CAMERARIA OHRIDELLA DESCHKA & DIMIĆ 1986

***Bożena Kordan*[1], *Agnieszka Kosewska*[1], *Antoni Szumny*[2], *Czesław Wawrzeńczyk*[2], *Beata Gabryś*[3]**

[1]Katedra Fitopatologii i Entomologii
Uniwersytet Warmińsko-Mazurski w Olsztynie
[2] Katedra Chemii
Uniwersytet Przyrodniczy we Wrocławiu
[3]Katedra Botaniki i Ekologii
Uniwersytet Zielonogórski w Zielonej Górze

S ł o w a k l u c z o w e: antyfidanty, stymulacja żerowania, *β*-escyna, tymol, *Cameraria ohridella*.

A b s t r a k t

Chemiczne zwalczanie szrotówka kasztanowcowiaczka *Cameraria ohridella* jest ograniczone do mikroiniekcji, które mogą powodować uszkodzenia drzew. Stosowanie opryskiwania nie jest polecane w terenach zurbanizowanych. Poszukiwane są alternatywne metody zwalczania szrotówka lub przeciwdziałania zasiedlaniu drzew przez tego owada np. wykorzystanie antyfidantów. Celem tej pracy było zbadanie wpływu olejków eterycznych roślin aromatycznych oraz ich najważniejszych składników terpenoidowych na żerowanie *C. ohridella*. Stwierdzono, że ekstrakt z *Solidago canadensis* miał właściwości przywabiające, ekstrakty z *Tanacetum vulgare* i *Heracleum mantegazzianum* potencjalnie przywabiające, *Pimpinella anisum*, *Carum carvi*, *Syzygium aromaticum*, *Thuja occidentalis*, *Origanum majorana* były nieaktywne, a ekstrakty z *Thymus vulgaris*, *Satureja hortensis*, *Rosmarinus officinalis* wykazywały właściwości potencjalnie deterentne. Spośród terpenoidów *β*-pinen, geraniol, linalool, i *p*-cymen miały właściwości przywabiające, *γ*-terpinen i linalool potencjalnie przywabiające, *α*-terpinen, terpinolen i kamfen nie miały wpływu na zachowanie larw szrotówka, a octan bornylu i *α*-pinen wykazywały działanie potencjalnie deterentne, natomiast tymol – działanie deterentne. *β*-escyna, saponina charakterystyczna dla kasztanowca zwyczajnego, stymulowała żerowanie larw szrotówka kasztanowcowiaczka.

Introduction

The horse-chestnut leaf miner (*Cameraria ohridella* Deschka & Dimić 1986) (Lepidoptera: Gracillariidae) appeared in Macedonia in 1985 but the place of its origin is still unknown (TOMICEK and KREHAN 1998). In Poland, it was recorded for the first time in Wojsławice near Wrocław, south-west Poland, in 1998 (ŁABANOWSKI, SOIKA 1998, BARANIAK et al. 2004, AUGUSTIN et al. 2009). In Poland, *C. ohridella* develops usually three generations a year and the mining larvae feed between the two epidermis layers, which mau cause the defoliaion of trees already in summer (SUKOVATA et al. 2011).

Generally, the horse-chestnut leaf miner is defined as a monophagous species almost exclusively developing on white-blooming horse chestnut trees

Aesculus hippocastanum L. *C. ohridella* is occasionally found on other *Aesculus* species, such as Japanese horse chestnut *A. turbinata* Blume, yellow buckeye *A. flava* Sol., or red buckeye *A. pavia* L., and also *Acer platanoides* L. and *A. pseudoplatanus* L. adjacent to heavily infested horse-chestnut trees (AUGUSTIN et al. 2009). The red horse-chestnut *A. x carnea* Hayne is rarely considered a host of *C. ohridella* because despite the abundant oviposition by females of each generation, the larvae usually die within leaf tissues before they reach the third stage (KUKUŁA-MŁYNARCZYK et al. 2006). However, DZIĘGIELEWSKA and KAUP (2007) found that the horse-chestnut leaf miner is able to develop two full generations on the red horse-chestnut under special circumstances: heavy infestation of white horse chestnut in the vicinity, high *C. ohridella* population numbers and mild winters in several consecutive years at the location. Nevertheless, the number of larvae and the leaf damage on the red horse-chestnut are relatively low, i.e. maximum 10% of the leaf has been damaged throughout the vegetative period (DZIĘGIELEWSKA and KAUP 2007).

Considering the rapid dispersal, the mass appearance, and high biological potential of the horse-chestnut leaf miner as well as the fact that the horse chestnut is one of the most abundant ornamental trees in parks and other public areas in Europe, many methods have been proposed to control the pest: biological, cultural, and chemical. The natural biological control of *C. ohridella* is limited due to a narrow spectrum and low impact of natural enemies: the parasitism level is below 10% and the predation rates of birds, mainly the tits, range from 2 to 4% of leafminer populations (GRABENWERGER 2003, GRABENWERGER et al. 2005). Cultural control by removing fallen leaves of horse chestnut in autumn contributes significantly to reduce *C. ohridella* damage and it is suggested for application in the context of Integrated Pest Management (PAVAN et al. 2003, BARANIAK et al. 2004). However, this kind of control measure is difficult to apply on a large scale, so it is recommended rather in small and isolated stands of the horse-chestnut trees (PAVAN et al. 2003). Chemical control can be applied either by tree injection or aerial spraying. Tree injections are expensive and the holes drilled into the trunk can injure trees (TOMCZYK et al. 2007). Aerial spraying has limited use due to environmental concerns: broad spectrum insecticides are proposed and the spraying involves urban areas usually densely inhabited by people (KOBZA et al. 2011). Considering these limitations, alternative methods of control and/or prevention of *C. ohridella* infestations are studied. For example, attempts to control *C. ohridella* using an attract-and-kill technique have been made: the formulation of *C. ohridella* sex pheromone and a fast acting contact toxicant was applied directly to the bark of the trees but no effect on leaf infestation was found (SUKOVATA et al. 2011). Another method studied is to disrupt host recognition behaviour, affect the oviposition, and/or deter the feeding

of *C. ohridella* by applying plant-derived (botanical) insecticides or deterrents. For example, the application of plant allelochemicals to the horse chestnut foliage may alter the behavioural response of adult *C. ohridella*: the extract of red chestnut leaves sprayed on white horse chestnut leaves decreased the attractiveness of sprayed areas to the adults of *C. ohridella* (TOMCZYK et al. 2008). Extract of *Polyscias filicifolia* Bailey (Araliaceae) was repellent to the females of the horse chestnut leaf miner, which resulted in the lower number of eggs laid on treated leaves as compared to the control (TOMCZYK et al. 2007).

The aim of the present study was to evaluate the effect of essential oils of common aromatic and medicinal plants on the feeding activity of *C. ohridella* larvae. Moreover, we examined the response of the larvae to major terpenoid ingredients of the most active essential oils in this study and to *β*-aescin, which is the main biologically active saponin constituent of horse chestnut (KALEMBA et al. 2001, SIRTORI 2001, SEDLAKOVA et al. 2003, TOUAFEK et al. 2004, BHUIYAN et al. 2010, TKACHENKO 2010, MAHBOUBI, KAZEMPOUR 2011, SZCZEPANIK, SZUMNY 2011, TSAI et al. 2011, RAINA, NEGI 2012, SZCZEPANIK et al. 2012). Essenial oils of common aromatic plants are known for their broad spectrum of biological activity: antiseptic (i.e., bactericidal, virucidal and fungicidal), and medicinal (e.g., antioxidant and anticancer) (BAKKALI et al. 2008, ZU et al. 2010, HUSSAIN et al. 2011). Aromatic plants and essential oils have also been applied for the protection of food, plants, and animals against pests and diseases (PICKETT et al. 1997, ISMAN 2000, BAKKALI et al. 2008,) because they are generally nontoxic to mammals, birds, and fish (KOUL et al. 2008). The extracts of the following material was used: dried seeds of caraway *Carum carvi* L., giant hogweed *Heracleum mantegazzianum* Sommier & Levier, fruit of anise *Pimpinella anisum* L., dried buds of cloves *Syzygium aromaticum* (L.) Merrill & Perry, fresh green parts of marjoram *Origanum majorana* L., oregano *O. vulgare* L., rosemary *Rosmarinus officinalis* L., thyme *Thymus vulgaris* L., goldenrod *Solidago canadensis* L., tansy *Tanacetum vulgare* L., leaves and seeds of *Thuja occidentalis* L., and dried summer savory *Satureja hortensis* L.

Material and Methods

Plant extracts and pure compounds

The plant material was obtained from Svedeponic Company (Kraśnicza Wola) and from Kawon-Hurt (Krajewice). Essential oils were obtained from plant material by hydrodistillation on Deryng apparatus (SZUMNY et al. 2010). In brief, approximately 200 g of fresh or 50 g of dried plant material was placed

in a 2 L round flask together with 900 mL of distilled water. The sample flask was heated for 2 h after the boiling point was reached. The vapors were condensed by means of a cold refrigerant. After 120 min of distillation, depending on plant material, from 0.25 to 2.5 mL of essential oil containing the volatile compounds was collected in a 2.5 mL vial and kept at -15°C until the GC-MS analyses and biological tests were performed. The identification and quantification of the volatile compounds was performed using a gas chromatograph (GC) coupled to a mass spectrometer (MS), a Saturn 2000 MS Varian Chrompack with a DB-5. Most of the compounds were identified by using three different analytical methods: (1) Kovats indices, (2) GC-MS retention indices with authentic chemicals – standards and (3) mass spectra (authentic chemicals and NIST05 spectral library collection (MS). Basing on the results of chemical analysis (SZCZEPANIK and SZUMNY 2011, SZCZEPANIK et al. 2012), the following major terpenoid components of the extracts studied were bioassayed: bornyl acetate, camphene, p-cymene, geraniol, linalool, α-pinene, β-pinene, α-terpinene, γ-terpinene, terpinolene, and thymol. All pure chemicals were purchased from Sigma-Aldrich.

Biological assays

White horse chestnut (*A. hippocastanum*) compound leaves with visible mines of the first generation larvae of the horse chestnut leaf miner (*C. ohridella*) were collected and transferred to laboratory. The mines were examined for the presence of larvae using a binocular microscope and the t0 (=time of application) area of the mine was calculated according to a formula: A0=Πab, assuming the elliptical shape of the mine (A0 – area of the ellipse at t0; a and b – one-half of the ellipse's major and minor axes, respectively). 15 µl of the studied substances (1% ethanolic solutions; 20 replications per studied substance) were applied to the surface of the mine using a BRAND Transferpette®. The leaves were put individually in flasks containing water and placed in the growing chamber Sanyo (t = 23°C, L16 : D8) for five days. After the incubation period, the t1 (=time after incubation period) area of the mines was calculated, according to a formula: A1=Πa1b1. The feeding activity index (FAI) of individual larvae was determined using a formula: FAI=A1/A0. The data thus obtained were log transformed and analysed statistically using two-tailed Dunnett's test to find significant differences between individual treatments and control (untreated mines) at $p<0.05$.

Results and Discussion

The essential oils from aromatic plants and pure compounds applied in the present study had a varied effect on the feeding of *C. ohridella* larvae. The essential oil from *S. canadensis* caused statistically significant increase in the feeding activity of the horse chestnut leaf miner larvae: a 1.6-fold increase in plant tissue consumption by *C. ohridella* was found after the application of this oil (Table 1). The effects of *T. vulgare* and *H. mantegazzianum* oils were also relatively strong (1.3- and 1.2-fold increase in tissue consumption, respectively) but the effect was not statistically significant.

Table 1
Feeding Activity Indices (FAI) of the horse chestnut leaf miner *Cameraria ohridella* larvae after application of essenial oils from aromatic plants[a]

Plant essential oil	FAI[b]	p[c]
Control	1.94 (+1.23)	
Carum carvi	1.86 (±0.82)	0.997
Haracleum mantegazzianum	2.42 (±0.99)	0.136
Origanum majorana	1.96 (±2.38)	0.587
Origanum vulgare	2.13 (±1.53)	0.700
Pimpinella anisum	2.33 (±0.95)	0.211
Rosmarinus officinalis	1.42 (±0.62)	0.187
Satureja hortensis	1.60 (±1.02)	0.329
Solidago canadensis	2.99 (±2.18)	0.026
Syzygium aromaticum	2.21 (±1.21)	0.433
Tanaceum vulgare	2.55 (±2.01)	0.243
Thuja occidentalis leaves	2.04 (±1.18)	0.755
Thuja occidentalis seeds	2.31 (±1.44)	0.373
Thymus vulgaris	1.69 (±1.17)	0.458

[a] Numbers are the means of 20 replicates and are presented with standard deviations (±SE), [b] FAI – Feeding Activity Index, [c] Two-tailed Dunnett's test was applied to find significant differences between individual treatments and control at $p<0.05$

The horse chestnut characteristic saponin β-aescin appeared a feeding stimulant for *C. ohridella*: 1.7-fold increase in plant tissue consumption occurred after the application of this compound (Table 2). A significant increase in the feeding activity of larvae occurred after the application of β-pinene, geraniol, linalool, and *p*-cymene (1.7, 1.6, 1.5, and 1.5-fold increase, respectively). The application of thymol caused a significant decrease in the feedig activity of larvae (nearly 60% less consumed food as compared to control) – Table 2.

Table 2
Feeding Activity Indices (FAI) of the horse chestnut leaf miner *Cameraria ohridella* larvae after application of individual terpenoids and *β*-aescin[a]

Terpenoid	FAI[b]	*p*[c]
Control	1.94 (±1.23)	
β-Aescin	3.32 (±1.75)	0.002
Bornyl acetate	1.74 (±0.91)	0.681
Camphene	1.99 (±0.87)	0.694
p-Cymene	2.87 (±1.46)	0.026
Geraniol	3.01 (±2.12)	0.011
(±/-)-Linalool	2.38 (±1.88)	0.476
(-)-Linalool	2.9 (±1.38)	0.016
α-Pinene	1.36 (±0.46)	0.157
β-Pinene	3.38 (±3.19)	0.013
Terpinolene	2.01 (±1.19)	0.804
α-Terpinene	2.06 (±1.77)	0.967
γ-Terpinene	2.49 (±1.04)	0.105
Thymol	1.08 (±0.21)	0.018

[a] Numbers are the means of 20 replicates and are presented with standard deviations (±SE), [b] FAI – Feeding Activity Index, [c] Two-tailed Dunnett's test was applied to find significant differences between individual treatments and control at $p<0.05$

The total and relative content of individual components in plant tissues depends on many factors, such as the botanical variety, vegetative stage, plant part, time of harvest, geographical location, e.t.c (WITTSTOCK, GERSHENZON 2002). However, the composition of the set of allelochemicals in aromatic plants is species- or at least genus-specific. Nevertheless, it must be kept in mind that plants usually contain more than one group of protective anti-herbivore seconadary metabolites (GABRYŚ, PAWLUK 1999) This particular attribute may be responsible for *C. ohridella* response to some of the essential oils applied in this study. Interestingly, the goldenrod extract was highly attractive to *C. ohridella* larvae despite the content of *α*-pinene and bornyl acetate, which showed potentially deterrent activity when applied individually. Goldenrods, the plants of the genus *Solidago*, contain considerable amount of flavonoids and saponins that are responsible for many biological (e.g., therapeutical) effects of these plants (KOŁODZIEJ et al. 2011). The highly attractive to *C. ohridella β*-aescin is a saponin, so it is possible that the weakly deterrent effect of *Solidago* terpenoids was 'overshadowed' by attractant properties of saponins. However, the presence of saponins in the essential oil studied remains to be confirmed in the further study. The lower potency of attractant properties of tansy and giant hogweed extracts to *C. ohridella* larvae is

probably caused by the complexity of terpenoid composition in their essential oils. On one hand, tansy contains highly attractive β-pinene and p-cymene but on the other hand – the deterrent α-pinene is present as well (WOLF et al. 2012). Likewise, giant hogweed contains the attractive β-pinene and γ-terpinene, which may be 'screened' by the deterrent α-pinene (TKACHENKO 2010). Similarly, the highly deterrent effect of thymol may be neutralized by geraniol, linalool and p-cymene in the thyme extract (GRIGORE et al. 2010, ZU et al. 2010, SZCZEPANIK et al. 2012), and by p-cymene in the summer savory extract (MAHBOUBI, KAZEMPOUR 2011). The rosemary oil has probably the highest feeding deterrent potential to *C. ohridella*: its oil contains considerable amounts of α-pinene and bornyl acetate (PINTORE et al. 2009) and in present experiments it caused the highest reduction in food consumption by *C. ohridella* larvae.

In conclusion, the extracts studied can be divided into four groups according to the effect they had on *C. ohridella* larvae: attractant (goldenrod), potentially attractant (tansy and giant hogweed), inactive (anise, thuja, clove, oregano, marjoram, caraway), and potentially deterrent (thyme, summer savory, rosemary). The individual terpenoids can be divided into five groups: attractant (β-pinene, geraniol, (-)-linalool, *p*-cymene), potentially attractant (γ-terpinene, (+/-)-linalool), inactive (α-terpinene, terpinolene, camphene), potentially deterrent (bornyl acetate, α-pinene), and deterrent (thymol). Thymol, due to its feeding deterrent activity can be considered in the Integrated Pest Management (IPM) programmes against *C. ohridella* larvae, probably as a supplementary behaviour-controlling allelochemical.

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FEEDING DETERRENT ACTIVITY OF NATURAL MONOTERPENOIDS AGAINST LARVAE OF THE LARGE WHITE BUTTERFLY *PIERIS BRASSICAE* (L.)

***Bożena Kordan*[1], *Beata Gabryś*[2]**

[1] Department of Phytopathology and Entomology
University of Warmia and Mazury in Olsztyn
[2] Department of Botany and Ecology
University of Zielona Góra

K e y w o r d s: antifeedants, *Pieris brassicae*, monoterpenoids, large white butterfly, plant protection.

A b s t r a c t

The large white butterfly *Pieris brassicae* (L.) (Lepidoptera: Pieridae) is a cosmopolitan insect that is specialized to feed on the plant family Brassicaceae. The caterpillars may cause severe losses in yield of cabbage plants. In search of environmentally safe control chemical substances, the effect of 17 natural monoterpenes on the feeding activity and food assimilation of *P. brassicae* larvae was studied. According to the analysis of behavioural and physiological effects caused by the substances applied in the present study, these chemicals can be divided into into five groups: highly active deterrents that practically completely inhibited the feeding of caterpillars (α-phellandrene and β-ionone), strong deterrents (α-terpinene and α-ionone), relatively strong deterrents (citronellol, (-)-linalool, *p*-cymene), moderate deterrents ((+)-fenchone, (+)-R-limonene, γ-terpinene, and (S)-(+)-carvone), and inactive substances (α-pinene, eucalyptol, bornyl acetate, geraniol, thymol, and L-menthol). α-Phellandrene, β-ionone, α-ionone, α-terpinene, citronellol, and (-)-linalool may be classified as preingestive deterrents that act before food ingestion. *p*-Cymene may be considered as postingestive deterrent that causes a loss in body weight.

Address: Bożena Kordan, University of Warmia and Mazury in Olsztyn, ul. Romana Prawocheńskiego 17, 10-957 Olsztyn, Poland, phone: +48 (89) 523 37 81, e-mail: bozena.kordan@uwm.edu.pl

AKTYWNOŚĆ DETERENTNA NATURALNYCH MONOTERPENOIDÓW WOBEC GĄSIENIC BIELINKA KAPUSTNIKA *PIERIS BRASSICAE* (L.)

***Bożena Kordan*[1], *Beata Gabryś*[2]**

[1] Katedra Fitopatologii i Entomologii
Uniwersytet Warmińsko-Mazurski w Olsztynie
[2] Katedra Botaniki i Ekologii
Uniwersytet Zielonogórski

S ł o w a k l u c z o w e: antyfidanty, *Pieris brassicae*, monoterpenoidy, bielinek kapustnik, ochrona roślin.

A b s t r a k t

Bielinek kapustnik *Pieris brassicae* (L.) (Lepidoptera: Pieridae) jest kosmopolitycznym gatunkiem wyspecjalizowanym w żerowaniu na roślinach z rodziny Brassicaceae. Gąsienice mogą powodować poważne straty u roślin kapustowatych. W poszukiwaniu przyjaznych środowisku środków ochrony roślin zbadano wpływ 17 naturalnych monoterpenoidów na żerowanie i przyrost masy ciała gąsienic *P. brassicae*. Analiza behawioralnych i fizjologicznych efektów wywołanych przez poszczególne substancje pozwoliła na zaliczenie ich do pięciu grup: bardzo aktywne deterenty, które prawie całkowicie zniechęcały gąsienice do żerowania (α-felandren i β-jonon), silne deterenty (α-terpinen i α-jonon), stosunkowo silne deterenty (citronellol, (-)-linalool, p-cymen), słabe deterenty ((+)-fenchon, (+)-R-limonen, γ-terpinen i (S)-(+)-karwon) oraz substancje nieaktywne (α-pinen, eukaliptol, octan bornylu, geraniol, tymol i L-mentol). Ponadto najbardziej aktywne deterenty (α-felandren, β-jonon, α-jonon, α-terpinen, citronellol, (-)-linalool) można określić jako deterenty smakowe działające przed pobraniem pokarmu, zaś *p*-cymen – jako deterent metaboliczny działający po pobraniu pokarmu i powodujący spadek masy ciała gąsienic.

Introduction

The large white butterfly *Pieris brassicae* (L.) (Lepidoptera: Pieridae) is specialized to feed on the plant family Brassicaceae. It is a cosmopolitan insect species in Europe and it occurs wherever cruciferous plants are grown. The larvae of *P. brassicae* feed on cabbage foliage and create large, irregular holes. In consequence, the severe reduction of the marketable yield or complete destruction of the crop occurs (JANKOWSKA 2006, JANKOWSKA et al. 2009, 2011). Till now, the control of *P. brassicae* has been oriented towards the use of efficient but high-risk insecticides. Considering various negative effects of their application there is an increasing demand for more specific, indirectly acting crop protection agents, such as repellents, insect-growth regulators, oviposition inhibitors, and antifeedants, which might, at least in part, replace conventional insecticides (SCHOONHOVEN 1982, VAN BEEK, DE GROOT 1986, LAY, TOOGOOD 1990, NORIN 2007). Of the behaviour-controlling chemicals,

insect antifeedants have attracted a lot of research in the recent years, and the most interesting discoveries included the terpenoids of plant origin: ajugarin, azadirachtin, and polygodial. An antifeedant (= feeding deterrent) is a behaviour modifying substance that deters feeding through a direct action on peripheral sensilla (= taste organs) of insects (ISMAN 2002). The most spectacular antifeedant effects on *P. brassicae* larvae were reported by SHARMA and GUPTA (2009), who showed that the aqueous extract of *Azadirachta indica* and *Melia azedarach* protected 94.0 and 89.2 percent cabbage foliage against *P. brassicae*, respectively. Similar results were obtained by WAWRZYNIAK and WRZESIŃSKA (2000). Moreover, synergistic effect of these botanicals on the virulence of granulosis virus (GV) against *P. brassicae* was also found (BHANDARI et al. 2009). A number of terpene-containing plants that are native to Polish flora have also been studied in respect of feeding deterrent activity to *P. brassicae*. For example, WAWRZYNIAK (1996), studied the activity of aqueous as well as alcohol extracts of 65 plant species of 21 families, both in the field and in the laboratory. The results demonstrated a high feeding and oviposition deterrent activity of *Ajuga reptans*, *Callendula officinalis* and of the plants of Apiaceae and Geraniaceae families. The individual terpenoid constituents of aromatic plants were highly deterrent to other insect species, e.g. peach potato aphid *Myzus persicae* (GABRYŚ et al. 2005).

The aim of the present work was to assess the behavioural and physiological responses of the large white butterfly larvae to selected lower plant terpenoids. The effect of 17 monoterpenes on the feeding activity and food assimilation of *P. brassicae* larvae was studied in no-choice tests on leaf material of the host plant *Brassica oleracea*.

Material and Methods

Insects and plants. White cabbage *Brassica oleracea* L. var. *capitata* f. *alba* cv. Sława was grown under field conditions with no insect control measures applied. The L4 larvae of the large white butterfly *Pieris brassicae* (L.) and cabbage leaves were collected and transferred to the laboratory for the experiments.

Chemicals. The following 17 monoterpenoids were used in the study: 12 cyclic monoterpenoids (bornyl acetate, carvone, *p*-cymene, eucalyptol, (+)-fenchone, (+)-R-limonene, L-menthol, α-phellandrene, (+)-α-pinene, α-terpinene, γ-terpinene, thymol) and 5 acyclic monoterpenoids (citronellol, geraniol, (-)-linalool, α-ionone, β-ionone). All compounds were purchased from Sigma-Aldrich company.

Bioassays. Each monoterpenoid was tested in a 24-hour no-choice test with 10 replicates per test. The 40 mm x 40 mm fragments of cabbage leaves were

immersed in 1% ethanolic solutions of individual monoterpenoids for approximately 3 seconds, dried, weighed and placed individually in Petri dishes of 10 cm diameter. Cabbage leaves immersed in 1% ethanol were used as control. The field collected L4 larvae of *P. brassicae* were weighed and placed in the Petri dishes containing the studied plant material (one larva/Petri dish). The experiment was carried out in the growing chamber Sanyo MLR-350H at 20°C and L14h:10hD photoperiod for 24 hours. At the end of the experiment, the plant material and the larvae were weighed.

Data analysis. The following parameters were calculated: amount of consumed food by the *P. brassicae* larvae, change in body weight of the larvae, and the absolute index of deterrence (DI) according to a formula: $DI = (C–T)/(C+T) \cdot 100$, where C and T represent the amount of control and treated material consumed by the larvae, respectively. The data were subjected to statistical analysis using one-way ANOVA. The significance of differences in relation to control was estimated using the Dunnett's test at $p<0.05$. The data on the change in larval body weight were Box-Cox transformed ($\lambda = 4.99$, shift = 1.94). Additionally, the Tukey test (HSD) was used on the index of deterrence (DI) data to find significant differences in the activity among the studied compounds.

Results and Discussion

The significant reduction in the amount of the consumed food by *P. brassicae* larvae occurred after the application of α-phellandrene, β-ionone, α-ionone, α-terpinene, citronellol, (-)-linalool, and *p*-cymene (Table 1). The strongest deterrent effect was found in the case of α-phellandrene- and β-ionone-treated leaves: the larvae consumed approximately four times less food than in the control experiment. The least active compound *p*-cymene caused 1.5-fold reduction in the food consumption. The deterrence indices (DIs) for these substances ranged from 59.3 (α-phellandrene) to 21.2 (*p*-cymene). (+)-R-limonene, (+)-fenchone, γ-terpinene, and (S)-(+)-carvone had moderate but not significant antifeedant effect: the reduction of the feeding of *P. brassicae* larvae was approximately 1.4-fold. The DIs range was 21.1 ((+)-R-limonene) – 17.2 ((S)-(+)-carvone). The remaining compounds either did not show any effect on the food consumption of the larvae ((+)-α-pinene, eucalyptol, bornyl acetate; DIs: 9.2–1.3) or were very slightly attractant (geraniol, thymol, and L-menthol; DIs: -2.0 to -5.2) – Figure 1.

There were no significant differences in the change of body weight after the 24-hour experiment in caterpillars that were exposed to leaves treated with the studied monoterpenoids in comparison to control (Table 1). Nevertheless, the caterpillars that were offered leaves treated with α-phelandrene, β-ionone, and (-)-linalool showed almost no increase in body weight (14% of the control

Table 1
The effect of monoterpenoids on food consumption and assimilation of larvae of the *Pieris brassicae*

	Consumed food (g) mean (±SD)	Dunnett's test *p*	Change in body weight (g) mean (±SD)		Dunnett's test *p*
			non--transformed	Box-Cox--transformed	
Control	0.52 (±0.11)		0.07	6.41 (±0.79)	
α-phellandrene	0.13 (±0.04)	0.0000	0.01	5.46 (±0.20)	0.1377
β-ionone	0.16 (±0.05)	0.0000	0.01	5.45 (±0.27)	0.1232
α-ionone	0.27 (±0.11)	0.0008	0.05	6.06 (±0.54)	0.9913
α-terpinene	0.28 (±0.18)	0.0015	0.03	5.74 (±0.38)	0.5261
Citronellol	0.31 (±0.13)	0.0085	0.06	6.26 (±0.90)	1.0000
(-)-linalool	0.32 (±0.10)	0.0165	0.01	5.46 (±0.54)	0.1357
P-cymene	0.34 (±0.09)	0.0420	-0.04	5.69 (±2.08)	0.4425
(±)-R-limonene	0.35 (±0.14)	0.0717	0.05	6.14 (±0.52)	0.9996
(±)-fenchone	0.35 (±0.19)	0.0792	0.06	6.24 (±0.82)	1.0000
γ-terpinene	0.36 (±0.05)	0.0877	0.04	5.80 (±0.27)	0.8132
(±)-*α*-pinene	0.40 (±0.21)	0.3735	0.02	5.68 (±0.71)	0.4265
(S)-(±)-carvone	0.41 (±0.23)	0.4602	0.06	6.30 (±1.07)	1.0000
Eucalyptol	0.46 (±0.13)	0.9855	0.08	6.57 (±0.99)	1.0000
Bornyl acetate	0.50 (±0.07)	1.0000	0.05	6.05 (±0.71)	0.9886
L-menthol	0.50 (±0.09)	1.0000	0.09	6.73 (±0.56)	0.9971
Geraniol	0.57 (±0.22)	0.9983	0.09	6.84 (±1.27)	0.9572
Thymol	0.58 (±0.17)	0.9787	0.05	6.15 (±0.81)	0.9998

value). Additionally, the larvae that consumed leaves treated with *p*-cymene showed a decrease in body weight (1.6-fold reduction in relation to control). The food selection process by the caterpillars of the large white butterfly involves the response to plant surface chemicals that are detected by contact chemoreceptors (= taste receptors) on the mouthparts (SCHOONHOVEN, LIN-ER 1994). Glucosinolates, the characteristic chemicals of the Brassicaceae play a crucial phagostimulant role in this process (RENWICK, LOPEZ 1999, SMALLEGANGE et al. 2007). The deterrent chemicals are also sensed by *P. brassicae* caterpillars at the plant surface level and cause the inhibition of the feeding activity (MESSENDORP et al. 2000).

Basically, an antifeedant is a behaviour modifying substance that deters feeding through a direct action on taste organs (Isman 2002). However, FRAZIER and CHYB (1995) suggested that insect feeding can be inhibited at three levels: preingestional (immediate effect associated with host finding and host selection processes involving gustatory receptors), ingestional (related

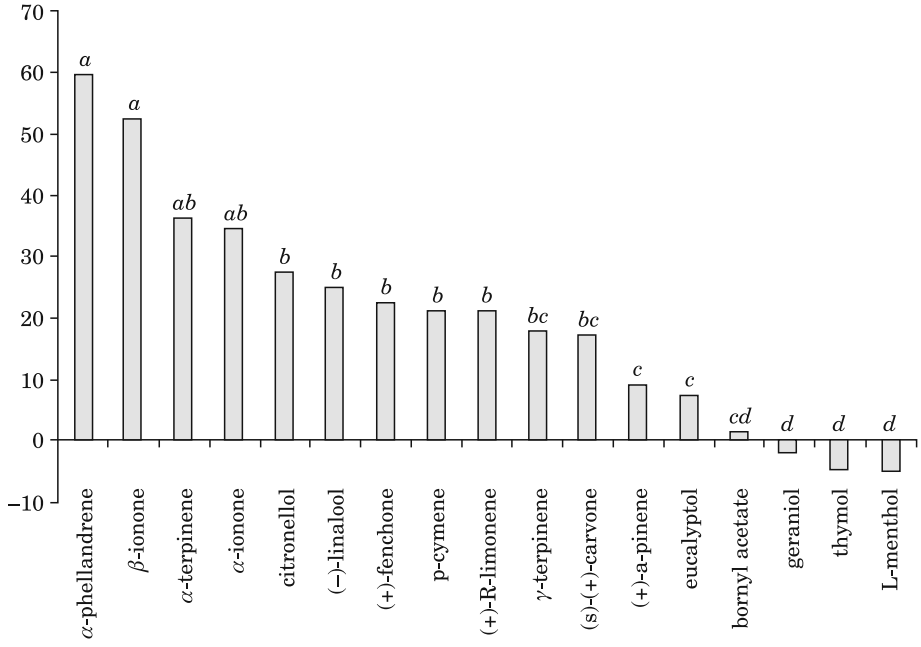

Fig. 1. Deterrence indices (DI) of monoterpenoids applied against larvae of the *Pieris brassicae*. Different letters show significant differences in activity among the terpenoids (Tukey's test at $p<0.05$)

to food transport and production, release, and digestion by salivary enzymes), and postingestional (long-term effects involving various aspects of digestion and absorption of food).

Conclusions

According to the comparative analysis of the feeding deterrence indices (DIs), all substances applied in the present study can be divided into five groups: highly active deterrents that practically completely inhibited the feeding of caterpillars (α-phellandrene and β-ionone; DI = 59 and 52, respectively), strong deterrents (α-terpinene and α-ionone; DI = 36 and 34), relatively strong deterrents (citronellol, (-)-linalool, *p*-cymene; DI = 27, 24, 21), moderate deterrents ((+)-fenchone, (+)-R-limonene, γ-terpinene, and (S)-(+)-carvone; DI = 22, 21, 17, 17), and inactive substances (h-pinene, eucalyptol, bornyl acetate, geraniol, thymol, and L-menthol). Moreover, α-phellandrene, β-ionone, α-ionone, α-terpinene, citronellol, (-)-linalool, and *p*-cymene may be classified as preingestive deterrents and *p*-cymene may be considered a postingestive deterrent.

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POSSIBILITIES FOR SUSTAINABLE TOURISM DEVELOPMENT IN THE COUNTY OF MRĄGOWO (POLAND)

***Anna Hakuć-Błażowska*[1], *Konrad Turkowski*[2]**

[1] Department of Lake and River Fisheries
[2] Department of Spatial and Environmental Economics
University of Warmia and Mazury in Olsztyn

K e y w o r d s: sustainable tourism, lakeland regions, county of Mrągowo, rural areas.

A b s t r a c t

Tourist activities consistent with sustainable development are an important component of the development strategies of many communes and counties in lakeland regions, including the county of Mrągowo in the Masurian Lake District. In the county under study, the abundance of lakes (over 12% of its area) and forests (constituting 30% of its area) and expanded recreation infrastructure (third place in the province of Warmia-Mazury) create excellent conditions for many forms of tourist activities as well as solid foundations for the development of sustainable tourism. National and international events are organized in the county of Mrągowo and the majority of accommodation providers are available all year round. This county offers numerous attractions of the cultural heritage. Promotions include events promoting regional cuisine. Natural and cultural resources and expanded infrastructure serve as the basis for development of sustainable tourism in the county of Mrągowo.

MOŻLIWOŚCI ROZWOJU TURYSTYKI ZRÓWNOWAŻONEJ W POWIECIE MRĄGOWSKIM (POLSKA)

***Anna Hakuć-Błażowska*[1], *Konrad Turkowski*[2]**

[1] Katedra Rybactwa Jeziorowego i Rzecznego
[2] Katedra Ekonomiki Przestrzennej i Środowiskowej
Uniwersytet Warmińsko-Mazurski w Olsztynie

K e y w o r d s: turystyka zrównoważona, pojezierza, powiat mrągowski, obszary wiejskie.

Address: Anna Hakuć-Błażowska, University of Warmia and Mazury in Olsztyn, ul. Michała Oczapowskiego 5, 10-957 Olsztyn, Poland, phone: +48 (89) 523 44 36, e-mail: hakuc.blazowska@uwm.edu.pl

Abstrakt

Działalność turystyczna zgodna z zasadą zrównoważonego rozwoju jest ważnym elementem strategii rozwoju wielu gmin i powiatów pasa pojezierzy, także powiatu mrągowskiego na Pojezierzu Mazurskim. W powiecie mrągowskim bogactwo jezior (ponad 12% jego powierzchni), lesistość na poziomie 30% oraz rozbudowana infrastruktura wypoczynkowa (3 miejsce w województwie warmińsko-mazurskim) stanowią znakomite warunki do uprawiania wielu form turystyki, jak również mocne podwaliny do rozwoju turystyki zrównoważonej. W powiecie mrągowskim odbywają się cykliczne imprezy o zasięgu krajowym i międzynarodowym, a większość bazy noclegowej stanowią obiekty całoroczne. Znajduje się tu wiele atrakcji związanych z dziedzictwem kulturowym. Organizowane są imprezy promujące dziedzictwo kulinarne. Zarówno istniejące zasoby naturalne, jak i kulturowe oraz rozbudowana infrastruktura stanowią przesłankę do rozwoju turystyki zrównoważonej w powiecie mrągowskim.

Introduction

The various approaches to interpret the phenomenon of tourism, its interdisciplinary character and multi-faceted nature in social, industrial, cultural and environmental spheres make it difficult to formulate a single, universal and commonly-accepted definition of tourism. Tourism is simultaneously a psychological, social, cultural, spatial and economic phenomenon. The multi-faceted nature of tourism necessitates an adequate tourist policy, which translates into creating conditions that favor the development of the tourist sector. Within the framework of tourist policies, the following components may be preferred (*Kompendium wiedzy*... 2009):

– types of communities that participate in tourism in a preferential way (e.g. youth, pensioners);

– selected types of tourist flow (e.g . ecotourism, educational tourism);

– regions, counties and cities for which the growth of tourism creates the potential for industrial development.

All human activities are seated in the natural environment and therefore have an impact on its current and future status. Article 5 of The Constitution of The Republic of Poland states that "the Republic of Poland (...) provides the protection of the environment with the principle of sustainable development". It means that all management procedures should be conducted to secure the environment in an optimal condition for future generations. Among the methods of putting ecological policies into action, the priority is to implement so-called "good management practices" and environmental management systems which combine industrial effects with ecological results (HAKUĆ-BŁAŻOWSKA and TURKOWSKI 2011). The criteria for sustainable development should be taken into consideration in all strategic documents of industry sectors (*Polityka ekologiczna*... 2007) including the strategies of tourism development. In tourism, the idea of sustainable development is reflected in

the notion of "sustainable tourism" that defines environment-friendly tourist activities and refers to all areas, rural and urban, and all types of tourism after their "ecological transformation" (ZARĘBA 2000). While this notion is widely used in the literature, it is difficult to precisely determine and define sustainable tourism. Despite numerous studies undertaken by many researchers (e.g. BUTLER 1999, SWARBROOKE 1999, HARDY 2002, RITCHIE and CROUCH 2003, EDGELL 2006, WEAVER 2006, PAWLIKOWSKA-PIECHOTKA 2009; GÖSSLING et. al. 2009, *Turystyka zrównoważona.* 2010), the term "sustainable tourism" has not been yet described with one comprehensive and commonly accepted definition. In 1993, the World Tourism Organization (*Sustinable tourism...* 1993) defined sustainable tourism as an activity that fulfills the needs of modern tourists and receptive regions simultaneously protecting and supporting opportunities for future generations. However, according to the definition presented by the European Commission, sustainable tourism is a form of tourism that is cost-efficient economically and socially and does not harm the environment or local culture. It includes industrial and financial success, care for the environment together along with its protection and development and responsible management of society and cultural values – these three elements being correlative (*Communication...* 2003).

The concept of sustainability has been extended and supplemented with the integration of tourist flow into local communities and social and industrial activities. The aim of this concept is to integrate tourist activities with the protection of the environment as well as to create new attitudes and behaviors among tourists and the organizers of tourist flow. The following rules should be implemented (*Kompendium wiedzy...* 2009):

– development of tourism should be adapted to the type and quality of natural resources and should not contribute to their degradation,

– local communities should participate in all undertakings related to tourism that are conducted in a given region,

– the tourist offer should be based on local resources, both human and material; small facilities adapted to the surrounding area should be constructed,

– development of tourism should be integrated with local industrial development and should bring ethical, social and economic benefits to local communities.

Lakeland regions are characterized by varied landscape with numerous postglacial lakes as well as diverse types of postglacial formations. The specific character and the need to protect and preserve precious natural values which shape the tourist attractiveness of these areas justify the development of sustainable tourism. The main concepts of sustainable tourism development are aimed at ensuring its economic effectiveness by means of protection and

rational use of environmental resources, both natural and cultural, with simultaneous improvement of the quality of life of local communities. It is connected with the assumptions of sustainable development of rural areas in accordance with The Common Agricultural Policy outlined in "The Programme for Development of Rural Regions 2007–2013" (HAKUĆ-BŁAŻOWSKA et al. 2012). Tourist activities consistent with sustainable development are an important component of the development strategies of many communes and counties in lakeland regions, including the county of Mrągowo in the Masurian Lake District. This paper focuses on an analysis of the developmental potential in one of the counties in The Masurian Lake District, i.e. the county of Mrągowo and associated rural communes.

Methods

This paper reviews the literature on the concept of sustainable tourism in Poland, including rural regions, and observation of indices of sustainable development of tourism on a selected area. The statistical data from the publications discussing the examined issues in the county of Mrągowo and strategic documents prepared for selected area were also analyzed. The review of indices used to evaluate the sustainable development of tourism (WEAVER and OPPERMAN 2000, *Indicators*... 2004, The VISIT 2004, GÖSSLING et. al 2009, JANIKOWSKI 2010, *Turystyka zrównoważona.* 2010) has revealed a lack of a widely-accepted method of monitoring sustainable tourism. The studies were conducted on a local level and therefore only indices that applied to local communities were selected from a variety of parameters of sustainable tourism.

The aim of the paper was to present the background of development of sustainable tourism in the county of Mrągowo and implement a method of observing the indices of sustainable tourism by means of field studies as well as a method of critical analysis of the indices of sustainable development available in strategic documents. The Strategy for Social and Industrial Development of the County of Mrągowo in 2007–2020, The Strategy for Development of Tourism in the Province of Warmia and Mazury, The Investment Plan for the County of Mrągowo in 2008–2013 (*Wieloletni Plan*... 2008), Tourism in Warmia and Mazury in 2009 (*Strategia rozwoju*... 2008) and numerous websites, e.g. www.powiat.mragowo.pl, it.mragowo.pl, are the basic source of information on the tourist potential of the county. The publications "Warmia and Mazury 2020. Which direction towards development?" and *The Regional Operational Programme Warmia and Mazury (Regionalny Program*... 2007) are a valuable source of information on tourism in the county of Mrągowo.

The results of detailed analysis of the indices of sustainable tourism development, including the surveys of local communities in the individual communes of the county of Mrągowo, will be presented in separate publications.

Tourist potential in the county of Mrągowo

The county of Mrągowo is situated in north-eastern Poland in the central region of the province of Warmia and Mazury. The territory of the county constitutes app. 5% of the area of the province. The county neighbors five counties: Olsztyn, Kętrzyn, Giżycko, Pisz and Szczytno. The county of Mrągowo comprises five districts:

– the district of Mrągowo Town,
– the district of Mrągowo,
– the town and district of Mikołajki,
– the district of Piecki,
– the district of Sorkwity.

It terms of physiographic location, the county of Mrągowo is situated within two regions:

– the western part to the line of Lipowo – Kosewo – Baranowo – Cudnochy is the area of The Lakeland of Mrągowo,

– the eastern part is The Great Masurian Lake District (a vast lowland within the lakelands of north-eastern Poland).

The geography and lithology of both areas are typical of post-glacial regions and the unique feature of their landscape is the abundance of large, natural water reservoirs, which constitute app. 14% of the area of the county (in the county of Mikołajki this index amounts to app. 23%).

Beaded lakes are most common (Tałty-Ryńskie, Mikołajskie, Wągiel, Juno, Gielądzkie, Mokre, etc.) along with thaw lakes as well as lakes with complex genetics (e.g. Lake Śniardwy) are far less numerous.

The second characteristic component of the landscape of this region, apart from lakes, are vast well-stocked forest complexes. In the county of Mrągowo, forests constitutes app. 31% of its area and are represented mainly by the Piska Primeval Forest. The forests and water reservoirs cover app. 45% of the area of the county, i.e. app. 480 km^2. The farmland and urban fields (towns, villages, and communication) constitute the rest of its territory. Numerous floral and faunal reserves have been established in the county of Mrągowo. Many plant species originating from diverse climatic environments are found in the county; these are often very rare species in Poland and Europe and their protection is maintained in numerous reserves, such as “Jezioro Lisiunie”,

"Krutynia Dolna", "Strzałowo", "Zakręt", "Królewska sosna" with died-back pine and common oak called "The oak of Karol Małłek", "Krutynia", "Pierwos" and "Gązwa". The Piska Primeval Forest is the main sanctuary for animals and the lakes are inhabited by many precious fish species such as eel, pike, tench, pike perch, perch, bream and roach. European white-fish and Baltic whitefish are still found in the purest and deepest reservoirs (Piłakno and Mokre Lakes). The abundance of fish makes the region attractive for anglers. The faunal and floral-faunal reserves have been created to protect the most precious animal species; the most important reserves include the "Jezioro Łukajno" Reserve, entered on the list of UNESCO World Natural Heritage Sites and covered by the international RAMSAR Convention which protects wetlands and swamps; the "Czapliniec" Reserve and the "Czaplisko – Ławny Lasek" Reserve. In 1977, The Masurian Landscape Park was established in order to protect the natural values and landscape features of the southern part of the Great Masurian Lake District, The Lakeland of Mrągowo and the lower course of the Krutynia River. The area of the park covers app. 53,700 ha and, together with the protection zone, it amounts to app. 72,300 ha, of which about 50% (i.e. app. 26,800 ha without the protection zone) is situated within the county. The park hosts numerous natural monuments, such as the boulder located near "Gązwa" Reserve or "Pomnik Wolności Ojczyzny". The protected landscape zones further contribute to the protection of nature and landscape. The Protected Landscape Zone of the Legińsko-Mrągowskie Lakes and three natural landscape complexes ("Rzeka Brabant i Jezioro Białe", "Jeziora Sorkwickie" and "Zyzdrój") were established in the area of the county of Mrągowo.

The historical monuments representing different architectural styles show the attractiveness of the area of Mrągowo. Tourists interested in sightseeing may visit numerous historical building, for instance:

– architectural complexes, such as the manor and farm complex in Boże,
– castles, e.g. the ruins of Teutonic castle in Szestno,
– historical tenements and buildings in, for example, Mrągowo,
– Masurian cottages in, among others, Ruska Wieś, Warpuny, Choszczewo, Inulec and Piecki,
– palaces and manor houses such as Baranowo, Sorkwity and Szestno,
– technical monuments such as water mills in Babięty and Zielony Lasek or the smithy in Boże,
– Catholic, Evangelical and Orthodox churches (e.g. the former synagogue in Mrągowo),
– cemeteries, eg. in Mrągowo, Szestno, Krzywe, Gizewa, and Zełwągi,
– monuments.

The museums, memorial chambers or galleries are also worth visiting. In the county of Mrągowo there are the remains of the heritage of Prussian tribes

such as gords (e.g. Boże, Kiersztanowo, Wyszembork, Sorkwity), kurgans (e.g. in Sorkwity, Warpuny, Stary Gieląd), embankments (e.g. Lemburk, Boże) and sacrificial stones (e.g. Devil Stone in Słowiczy Wąwóz).

During their stay, tourists may participate in cyclic or occasional cultural events, such as Masurian Night of Cabarets, The Festival of Borderland Culture, Mikołajki Days, Pieckowiada, The Festival of Shanties and other national, regional and local events. Some of these attractions are recognized as The Best Tourist Products or Services: Country Picnic and the Mrongoville Western Town, rafting in an old-masurian boat along the Krutynia River or the all-year sport center "Góra Czterech Wiatrów". The town of Mrągowo was honored with the certificate "Mrągowo: a town of festivals". The attractiveness of the region is further enhanced by events that promote the cultural heritage such as the Regional Festival of Pork, Beef, Lamb and Goat Meat Dishes, the Pork Knuckle Festival and The Baked Potato Festival.

The well-developed road infrastructure and potentially good train network are the advantages of the county of Mrągowo. Two major communication routes run across the territory of the county from west to east:

– national road No 16 (Grudziądz – Olsztyn – Mrągowo – Mikołajki – Ełk – Augustów),

– train network Olsztyn – Mrągowo – Mikołajki – Ełk.

In addition, there are numerous communication routes in a north-south arrangement with the following being the most important:

– road No 602/601 Mrągowo – Piecki – Szczytno – Pułtusk
– road No 591 Mrągowo – Kętrzyn,
– road No 610 Mrągowo – Piecki – Ruciane Nida,
– road No 600 Mrągowo – Rybno – Szczytno,
– road No 642 Mikołajki – Ryn,
– road No 608 Mrągowo – Ryn – Giżycko.

The sailing route of The Great Masurian Lakes (Węgorzewo – Pisz) whose central part runs across the territory of the county (the district of Mikołajki) plays an important role. However, the poor technical condition of roads which are not adapted to heavy traffic may create some transportation and communication problems.

The county of Mrągowo is the leader in the number of accommodation places in the province of Warmia and Mazury and outdistances Olsztyn, the capital of the region (*Turystyka*... 2010, *Regionalny Program*... 2007, *Strategia rozwoju*... 2008, *Strategia rozwoju turystyki*... 2010). It confirms the excellent potential for development of tourism and agritourism.

An analysis of tourist group accommodation facilities indicates that national and foreign tourists who visited Warmia and Mazury in 2009 most often chose lodgings situated in Mrągowo, Olsztyn, Giżycko and Ostróda.

The highest number of accommodation places was provided for tourists in the counties of Mrągowo, Giżycko, Ostóda and in Olsztyn (*Turystyka*... 2010).

The rural areas in the county provide mainly seasonal lodgings. The small percentage of year-round facilities in rural communes significantly limits the tourist offer and further contributes to a seasonal effect of tourist flow on industrial activities in some towns in the county. The tourist flow in the county centers around the district of Mikołajki (app. 68% of the total tourist flow), which is undoubtedly a tourist center on a regional and even national scale. Mrągowo has a special place (app. 23% of total tourist flow) since it is a starting point for sightseeing trips and it attracts tourists with its cultural and social events organized on a national and international scale. About 70% of visitors stay in the county from June to September with the peak of tourist flow in July and August (*Strategia rozwoju*... 2008).

The development of tourism is associated with business entities that provide accommodation places and short-term lodgings and run restaurants, bistros, canteens and catering services. As far as the number of gastronomic companies is concerned, the county of Mrągowo is fourth after Olsztyn, Elbląg and the county of Olsztyn. The territorial distribution of business entities categorized as hotels and restaurants reveals that the county of Mrągowo is overtaken only by the biggest cities of the region, i.e. Olsztyn and Elbląg (*Turystyka*... 2010).

The strategic supralocal documents (*Warmia i* Mazury 2020...2010, *Strategia rozwoju*... 2010) enumerate the county of Mrągowo, in particular its towns, as the developmental tourist centers on supra-regional scale. The territory of the county has been defined as an area with the best management practices and the highest attractiveness and concentration of the tourist industry.

Conclusion

The basic developmental potential of the county is associated with its geographical location and natural features. The location of the county on unique tourist and recreational areas, situated near big urban complexes, determines to a large extent the current and future directions of development and creates the possibility to support local industry with a tourism sector that has recently grown very dynamically. The abundance of lakes (over 12% of the area), 30% forestation and expanded recreational infrastructure (third place in the province of Warmia and Mazury) create excellent conditions for many types of tourism and a solid foundation for the development of sustainable tourism.

The most important tourist values that determine further development of tourism in the county include:

– location in the heart of the region which is one of the most attractive tourist locations in Europe (forests, lakes, Krutynia River, the sailing route along The Great Masurian Lakes, landscape, nature),

– the possibility to participate in different forms of tourism, including active and natural as well as the so-called conference tourism, based on the natural resources of the region,

– interesting architectural, cultural and historical monuments of the region,

– location in the region with multinational and diverse culture and turbulent history,

– relatively short distance from Warsaw (app. 3 hours by car),

– the existing tourist base, offering different standards and functions,

– convenient conditions for the development of "ecological" agriculture to supply demand which exceeds the local market.

The tourist potential of the county of Mrągowo involves many market sectors which, according to World Tourism Organization, will play an important role in tourism (BARTOSZEWICZ and ŁOPACIŃSKI 2007). They include:

– natural tourism,

– cultural tourism,

– tourism in rural areas,

– well-being tourism.

Tourism in lakeland regions, which mainly comprise rural areas, supports the development of non-agricultural ventures, the restructuring of agriculture and improvement of living conditions of local communities through generating additional income. The existing natural and cultural resources and expanded infrastructure promote the development of sustainable tourism in the county of Mrągowo.

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SPATIAL DIFFERENTIATION OF TOURIST INFRASTRUCTURE IN THE RIPARIAN ZONE OF THE BIAŁE LAKE (MIDDLE-EAST POLAND)

***Renata Krukowska*[1], *Mirosław Krukowski*[2]**

[1] Department of Regional Geography and Tourism
[2] Department of Cartography and Geomatics
Maria Curie-Skłodowska University in Lublin

K e y w o r d s: tourist infrastructure, land use, cartographic modelling.

A b s t r a c t

The aim of this study is to analyze the degree of impact of different forms of tourist infrastructure on the natural environment of the riparian zone of Białe Lake. The spatial variation of the index of impact on environment was calculated (MIKA 2004, FURGAŁA et al. 2010) depending on the distance from the shoreline. The analysis was carried out in fixed minimal mapping units and in the buffer zones with segmentation based on shoreline type criterion and distance from the lake.

ZRÓŻNICOWANIE PRZESTRZENNE ZAGOSPODAROWANIA TURYSTYCZNEGO STREFY BRZEGOWEJ JEZIORA BIAŁEGO (POLSKA ŚRODKOWO-WSCHODNIA)

***Renata Krukowska*[1], *Mirosław Krukowski*[2]**

[1] Zakład Geografii Regionalnej i Turyzmu
[2] Zakład Kartografii i Geomatyki
Uniwersytet Marii Curie-Skłodowskiej w Lublinie

S ł o w a k l u c z o w e: infrastruktura turystyczna, użytkowanie ziemi, modelowanie kartograficzne.

A b s t r a k t

Celem pracy jest analiza stopnia oddziaływania różnych form zagospodarowania turystycznego na środowisko przyrodnicze strefy brzegowej Jeziora Białego. Określono przestrzenne zróżnicowanie wskaźnika obciążenia środowiska przyrodniczego (MIKA 2004, FURGAŁA i in. 2010) w zależności od odległości od linii brzegowej. Analizę przeprowadzono w polach podstawowych jednakowej wielkości oraz w strefach buforowych posegmentowanych według kryterium typu użytkowania linii brzegowej i odległości od jeziora.

Address: Renata Krukowska, Maria Curie-Skłodowska University, al. Kraśnicka 2cd, 20-718 Lublin, phone: +48 (81) 537 68 52, e-mail: renata.krukowska@umcs.pl

Introduction

Waters and their shore zones are attractive element and play an important role in recreation and holidays. They are one of the most valuable tourism attractions because of their vivid natural landscape and high quality environment (HALL and HÄRKÖNEN 2006, BAHAR and KOZAK 2008). Besides coastal tourism, a large number of lake and wetland destinations can be found worldwide. Most of those lakes destinations are very different in terms of morphology, climate and so on. However, they show also various similarities concerning their characteristics, development potentials and the threats they are exposed to, including those caused by tourism (GATTENLÖHNER 2006).

One of the major causes of the degeneration of environment is unplanned and unchecked developmental activities in the tourist destinations. Tourism also results in disorderly and scattered tourist facilities which generally are not eco-friendly and that leads to aesthetic degradation of the landscape (SHRUTI 2010). Successful tourism development depends on a proper balance of the use of environmental resources and the negative environmental effects tourism might cause to the environment and nature (GATTENLÖHNER 2006).

The Łęczyńsko-Włodawskie Lake District is the only group of lakes in Poland located beyond the extent of the ice sheet in the last glacial period. The Lake District is one of the most important tourist areas in mid-eastern Poland. An analysis of tourist attractiveness of the Łęczyńsko-Włodawskie Lake District shows that area of Białe Lake is classified in the highest attractiveness degree (KRUKOWSKA and KRUKOWSKI 2009).

Białe Lake covers an area of over 106 ha (it is 1616 m long and 806 m wide), and its maximum depth is 33.6 m. With the highest average depth (14.1 m) Białe Lake is the most capacious reservoir of the area. Its waters are classified as first class of water quality – "water for human consumption". The Lake's basin is formed on the chalk. Development of riparian vegetation in the Białe Lake is minimal; grater agglomerations of reed beds which primarily consist of Lesser Bulrush (*Typha angustifolia*) and Common reed (*Phragmites australis*) are formed only in the north-western and western parts of the lake. In other parts there are only small parts of reed beds. In lacustrine zone there are mainly beaches and meadows. From the south, to surrounding road, is adjacent forest complex of the Sobiborski Landscape Park.

Main aim of this study is to analyse the degree of impact of different forms of tourist infrastructure (facilities) on the natural environment of the riparian zone of Białe Lake. The spatial variation of environmental impact (MIKA 2004, FURGAŁA-SELEZNIOW et al. 2011) was determined depending on the distance from the shoreline. The analysis was carried out in buffer zones segmented by type of use the criterion of the shoreline and in hexagon mapping units.

Materials and Methods

The previously conducted research on landscape changes in the recreation area of Białe Lake (KRUKOWSKA et al. 2010) have shown a correlation between the changes the landscape of the analysed area, and an increasing tourist function. Transforming the landscape was characterized by a very dynamic growth of tourism development area, especially in the immediate vicinity of the lakes. In the years of 1980–2005 the built-up area occupied by accommodation increased by about 90%, and the area of recreational plots (summer houses) by about almost 1360%.

At present, the area around the lake is almost entirely developed for tourism and recreation. There are 101 accommodation facilities offering 7200 beds and about 1200 recreational plots with reception capacity for 5300 people. On the northern shore of the lake, a shopping centre with numerous catering and entertainment facilities and shops has developed (KRUKOWSKA et al. 2010)

In connection with such a large tourist pressure studies were undertaken on the differentiation of forms of tourist infrastructure of the Białe Lake and its use by selected forms of tourism and recreational activities. The basis for its determination was to separate areas with different forms of tourist use: tourist settlement, active recreation areas and other recreational areas. In order to determine the extent of their impact on the environment three different values of valuation were assigned (Table 1). The index of tourism infrastructure impact on lake' shoreline environment was used as proposed by MIKA (2004) and modified by FURGAŁA-SELEZNIOW et al. (2011). The index was calculated using the formula (MIKA 2004):

$$K = \frac{\Sigma P_i \cdot B_i}{P_o},$$

where:
K – index of tourism infrastructure impact on lake' shoreline environment;
P_i – area under different types of tourist use;
B_i – valuation score;
P_o – reference unit area.

In adopted method, the numerical ratio allows to classify the degree of environmental impact in the three-scale (Table 2).

Analyses were carried out in two types of mapping units:

1. Buffer zones designated every 100 meters from the shoreline to a distance of 1 km. In addition, every buffer zone area is divided into sectors, which are determined by criteria type of land use of the shoreline (beach, grassy area with access to water, grassy area with no access to water (reeds), grassy wetland area).

2. Fixed hexagon shaped units of 50 acres, covering area about 1 km around the lake. Geometric fields of the same size allow for comparability of results in terms of spatial analysis.

In all fields designated this way areas occupied by the different forms of tourist infrastructure were identified. Analyses were carried out in an ArcGIS 10 (ESRI) on the base of aerial photographs (available on the website www.geoportal.gov.pl), cadastral maps and stocktaking.

Table 1

Form of tourist use of shoreline zone and valuation of its impact on natural environment

Form of tourist use	Symbol (P_i) and type of area	Kind of impact	Valuation symbol (B_i) and score
Tourist settlement	P_1 – technogenic areas under permanent tourist use	permanent transformation of land use, denaturalization of environment, noise, litter, vehicles pollutions, wastewater and sewage	$B_2 = 5$
Active recreation areas	P_2 – beaches, marinas, water equipment rentals, piers, sports grounds, playgrounds, ground car parks, catering facilities	trampling and mechanical damage of plants, erosion of shores, litter, pollution of lakeshores, water turbidity and pollution, noise	$B_2 = 4$
	P_3 – tent fields, camp sites, bicycle trails	destruction of plants and soil cover, noise, litter, vehicles pollutions, wastewater and sewage	$B_3 = 3$
	P_4 – hiking trails, angling piers and sites	trampling and mechanical damage of plants, pollution, soil erosion, water turbidity and pollution	$B_4 = 2$
Other recreational areas	P_5 – recreational plots, green areas around tourist facilities, green areas around villages	Change to the type of use of green areas, noise, litter, wastewater and sewage	$B_5 = 1$

Source: according to FURGAŁA-SELEZNIOW et al. (2011), MIKA (2004)

Table 2

The ranges of index of tourism infrastructure impact on lake' shoreline environment

Class	Impact	Range of K value
I	significant	> 0.1
II	moderate	0.1–0.01
III	small	<0.01

Source: MIKA (2004)

Results and Discussion

The study led to the designation of 7 sectors (1S-7S) associated with a different type of the shoreline. Among these there were identified: three sectors of dominance beaches and occasional occurrence of grassy banks and aquatic vegetation (1S, 2S, 7S), two grassland areas with access to water and an occasional occurrence of rushes (3S, 6S), one sector of grassy banks with difficult access to water and beach (4S), and one sector of wetlands and grasslands rushes (5S) – Figure 1).

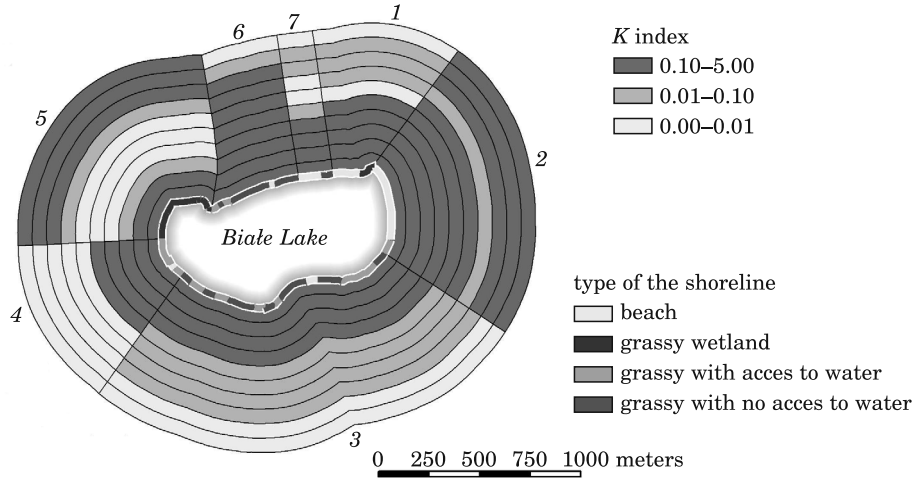

Fig. 1. Index of tourism infrastructure impact on lake' shoreline environment in sectors and buffer zones

The value of K index for the area around the lake (buffer zone 1 km) is 0.803 – that means that the impact on lake' shoreline environment is in the highest level – "significant". The lowest rate of $K = 0.082$ determined for S5 (difficult access to water), which corresponds to the "moderate" impact of tourist infrastructure. This zone covers an area of wet meadows adjacent to the lake from the NW (Table 3).

Other sectors have a "significant" level of the impact on the lake's shoreline environment and achieve values from 0.774 (S4) to 1.237 (S2). It can be seen that the values of K index are related to the type of shoreline. The highest values are associated with designated sectors of shoreline with beaches domination (S1 – 0.939, S2 – 1.237, S7 – 0.915), followed by grassland area with good access to water (S3 – 0.781, S6 – 0.891) and area of grasslands with difficult access to water (S4 – 0.774).

Table 3

K index values calculated for sectors and buffer zones

Buffer zone	*K* indeks							
	zone	sector 1	sector 2	sector 3	sector 4	sector 5	sector 6	sector 7
100	3.401	4.171	4.720	3.894	2.428	0.004	4.582	4.006
200	2.465	3.307	3.752	2.904	3.283	0.002	1.331	2.673
300	0.985	1.338	1.741	0.666	1.249	0.001	0.651	1.246
400	0.502	0.312	1.093	0.153	0.448	0.000	0.363	1.144
500	0.187	0.118	0.455	0.062	0.329	0.000	0.306	0.041
600	0.069	0.004	0.166	0.052	0.003	0.000	0.256	0.000
700	0.123	0.054	0.087	0.060	0.000	0.013	0.646	0.000
800	0.180	0.060	0.120	0.018	0.000	0.353	0.690	0.015
900	0.077	0.020	0.107	0.000	0.000	0.303	0.085	0.024
1000	0.039	0.000	0.131	0.001	0.000	0.138	0.000	0.001
Average	0.803	0.938	1.237	0.781	0.774	0.081	0.891	0.915

An important element of the studies is an analysis of the degree of tourist infrastructure impact on the environment in 100 m wide buffer zones. In this case, only the area covered by 900 and 1000 meters buffer zones (which reached *K* values, respectively 0.077 and 0.039), are classified in the second class degree of environmental impact ("moderate"). The highest level of environmental impact is associated with zones located in the nearest 100 and 200 m from the shoreline. *K* index in 100 m buffer distance was 3.401, and in the zone 200 m – 2.465 (Table 3).

As shown in Figure 1 the degree of environmental impact of tourist infrastructure decreases with the distance from the shoreline of the lake. K index reached the highest value in the zone 100 m in the sector S2 (4.720). Very high levels are also associated with sectors: S6 (4.582), S1 (4.170), S7 (4.005), S3 (3.893). The lowest value of *K* index in 100 m zone was observed in S5 (0.005) – Table 3.

By analyzing the spatial distribution of the index *K* calculated for each sector and distance zones it can be seen that the rate of environmental impact of tourist infrastructure is fitting-radial distribution (centric), with its value decreasing with the distance from the shoreline.

A steady decline of *K* index value is especially marked for a distance of 500 m from the lake (Figure 2). Apart from this buffer distance the environmental impact of tourist infrastructure remains at the same level of slightly declining trend. On this background, two extreme cases can be described. First, for the shoreline with difficult access to the shore (S5) – the rate is relatively low (as for the study area) to a distance of 700 m, where it can be marked by slight

growth, resulting from the existence of the buildings of Okuninka village. On the other hand, we have cases of S6 and S2 sectors, with high availability and a favorable shoreline relaxation – here there are the intensive development of 800 meters and beyond.

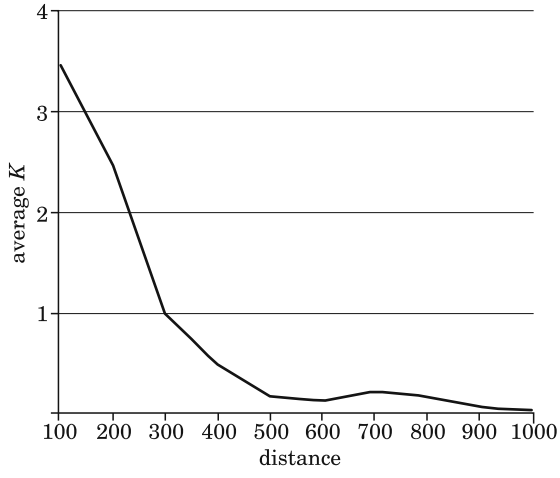

Fig. 2. Relations between average *K* index and distance from lake shoreline

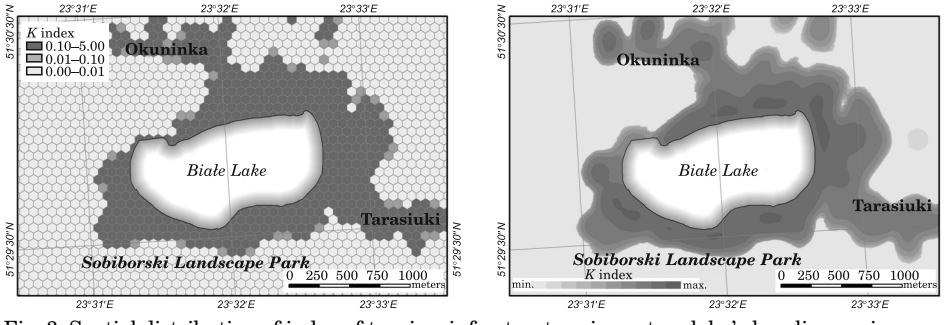

Fig. 3. Spatial distribution of index of tourism infrastructure impact on lake' shoreline environment in minimal mapping units (hexagons) – left; Local trends in the spatial distribution of Index *K* (isopleth map) – right

Such an arrangement of tourist infrastructure is the result of the existence of the village Okuninka built at some distance from the lake, and above all, build the road surrounding the lake. This road strongly determines the radial spread of the tourist infrastructure. The only one limitation (barrier) is the area of the Sobiborski Landscape Park, which covers the area of wetland forests, located south of the lake.

The above analysis were also carried out in other mapping units – 50 acres hexagons. On that base the map of detailed spatial variation of index

of tourism infrastructure impact on lake' shoreline environment was prepared (Figure 3). The area of the highest values of *K* index can be designated – it extends along the build-up area of Okuninka and Tarasiuki villages. As a result of further analysis an isopleth map was obtained (Figure 3) that shows the spatial distribution of the local tendency of tourist infrastructure impact.

Conclusions

One of the major causes of the degeneration of environment in areas near lakes is unplanned and unchecked development of tourist facilities. These infrastructure is often created near or on the banks of a lakes.

The example of Białe Lake gives an overview of the effects of uncontrolled land development. Intensive infrastructure development near the shoreline on the one side has a negative effect on landscape aesthetics, on the other hand – it decreases the availability of this zone for other tourists. This leads to the overpopulation of certain areas. The negative situation was additionally intensified by existing of the road encompassing the lake near the shoreline, which resulted in development of tide ring of infrastructure.

In conclusion it should be noted that the nature of the Białe Lake and its shoreline has caused (not often found) intensity of tourist infrastructure development. That's why we can talk about almost extreme anthropogenic influence of the lake and the resulting environmental hazards. It should be kept in mind that agglomerations of tourism infrastructure are a threat to the local ecological systems. It's mainly because of waste, sewage waters, emission of CFC, CO2 and other greenhouse gases, which are often a serious problem in most of the tourist destinations all over the world.

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SUSTAINABLE MANAGEMENT OF LAKES TAKING INTO CONSIDERATION THE TOURISM AND NATURE CONSERVATION IN AUSTRALIA AND NEW ZELAND

Małgorzata Kurleto

Department of Management in Tourism
Jagiellonian University in Cracow

K e y w o r d s: tourism lakes, sustainable development, comprehensive management.

A b s t r a c t

The paper attempts to present the issue of sustainable development of tourism lakes on the example of New Zealand, classified as world leaders in the field of tourism use of the lakes, and Australia featuring a variety of interesting use of the lakes, not only from tourism. point of view. The study is trying to focus on particular attention to the negative effects posed by the development of tourism in the lakes. The analysis has also been an attempt to show the strategy to counteract these negative effects and tested strategies for the comprehensive management of lakes in the economy with particular emphasis on tourism. This paper is trying to demonstrate the use of zoning strategies of tourism and "Triple Bottom Line" strategies for managing tourism in Australia and the specificity of the "Living Lake" project in New Zealand. This analysis would like to also find links entrepreneurial activity in understanding the dynamics of the tourist economy and protection scales of the lake ecosystems. Understanding the relevant processes of tourism lakes is essential to a better understanding and future planning of the economy of lakes. Despite the diversity of tourism lakes issues relating to its geographical location and their specificity in Australia and New Zealand seem to look for similarities on both the use of lakes and the threats posed by the development of tourist enterprises.

ZRÓWNOWAŻONE GOSPODAROWANIE JEZIORAMI ZE SZCZEGÓLNYM UWZGLĘDNIENIEM TURYSTYKI I OCHRONY PRZYRODY W AUSTRALII I W NOWEJ ZELANDII

Małgorzata Kurleto

Katedra Zarządzania w Turystyce
Uniwersytet Jagielloński

S ł o w a k l u c z o w e: turystyka jezior, zrównoważony rozwój, kompleksowe zarządzanie.

Address: Małgorzata Kurleto, Jagiellonian University, 30-304 Cracow, Poland, ul. Łojasiewicza 4, phone: (12) 664 55 78, e-mail: m.kurleto@uj.edu.pl

Abstrakt

W opracowaniu przedstawiono problematykę zrównoważonego rozwoju turystyki jezior na przykładzie Nowej Zelandii, zaliczanej do światowej czołówki w zakresie turystycznego ich wykorzystania i Australii cechującej się ciekawą różnorodnością wykorzystania jezior nie tylko z turystycznego punktu widzenia. Ze szczególną uwagą zanalizowano skutki negatywne, które niesie rozwój turystyki dla jezior. Podjęto także próbę ukazania strategii przeciwdziałania im i poddano badaniu strategie kompleksowego zarządzania gospodarką jezior ze szczególnym uwzględnieniem turystyki. W analizie starano się zaprezentować wykorzystanie strategii strefowania turystyki i strategii *Triple Bottom Line* w zarządzaniu turystyką w Australii i specyfikę stosowania programu *Living Lake* w Nowej Zelandii. Autorka szukała powiązań działalności przedsiębiorczości turystycznej ze zrozumieniem dynamiki gospodarki jezior i ochroną jej ekosystemów w różnych skalach. Zrozumienie istotnych procesów turystyki jezior jest niezbędne do lepszego zrozumienia i przyszłego planowania gospodarowania jeziorami. Pomimo różnorodności problematyki turystyki jezior związanej z geograficznym położeniem i ich specyfiką w Australii i w Nowej Zelandii, jak się wydaje należy szukać podobieństw zarówno w zakresie wykorzystania jezior, jak i w zagrożeniach związanych z rozwojem przedsięwzięć turystycznych.

Introduction

Lakes are the potential of interest to tourism. Understanding the relevant processes of lake tourism is essential to a better future planning of inland water resources management. For many years, experts in aspects of the environmental protection and water supply issues are trying to solve the problems of sustainable tourism and protection of lake ecosystems in the joint international conferences, such as the International Lake Environment Committee (ILEC). Strong interest in this type of conferences (previously held in Argentina, China, Denmark, Hungary, India, Italy, Japan, Kenya, and USA) proves that even the most remote geographical location are no barrier in the common search for solutions to the building optimal methods and conditions for lake tourism development.

This paper is attempting to present the issues of sustainable development of lake tourism on the example of New Zealand, classified as world leaders (COOPER 2006) in terms of their tourist use (such as Lake Taupo and Lake Wanaka) and on the example of Australia, which is characterized by an interesting variety of freshwater and saltwater lakes, used not only for tourism (Lake Eyre), but also to gain power (Lake Pedder), or other highly profitable projects (Lake Eildon). Sustainable economic development is the ongoing challenge of lakes in which water resource management and tourism projects should strive for closer cooperation in order to understand and protect the ecosystems of lakes both in local and global levels. This paper attempts to analyse the use of lakes, both in terms of the benefits of tourism, and from the threats it brings to ecosystems, especially in the degradation of biological diversity.

This analysis is trying to approach strategies to counteract the negative effects of tourism, taking into account: the so-called Comprehensive (Integrated) Lake Tourism Management, the so-called Planning of "Tourist Zoning" (*Zoning schemes* 2010) and very popular (recently in Europe) project of Living Lakes (*Eastern european network* 2006).

The analysis would like to provide examples of sustainable lake tourism management that benefit both tourists and local people, and above all for the environment – that is, taking into account the use of so-called strategy: Triple Bottom Line (*Sustainable recreation...* 2002) using a variety of issues associated with its geographical location of lakes and their specific case.

The economic use of the lakes

The lakes play an important role in sustainable water management challenges, which communities face today to unequal access of fresh water. Lakes also supports a number of human activities, including agriculture, commerce, transport, sport & recreation, tourism, food production and electricity supply. Lakes are often home to a variety of unique animal and plant organisms so important is biological regeneration of their areas.

The district of lakes, in particular areas close to lake shores, are important for urban land development. Lakes can be the reservoirs of drinking water also occupy an important place in fisheries management. The issues mentioned above should be regulated in accordance with the guidelines of the United Nations (*Making tourism...* 2005).

Lakes also form a microclimate, provide flood protection, are habitat for biodiversity, and are complementary to the groundwater. Microclimate of the lake area is beneficial to man, when the lake water level is maintained (COOPER 2006).

The existing empirical studies show that in lake tourism can be distinguished 53 different activities, which are described in the literature, as well as in newspapers and advertising materials of tour operators. All activities are taken in consideration in the development of tourism enterprises (TIKKANEN 2003, GROMADA and LORANT 2009).

Usefulness of lakes for tourism is examined from the perspective of leisure tourism, sightseeing and specialized tourism (MIRSANJARII 2007).

Lakes around the world are used for eco-tourism, recreational tourism, sports, conference (business) and usually attracts millions of tourists. Lakes can significantly contribute to the socio-economic development of the site (TIKKANEN 2003).

The threats of tourism to the ecosystem of lakes

The tourism industry is closely related to environmental protection. Rapidly developing patterns of modern travel and tourism has led to intense exploitation of natural resources. Tourism has caused negative impact on the ecosystem of lakes (MIRSANJARII 2009). It forced the local authorities for the conservation of the environment not just the lakes, but also their surroundings, especially in building tourist facilities. In addition, intense tourist activity in a limited space of environment-sensitive lakes brings a lot of negative effects. Some lakes are located in geologically unstable areas. Large areas are subject to settling and soil creep, which negatively affects the entire ecosystem. There are also other risks, mainly related to wastewater discharges from local villages, hotels and lodges. Lack of applicable laws, poor infrastructure, environmental protection and the growing tourism activities usually lead to adverse consequences for the natural reservoir of freshwater. One characteristic of lake tourism is a high degree of seasonality. This is true particularly for the sensitive ecosystem of lakes located at high altitude, as well as for lakes located in wetlands. Often visitor access to these lakes is limited to summer months, which are also the peak period of biological activity for the local fauna. Camps and activities of tourists is a threat to birds, especially when it concerns their nesting sites (RANADE 2007).

Another serious problem adversely affecting the environment is linked to increased traffic on the roads around the lake during the peak tourist season.

The effects of the negative impact of tourism on the natural environment of lakes are dependent on biodiversity and abundance of flora and fauna located in the area. Environmental pollution, as well as the introduction of foreign animal and plant species pose the greatest threat to biological diversity of the lakes.

Situation resulting from over-exploitation of wetland resources, pollution caused by fuel and plant protection products degrades water quality and pose a serious threat to the surrounding flora and fauna (SPIRES 1996). These problems stem largely from the impact of human activities. Water tourism and recreational activity is a threat to the most environmentally sensitive lakes. An increasing number of motorized boats and jet skis, especially when not governed by any legislation that imposes additional fuel pollution of lake water, both in the case of accidental spills, and as a result of deliberate discharges of waste oil into the lake.

These pollutants are a deadly threat to many aquatic animals and plants. In addition, noise and action of the waves generated by a turbine engine boats can damage the edges of lakes, and after some time it can lead to irreversible damage to their micro-ecology (*Community strategy*... 2004).

The increase in the large number of tourists leads to chaotic development of tourism infrastructure. Often intense tourist development is not integrated into the surroundings. The beauty of the landscape is changing so rapidly. Open spaces often are turned into car parks, recreational areas and golf courses (FINLAYSON et al. 1998).

But the greatest damage to the tourism economy of lakes occur in cases where their water resources are used for water transport, the supply of drinking water, for hydroelectric power, the economic intensive fishing, for the controlled release of flood, or the construction of irrigation systems (RANADE 2007).It seems that the particular interest in the subject matter deserves, should be given for the protection of biodiversity resources of the lakes. The fresh water biological diversity is declining faster than terrestrial ecosystems.

Although fresh water is only 0.01% of the stocks in the world and covers only 0.8% of the Earth, yet this small amount of water is used by at least 100,000 species of flora and fauna – for this reason, natural freshwater biodiversity is covered by international protection (UN Resolution 58/217 of 23 December 2003, "Water for Life"). If there would be no international protection of aquatic ecosystems (assuming that the trends in human consumption of water and its use of business and tourism remain the same) than a significant amount of remaining biodiversity living in fresh water would perish in a relatively short time. Threat to global freshwater biodiversity loss are available in five categories (DUDGEON et al. 2006):

– over-exploitation of the lakes,
– water pollution,
– the problem of water flow and its modifications,
– the destruction or degradation of habitat flora & fauna,
– introduction of alien species of exotic flora and fauna.

The total accumulation of these risks and their interactions affect the rate of biodiversity loss worldwide. In the literature on environmental protection there is a consistent view (ANIGACZ and ZAKOWICZ 2003) that nowadays there are following major sources of pollution of lakes, located near the living settlements of people: urban waste water (containing such detergents, pathogenic micro-organisms) and industrial (including salts of heavy metals, sulphur and nitrogen compounds). As a result of agricultural activities to surface of waters can get (used to excess) organic fertilizers and improperly applied pesticides. Extractive industry (including mining) discharge into groundwater very large amounts of highly saline wastewater (ANIGACZ and ZAKOWICZ 2003).

Sustainable development and management of lakes

Sustainable development has become of great importance at many different levels of management (ranging from international to local). Tourist companies and so-called tourist destinations are also to play a significant role in the achievement of sustainable forms of tourism in the innovation system (MISANJARII 2007).

– Management of lakes includes (HALL and HÄRKÖNEN 2006):
– setting the timing of phases of tourism,
– dividing the lake into zones,
– introduction of rules relating to the use of lakes,
– planning and management based on social needs,
– planning regulations related to sustainable use and protection of lakes.

Lake tourism managers must take into account the differences in the perception of the same issues by different groups of stakeholders (especially environmentalists and people connected with tourism ventures).

It is necessary also to complete the integrated management, which seeks to focus on securing a total of: (HALL and HÄRKÖNEN 2006) collective, educational, economic, environmental, recreational and cultural issues.

Integrated management of the lakes may have three interpretations (MITCHELL and BRUCE 1990):

– systematic management of the different sizes of lake water, surface water and groundwater, taking into account their quantity and quality,

– management of the lakes along with other water systems (rivers or the sea bordering the lake), and together with the terrestrial environment,

– management of lakes, including the interaction with the social and economic environment, which constitute the so-called. Environmental Approach Sustainable Development.

In light of the legal act issued in Australia, *Sustainable tourism...* 2002 in the management of tourism policy should be considered concept the so-called. Triple Bottom Line, (Concept of 3 P: *People, Planet and Profit* succinctly describes the Triple Bottom Lines and the goal of sustainability – ELKINGTON 1997) which include:

– protection of fair and beneficial business practices of the local community,

– protection of lake tourism,

– protection of biological diversity and maintaining ecological processes.

Released in Australia on 11 of October 2011 – The Act On Sustainable Tourism Policy (*Natural Resources...* 2011) also mentions the so-called Tourism Zoning Plan, which should be harmonized with the natural circumstances, so that tourism does not bring negative impact on the environment.

Plan of Tourism Zoning is based on the indexing of nature (including the conservation status of species and wildlife habitats) to determine their sensitivity on various forms and types of tourism activity (Eastern European network, Program *Living lakes* 2006).

Lakes tourism in Australia

Australian continent is rich in lakes. It is estimated that the total area of lakes and wetlands is about 81,000 square kilometres, of which nearly 20,000 square kilometres of lakes and wetlands is situated in Kakadu National Park (*A directory*... 2001). Within Australia there are glacial lakes, volcanic, coastal lakes and seasonal reservoirs. The largest freshwater lake Mackay with an area of 4737 square kilometres is located on the border between Western Australia and Northern Territory (1/3 of the surface), which is managed by the Lake Mackay Aboriginal Land Trust. The saltwater lake Eyre with an area of 4176 square kilometres is located in South Australia (*Australia's ramsar*... 2010).

Australian legislation concerning the regulation distinguishes the following types of lakes:

– constantly freshwater lake with an area of more than 8 hectares, including rivers and lakes of the arcs,

– seasonal freshwater lake with an area of more than 8 hectares,

– constant salt lakes,

– seasonal salt lakes.

Analysing the water environment in Australia, refer to the two key themes:

– How important are water ecosystems for tourism in Australia?

– What is the impact of tourism (if we believe that it exists at all) on aquatic ecosystems?

In the context of these two topics are organized in Australia conferences every two years, in order to exchange information on the review of the ecological status of lakes and water policy plan: annual, five-yearly and ten-yearly. Established at the government level specially Forum of Ministers (in the squad, which includes the ministers of all the economic ministries) established a "Joint Advisory Committee", whose aim was to provide continuous support in developing regional water policy decisions, including tourism lake (HADWEN et al. 2006).Forum of Ministers set up the "Scientific Advisory Committee", whose job was giving opinions scientific and technical matters relating to the sustainable management of lakes (HADWEN et al. 2006). A study conducted by experts, "Scientific Advisory Committee", generally acknowledged that: 1) despite dynamic development of the tourism industry in

Australia, the section on lake tourism has a relatively small proportion of total tourism. 2) influence of tourism on ecosystems in Australia is relatively small in comparison to other large ecosystems in the world, many of which are threatened by unsustainable water extraction, urbanization, and problems related to water quality and modifying its flow by dams, weirs and other accumulation of water (*Integrated water*... 2009).

The above-cited opinion it is questionable if one takes into account the ecological destruction caused by the construction of hydroelectric and damming the water at Lake Pedder in Tasmania. Example of Lake Pedder deserves special attention because it concerns not only the destruction of the environment of the lake, but the fight for its survival. Although the new Lake Pedder (with an area of 242 square kilometres) was established in 1972 as a result of the initial flooding of the lake of the same name, it does not like it before, neither biologically, nor the size or appearance (Lake pedder 2012).

A newly formed lake was connected to the canal from Lake Gordon and together create a large artificial reservoir hydroelectric power. The present Lake Pedder was the accumulation of water, resulting in construct three dams: Edgar with a height of 17 m, Scotts Peak – 43 m, Serpentine – 38 m, which had plans to meet the reserve tank for the hydro Gordon Power Station (Lake pedder 2012).

The protests in Tasmania and mainland Australia and around the world, referring to the primary reservoir of the lake, took place not only before the construction of hydroelectric power, but as well during construction and after commissioning the dam and hydroelectric power for use. These protests have already started in the stage of planning the creation of the hydroelectric power plant on Lake Pedder, which was approved in 1972 (McKenry 1972).

Opposition to the flooding of Lake Pedder, located in the so-called protected area the world's cultural heritage, caused its inclusion, in 1982, on the UNESCO heritage list (in the hope that it will be rebuilt the biological environment of the lake). Concern about the construction of the dam was caused by the threat of losing its unique flora and fauna. During the flooding of Lake Pedder lived in this lake seventeen endemic species of plants and animals. Flooding of the lake, destroying the original biological ecosystem. Since 2003, Lake Pedder is recognized as endangered ecological. Animal species living in this lake are on the Red List of IUCN (International Union for Conservation of Nature), as a species highly vulnerable to extinction (McKenry 1972). Special protection (under state law Threatened Species Protection Act 1995 and the Federal Biodiversity and Conservation Federal Protection Act 1999) include such endemic fish species Pedder Galaxias (*Galaxias pedderensis*) and Swamp Galaxias (*Galaxias parvus*). Currently, Gordon hydroelectric power management taken several initiatives for the sustainable development of both lakes: Gordon and Pedder.

As an example of integrated management of lakes in Australia is indicated in the Australian Government Documents (*Integrated water*... 2009) – Lake Eyre – largest saltwater lake in Australia, on which, in the third millennium, agreement was concluded between the state governments of South Australia, Queensland and the water company Lake Eyre Basin. This agreement covers the sustainable management of natural water resources related to the basin of Lake Eyre. The agreement contains the arrangements for resource management principles of the lake and associated values: environmental, economic and social. The agreement also includes the jointly accepted principles relating to eco-tourism as well taking into account the knowledge and experience of local communities. It should be emphasized that the Lake Eyre is certainly an unusual example, because the lowest part of the lake in Australia (about 15 m below sea level), in the desert. Lake Eyre was only 3 times in the last century (as a result of heavy rainfall) completely filled with water. It happens that during the dry season the lake is completely dry (*Integrated water*... 2009).

Managing water area of Lake Eyre, seems to be more focused on sustainable development and taking more preventive measures than in the cases of other lakes in Australia, although they certainly deserve in-depth discussion in a separate analysis.

An interesting example of the tourist use of permanent inland water in Australia could be Lake Eildon in Victoria, which for many years has been a place of rest and a haven for a large fleet of boats.

Lake Eildon is famous for its privileges for good conditions for water sports because of the large surface area (166 square kilometres) and an extensive line of coast (550 km). Infrastructure and facilities around the lake include camping, motels, boat rentals and a number of residential service facilities for tourists, picnic areas and public and private marinas for boats.

The Board of Lake Eyre Basin cares about preserving water quality, which is the main motto of the organization centre. Lake Eildon is the only reservoir in Victoria, where sail boats and yachts with luxurious cabins and sleeping places. To avoid any risk from contamination of water must be adhered to strict rules. Yachts that were allowed to sail in the lake must be equipped with sewage tanks approved for use by the water company.

Management, including planning and raising funds for the development of Lake Eildon, does not have the character of the integrated management (taking into account the needs of the local population), because the lake has become a multi-million project for the company, which charges the owners of dozens of luxury yachts, annual fees of several thousand dollars for the maintenance and control of all tourism projects, ensuring their ability to achieve the best housing and facilities for water sports, fishing and participating in other tourist attractions. In planning of Lake Eildon development are

involved the owners of yachts.At Lake Eildon, there are sanitation stations for pumping sewage from tanks of yachts and houseboats. Water Company also has a floating barge – sewage treatment. Discharge of sewage or solid waste into the lake is treated as a crime. Lake Eildon and the Goulburn and Murray rivers are combined into one body of water so the water resource management and management of tourism is common for the water system (*On land and water*... 2012).

Another interesting example of the development of lake tourism (and lake district area) in Australia may be pointed out – Metung Village, situated between Bairnsdale and Lake Entrance. Metung is a waterfront Village located on the Gippsland Lakes. Project of Metung was planed for every tourists practicing fishing boats and water sports. Metung has all reason to be an example of a well-organized integrated management taking into consideration not only the private interests of a limited number of owners luxury yachts, but also takes care of the local community, tourism and regional economic development as well taking into account the environmental protection of lakes. Metung join the waterway of the Gippsland Lakes (including famous – Lake Entrance – managed with regard to sustainable development as holiday destination and fishing port at the same time). This connection of water constitute the largest navigable inland waterway in Australia, which is a relict of a narrow channel that connected the Lakes to the ocean.

The research concerning water system in Australia (*Streams and lakes*... 2012), carried out by tourism businesses, local governments, water resource managers, residents and tourists provide much information on the frequency of use land and water, indicate the principles and strategies for sustainable development, trying to limit the negative impact of tourism on nature and protect the ecosystems of lakes. This research shows favourable assessment of using ecosystems of lakes in Australia for tourism.

Lake tourism in New Zealand

In the literature referring to lake tourism New Zealand is mentioned next to Canada as a place with the greatest number of lakes used for tourism with a properly prepared infrastructure (RANADE 2007).

In New Zealand, the total area of lakes covers an area of 3398 square kilometres (*A directory of wetland*... 1995). Lakes in New Zealand are covered by government grants for the restoration of its unique ecosystems. The problem of sustainable management of lake tourism in New Zealand is somewhat complicated. The monitoring and study of specific issues with respect to lake tourism in this country is extremely difficult (CARR 2006).

The main difficulty standing in the way of implementation of sustainable lake tourism has historical connections. Under the Treaty of Waitangi (1840), Maori community was to be guaranteed the right to "... to have their lands and estates forests, fisheries and other property, which may collectively or individually possess ...". Hence, using lake tourism local authorities must take into account the rights of the indigenous Maori population, for which the lake is their heritage (KURLETO 2011, TUOHINO 2006).

Interestingly it appears at this observation the fact that even New Zealand, which enjoys a reputation as a "green country" suffers from a lack of data that would be an objective basis for the estimation of lake tourism and that would allow monitoring of the tourist influence on lake environments (which in turn would indicate the size environmental impact of tourism on lakes).

ERKKILÄ (2006), which analysing this issue, says that the precondition for the success of lake tourism are: first, searching for an integrated approach to management development and marketing of this kind of tourism, and secondly, respect for the obligations of the "winning strategy" (*Win, Win Strategies* 2004), which shows host communities in harmony with the needs and expectations of tourists. The mentioned author also points out that lake tourism operates in an extremely complex and fragile environment. This is the main reason of balanced policy requirement for lake tourism.

It seems to, that interesting examples of policies for sustainable management of lake tourism in New Zealand refer to Lake Taupo and Wanaka.Lake Taupo – area of 606 square kilometres and a circumference of about 193 kilometres, is located in the middle of the North Island, in the Tongariro National Park (inscribed on the UNESCO World Heritage List) and is the largest lake in New Zealand. From this lake flows out of the country's longest river – Waikato, head north through areas covered with volcanic soil. Adjacent to the lake volcanoes Tongariro, Ngauruhoe and Ruapehu, a perfect background for all leisure and tourism, dominated by water sports, especially kayaking. Lake Tapuo annually visited by more than 1.2 million tourists (Lake Taupo. 2012).

In the sustainable management of Lake Taupo Tourism interact local and national security agencies. Local and regional authorities (Taupo District Council and Ruapehu District Council, Waikato Regional Council, Regional Council of Manawatu-Wanganui and Hawkes Bay Regional Council) have to consult together on matters of governance, including of water quality monitoring, fire control, removing solid waste, sewage, pest control, as well as on general issues of spatial development (especially in the context of the need to protect areas of natural, cultural and historical value of places) (WRATEN 2011).

Effective planning is the foundation of a strong tourism management for achieving an optimal balance the impact of sustainable tourism and protection of the ecosystem of the lake.

Lake Wanaka with an area of 192 square kilometres situated on the South Island is one of the best-organized tourist destinations in New Zealand. Due to its mountainous location, Lake Wanaka Tourism has two seasons: summer and winter. This place offering many tourists activities. Tourists can get involved in water sports including sailing, canoeing, rafting, jet-boating, but also there are the possibility of hiking, mountain biking, climbing, fishing, hang gliding and para-winter winter sports. The area surrounding Lake Wanaka tourists have an access point to the highest mountain in New Zealand, the Cook Mountain (3754 m), and the peaks of mountains Aspiring and Tititea (Lake Wanaka. 2012).

New Zealand successfully established its brand promoting the slogan "Clean & Green", "100% Pure New Zealand" (*How green...* 2011) attracting to the country millions of visitors from around the world. This country may be a good example of sustainable tourism, able to both: preserve the ecosystem resources of the lakes as well as all the comfort and security for tourists. However, this does not mean that here there are no problems with pollution of lakes, which result from intensive agriculture and farming (which is referred to "dirty dairying" – Lake Wanaka. 2012). Pollution on lakes Waikato, Rotongaro Hakanoa and Kainui and Ngaroto and Waahi and Whangape were the subject of press health warnings, appearing in the New Zealand Herald (From 2004 to 2011, Lake Wanaka. 2012). Water samples, which were taken from the lake Waikato has revealed a toxin microcystin, samples from Lake Rotongaro blue-green algae – Microcystis. Algae levels were 40 times higher, and the toxin levels were 760 times higher than water quality standards.

Toxins can get into lakes from fertilizer and sewage runoff, because there are lack currently filtering systems such as natural forest areas and wetlands. Over the past 50 years, many farmers drained the wetlands in order to achieve more production from additional grazing area. A large amount of toxins is also associated with a high level of fertilization in the absence of mini-ecosystems protection. The cases of water pollution of lakes in New Zealand underlines the importance of adequate checking of water purity and preserving of eco-systems.In New Zealand, similar like in the European countries, for the protection of life in the lakes are placed the program: Living Lake. In 2007, 2009 and 2011 conferences were held on this subject (WRATEN 2011).

A specific feature of New Zealand's Lake Living programs is that in addition to the recommendations relating to the environmental values of lakes, to protect its flora and fauna and the entire ecosystem and biological diversity also draw attention for historical awareness of these lakes (*Community strategy...* 2004).

Conclusions

The analysis shows that in Australia and even more so in New Zealand, sustainable management of lake tourism is balanced, caring for the protection of: ecosystems, the local community and also appreciating the value of tourism (Triple Bottom Line). It should be noted that Australia and New Zealand have the only one consul – ANZECC (the Australian and New Zealand Environment Conservation Council), which sets the guides on the water quality (Using Anzecc. 2012) common to the two "sister countries".

Some issues that affect the estimation of tourist influences (especially in New Zealand) must find a solution considering the implementation of the program Living Lake as soon as possible. Further research on the influence of tourists on lake environments are urgently needed. It is important to establish regulations on tourist influence on the environment of lakes (and for the tourist zoning necessary to protect the lakes) under which it will be possible to use proper engineering for the planning of lake tourism.

It should be emphasized that the travel management of hydrological resources, including the use of waterways will be in the coming years, more and more important both because of the increasing demand related to lake tourism and because of the escalating effects of climate change, which are becoming more severe. Managers of lake tourism must take into account the differences in the perception of the use and protection of lakes by various stakeholder groups and the paradox of improper behaviour by tourists, despite their apparent ecological awareness.

In conclusion, the risk that tourism brings to the sensitivity of the lake ecosystem should be noted, especially by: motor boats, intensive recreational fishing, throwing fuel and sewage into the waters of lakes and campsites, which are located too close to the shores of lakes.

The lake ecosystem recovery should strengthen the control of pollution of lakes and make their "rehabilitation", so as to restore the ecosystem and take action as soon as possible focus on positive changes in the ecological civilization (WUHAN 2009).

Sustainable economic development of lakes is a constant challenge, in which those responsible for the plans and management of lakes and lake districts should strive for closer cooperation. In order to understand the ecosystems of lakes, the global experts studying the problems of lakes (including tourism lakes) combined their efforts to create a new international network known as the Global Lakes Ecological Observation Network (*Global lake*... 2012). GLEON community is proof of effort undertaken to understand the dynamics of the economy and protect the lake eco-systems, flora and fauna, at different scales.

The recommendations relating to the management of lakes (including tourism) and all its stakeholders are as follows (*Global lake*... 2012):

– develop and implement a comprehensive strategy for rehabilitation of lakes, which include strict measures to protect the environment and promote sustainable development of tourism in order to reduce the pollution of lakes ecosystems;

– finding new and innovative financial instruments to provide financial resources necessary to maintain the natural ecosystems of lakes;

– promote cooperation with governments, communities, the tourism industry and NGOs, and promote the participation of the local population as the basis for joint action-oriented regulatory approach to the common goals of environmental protection of lakes and sustain ecosystem services.

Encouraging innovation in the implementation of new management concepts lakes in the zoning of tourism, promotion of integrated lake basin management and implementation of multi-disciplinary technology to enhance the ecological restoration of lakes.

All the above recommendations should be followed up care being careful and aware that her dwindling water resources of lakes, the pollution of their waters, degraded ecosystems, pose a serious threat both to the survival of mankind and sustainable development.

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THE USE OF WARMIA AND MAZURY BEACHES BY YOUNG WOMEN FOR RECREATIONAL AND HEALTH PURPOSES

***Robert Podstawski*[1], *Jarosław Klimczak*[2]**
***Ewelina Kolankowska*[3], *Renata Gizińska*[3]**

[1] Department of Physical Education and Sport
[2] Department of Ichthyology
[3] Chair of Machines and Separation Processes
University of Warmia and Mazury in Olsztyn

K e y w o r d s: 1st year female students, beaches in Warmia and Mazury, use.

A b s t r a c t

The aim of the study was to collect information regarding the opinions and attitudes of young women towards the use of beaches for recreational and health purposes. The study was conducted in 2011 during obligatory P.E. classes at the University of Warmia and Mazury in Olsztyn and involved a group of 298 first-year female students aged 19–20. The study was carried out with a diagnostic survey method with the use of an anonymous questionnaire. The survey revealed that beaches in Warmia and Mazury are widely available and easily accessible for women residing in this region, yet the respondents did not appear to show an interest in going there. Despite the availability of beaches, over half of the respondents did not report frequenting them. The main reason for not spending leisure time on beaches in Warmia and Mazury is their poor standard and the students' unwillingness. The majority of the women who reported going to the beach sought consumption and entertainment rather than recreational and health oriented activities.

REKREACYJNO-ZDROWOTNE ZACHOWANIA MŁODYCH KOBIET NA PRZYKŁADZIE PLAŻ WARMIŃSKO-MAZURSKICH

***Robert Podstawski*[1], *Jarosław Klimczak*[2] *Ewelina Kolankowska*[3], *Renata Gizińska*[3]**

[1] Studium Wychowania Fizycznego i Sportu
[2] Katedra Ichtiologii
[3] Katedra Maszyn Roboczych i Procesów Separacji
Uniwersytet Warmińsko-Mazurski w Olsztynie

S ł o w a k l u c z o w e: studentki I roku, plaże na Warmii i Mazurach, wykorzystanie.

Address: Robert Podstawski, University of Warmia and Mazury in Olsztyn, ul. Romana Prawocheńskiego 7, 10-720 Olsztyn, Poland, phone: +48 (89) 523 33 08, e-mail: podstawskirobert@gmail.com

Abstrakt

Celem badań przeprowadzonych wśród młodych kobiet była diagnoza opinii i postaw na temat wykorzystania przez nie plaż na Warmii i Mazurach w celach rekreacyjno-zdrowotnych. Badania przeprowadzono w 2011 r. podczas obligatoryjnych zajęć wychowania fizycznego na Uniwersytecie Warmińsko-Mazurskim w Olsztynie i objęto nimi 298 studentek I roku w wieku 19–20 lat. Zastosowano metodę sondażu diagnostycznego z wykorzystaniem anonimowego kwestionariusza ankiety. Stwierdzono dużą łatwość dostępu do plaż kobiet żyjących na Warmii i Mazurach. Plaże cieszyły się jednak małym zainteresowaniem studentek. Ponad połowa kobiet w wieku 19–20 lat nie uczęszczała na nie wcale. Brak spędzania czasu wolnego na plażach warmińsko-mazurskich był spowodowany głównie brakiem chęci ze strony ankietowanych oraz niskim standardem wyposażenia infrastruktury tych miejsc. Większość kobiet odwiedzających plaże nastawiona była bardziej na styl konsumpcyjno-rozrywkowy niż rekreacyjno-zdrowotny w postaci wypoczynku aktywnego na świeżym powietrzu.

Introduction

Warmia and Mazury is among the most beautiful regions of Poland and due to its uniqueness is likely to become an extremely attractive recreational destination for foreign tourists. A recent ranking for the New Seven Wonders of the Natural World staged by the Swiss Foundation New Seven Wonders is a good indicator of this. The landmarks appointed by this organization as potential candidates for the New Seven Wonders of the Natural World included the Amazon (the biggest river in the world), the Halong Bay in Vietnam (featuring thousands of limestone karsts and isles), the Falls of Iguazu on the Brazilian-Argentinian border, the volcanic isle of Jejy off the southern coast of South Korea, the National Park Komodo in Indonesia, Puerto Princessa in the Philippines (the longest underground river in the world), and the Table Mountain in the Republic of South Africa. Noteworthily, only 28 out of 440 landmarks submitted for the competition from all over the world qualified for the final, including Polish Mazury which, what is more, qualified to the final 14 (2011 edition of the New Seven Wonders of the Natural World).

The region's uniqueness results from its geographic location (north-eastern part of Poland, partial access to the Vistula Lagoon) and diversity which includes a large number of basins and ancient forests. It should be mentioned that the region of Warmia and Mazury is often referred to as The Great Masurian Lakes District or "The Land of a Thousand Lakes". This is because there are nearly 1100 lakes and over 3000 bodies of water in this region, which provides excellent conditions for the development of water recreation. According to the data collected by the Sanitary and Epidemiological Station in Olsztyn in 2010, there are nearly 214 beaches in Warmia and Mazury: 208 neighboring lakes and 6 on the Vistula Lagoon.

Recent findings revealed a lack of literature concerning the use of lake beaches for recreational and health purposes by the residents of Warmia and

Mazury, as well as a lack of monographs concerning their needs for a whole range of beach recreation. Very little research has adequately addressed the management of beaches and related recreational areas (MICALLEF and WILLIAMS 2002). Therefore, a survey which reveals the attitudes of young women towards the ways of spending their leisure time at Warmia and Mazury beaches deserves attention.

The aim of the survey that involved 1st year female students enrolled at the University of Warmia and Mazury in Olsztyn (UWM) was to diagnose their attitudes towards the use of beaches in Warmia and Mazury for recreational and health purposes. Raising the question of beach popularity in our region and determining the key factors which influence it can be a source of very valuable information for beach managers as well as associated industries. Identifying the current social needs and emerging trends in the lifestyles of potential beachgoers in given environment will facilitate the development of beach recreation in Warmia and Mazury. To accomplish this aim, respondents were asked to answer the following questions:

1. Do you have easy access to beaches in your place of permanent residence?
2. How and how often do you use beaches in your place of permanent residence?
3. What do you think of the standard of the beaches in Warmia and Mazury?
4. Do you go to the beach for health, consumption or entertainment purposes?

Materials and Methods

The survey was conducted in 2011 during obligatory PE classes at the UWM in lsztyn and involved 298 1st year female students aged 19–20. Students of Polish universities and other tertiary institutions are required to complete a minimum of two semesters (60 hr) of P.E. lessons of their choice e.g., swimming, martial arts, tennis etc. All participants willingly agreed to participate in the study, after being informed about the aims of the experiment. The research was carried out in compliance with the Declaration of Helsinki and prior consent from the bioethical Committee of the UWM. All women from randomly selected groups of students took part in the survey. As the respondents were all residents of Warmia and Mazury, the cohort should be recognized as homogenous and appropriate for this kind of survey. A detailed analysis of the cohort is given in Table 1.

Table 1

Characteristics of the cohort surveyed

Place of permanent residence											
Village		cities below 20,000 population		cities between 20 and 50,000 population		cities between 50 and 100,000 population		cities over 100,000 population		total	
N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
82	27.52	133	44.63	55	18.46	11	3.69	17	5.7	298	100
Mother's Education											
Primary		secondary		university		total					
N	%	*N*	%	*N*	%	*N*	%				
32	10.74	159	53.36	107	35.91	298	100				
Father's Education											
Primary		secondary		university		total					
N	%	*N*	%	*N*	%	*N*	%				
30	10.07	156	52.35	112	37.58	298	100				
Monthly Cost of Living											
<PLN 1000		PLN 1000–1500		PLN 1500–2000		PLN 2000 <		total			
N	%	*N*	%	*N*	%	*N*	%	*N*	%		
182	61.07	105	35.23	11	3.69	0	0	298	100		

Explanations: *N* – number of responses, % – percentage share

Table 1 reveals that the highest percentage of women (44.63%) were residents of cities with a population below 20,000 population, a considerable percentage (27.52%) were village residents, whilst the lowest percentage (3.69%) resided in cities between 50,000 and 100,000 in population. The majority of the students' mothers and fathers had completed their secondary (high school) education (53.36% and 52.35% respectively), with a slightly lower percentage having a university degree (35.91 and 37.58% respectively), and the lowest percentage of parents having only a primary education (10.74 and 10.07% respectively). As regards to the monthly budget, the majority of the women under survey (61.07%) had below PLN 1000 per month, a considerably lower percentage (35.23%) had between PLN 1000–1500, and none of the women had over PLN 2000 per month.

A diagnostic survey method with the use of anonymous questionnaire was applied in the survey. Students taking part in the research were instructed how to fill in the questionnaire and given sufficient time to do so. Moreover, it was examined whether the number of women involved in the survey was sufficient and thus, whether the cohort could be recognized as representative. The following formula was applied to perform this task (1):

$$n = \frac{\mu_\alpha^2}{4d^2}, \quad (1)$$

where:
d – the maximum (acceptable) error of estimation,
μ_α – the value from the normal distribution table N(0.1) at the acceptable confidence coefficient $1 - \alpha$. It was assumed that for the accepted confidence coefficient $1 - \alpha = 0.90$ ($\mu_\alpha = 1.64$) the average estimation error doesn't exceed 5% (KREFFT and CHOSZCZ 2000, NOWAK 2002). Formula (1) made it possible to calculate that the minimum number women who ought to be surveyed was 269 and therefore lower than the number of people involved in the experiment (298). Thus, the sample was found to be representative for the population of UWM female students and appropriate for such kind of survey. The survey results were processed statistically using Statistica Pl software (STANISZ 2008).

Results

Table 2 and Table 3 present opinions on the accessibility and use of the beaches in Warmia and Mazury.

Table 2

Distance to the Beach

Place of permanent residence									
Below 1 km		between 1 and 2.5 kms		between 2.5 and 5 kms		between 5 and 10 kms		total	
N	%	*N*	%	*N*	%	*N*	%	*N*	%
48	16.11	106	35.57	107	35.91	37	12.42	298	100
Beach type									
Municipal or guarded beach		wild beach		private beach		no beach		total	
N	%	*N*	%	*N*	%	*N*	%	*N*	%
147	49.33	130	43.62	0	0.00	21	7.05	298	100

Explanations as in Table 1

The largest number of beaches are located only a short distance from the place of residence: 1–2.5 km (35.57%) and 2.5–5 km (35.91%), yet a considerable percentage of respondents live within 1 km of a beach (16.11%) or between 5 and 10 km away (12.42%). Municipal and wild beaches accounted for a similar percentage (49.33 and 43.62% respectively). A low percentage of women reported the lack of beaches in their place of residence and nobody reported private beaches in the region under survey (Table 2).

Table 3

The use of beaches by the Olsztyn UWM women students

Use of beaches					
I use them		I do not use them		total	
N	%	*N*	%	*N*	%
141	47.32	157	52.68	298	100

Frequency of use									
> 5 times a year		6–15 times a year		16–30 times a year		30 < times a year		total	
N	%	*N*	%	*N*	%	*N*	%	*N*	%
83	58.86	58	41.14	0	0.00	0	0.00	141	100

Explanations as in Table 1

Over half of the students surveyed (52.68%) did not frequent Warmia and Mazury beaches. From the group of women who went to beaches, 58.86% went there fewer than 5 times a year and the rest (41.14%) between 6 and 15 times a year. Nobody went to the beach more than 16 times a year (Table 3).

Table 4 and Table 5 present the female students; reasons behind going or not going to beaches, and their evaluation of the standard of Warmia and Mazury beaches.

Table 4

Reasons for using or not using beaches in Warmia and Mazury

I use because:	*N*	%
I can swim	32	11.68
I sunbathe	82	29.93
I paddle a kayak or ride a water bicycle	7	2.55
Take a motor boat trip	31	11.31
Ride a jet ski	0	0.00
I have a meal	31	11.31
I drink alcohol	30	10.95
I dance at the disco	23	8.39
I have a nice time	38	13.87
Total	274	100
I do not use because:	***N***	**%**
Water is dirty	19	9.36
I cannot swim	7	3.45
Infrastructure is poor	27	13.30
It is too far	38	18.72
I do not want	33	16.26
I prefer aqua parks	28	13.79
Water is cold	25	12.32
Weather is bad	26	12.81
Total	203	100

Explanations as in Table 1

Table 5

Scoring and detailed evaluation of the standard of beaches in Warmia and Mazury

Point Scoring Evaluation of the Standard of Beaches		
Scale	*N*	%
1	27	9.06
2	32	10.74
3	64	21.48
4	71	23.83
5	73	24.50
6	29	9.73
7	2	0.67
8	0	0
9	0	0
10	0	0
Total	298	100
Detailed Evaluation of the Standard of Beaches		
Evaluation Criteria	*N*	%
It is clean	164	12.34
It is dirty	136	10.23
Dirty water	108	8.13
Clean water	116	8.73
Water recreation equipment unavailable	168	12.64
Water recreation equipment available	66	4.97
Slide unavailable	73	5.49
Slide available	7	0.53
Cafeteria available	87	6.55
Cafeteria unavailable	10	0.75
Bar available	89	6.7
Bar unavailable	68	5.12
Sporting fields available	2	0.15
Sporting fields unavailable	14	1.05
Disco available	44	3.31
Disco unavailable	98	7.37
Changing room available	16	1.2
Changing room unavailable	63	4.74
Total*	1329	100

Explanations: *N* – umber of responses, % – percentage share, * – respondents could indicate more than one facility

The main determinants for frequenting beaches in the Warmia and Mazury region include sunbathing (29.93%), having fun (13.87%), the opportunity to swim (11.68%), dancing at the disco (10.95%) and drinking alcohol (8.39%). The reasons behind not spending leisure time at beaches include too long of a distance (18.72%), unwillingness (16.26%), preferring aqua parks (13.79%), cold and dirty water (12.32 and 9.36% respectively), a poor infrastructure (13.30%), and bad weather (12.81%) – Table 4.

To allow for a comprehensive evaluation of the standard of Warmia and Mazury beaches, the respondents awarded the beaches with points on a scale of

1–10 (1 being the lowest standard) in addition to giving a detailed (descriptive) evaluation. The point scoring evaluation method revealed that the overwhelming majority of the students' assessment of beach standard ranged from 3 to 5 points (21.48, 23.83, and 24.50% respectively). None of the students awarded the beaches with top points (8–10). As regards the detailed (descriptive) evaluation, the responses of surveyed women varied, including their opinion of what the beaches lack/offer. A similar percentage of female students indicated that beaches are clean/dirty (12.34 and 10.23% respectively), the water is clean/dirty (8.73 and 8.13% respectively), there are/are not any bars (6.7 and 5.12% respectively). Other responses were more varied, with a relatively high percentage of respondents indicating the unavailability of water equipment (12.64%), discos (7.37%), and cafeterias (6.55%), with a considerably lower percentage of stating that beaches lacked changing rooms (4.74%) and sports fields/courts (1.05%).

Discussion

As the region of Warmia and Mazury is strongly affected by high unemployment, maximizing the use of beaches may constitute a critical economic factor, which can contribute to economic recovery. This task should be given much importance as it corresponds with the primary assumptions of tourism, which are that beaches should be fully exploited to manage people's leisure time (ARIZA et al. 2008). The beaches off the coast of Spain, Australia, Greece, Egypt, Lebanon, Croatia and the United States of America prove how much can be done in this respect (de DIOS 2012). In Spain, for example, tourism accounted for 11.4% of its GDP in 2003, and the so called "sun and sand model" predominates in the Spanish tourism industry (AGUILÓ et al. 2005). For that reason, beaches should be considered one of the main national assets and their potential exploited for recreational purposes (BRETON et al. 1996). This would provide an opportunity to improve the quality of life of the region's inhabitants.

Beach management should be based on a specially designed plans the directives of which aim to help exploit the potential of coastal areas for recreational purposes (e.g. by the correct arrangement of sunbeds and umbrellas) (BRETON et al. 1996). Otherwise, stagnation in the development of beaches in Warmia and Mazury will persist (PRIESTLEY and MUNDET 1998). Their adaptation to the individual needs of potential users should be supported by the municipalities whose duties would include preparing special "recovery programmes" financed from EU funds and government subsidies. Moreover, the programmes should consider the future commercialization of beaches,

including access fees paid for environmental protection, when the tax-exemption period necessary to develop investments is over. In countries where beach tourism is well developed, beach managers pay special fees depending on the number of tourists (beds) visiting the tourist centre. The rates are determined according to the Environmental Management Systems, and exemplary rates for the beaches in Valencia (Spanish Mediterranean coast) are about €700 per square metre (YEPES 2004). Well-prepared and well-managed beaches be of great socio-economic value; by attracting a large number of tourists they improve the local people's quality of life and offer other economic advantages (DE DIOS 2012).

According to MICALLEF et al. (2002), effective beach management may result in:

– increased beach use (HOUSTON 1996),

– lower maintenance/restoration costs related to beach management (COOPER et al. 1996),

– improved coastal defence (HOLMES and BAVERSTOCK 1996),

– increased conservation value,

– high multiplier effect on the socio-economic structure of the beach locality (NELSON and WILLIAMS 1997).

Pursuant to a new approach, beaches should be considered as a multidimensional system based on the interactive cooperation of their natural, socio-economic and administrative components (BIRD 1996, JAMES 2000). If beaches are regarded as coastal environmental units, their management should be integrated into a broader framework, such as the Integrated Coastal Zone Management (ICZM). Recent recommendations for the ICZM include the adaptation of the ecosystem management approach that can and should be adapted to beach management. The proper implementation of ecosystem management should be based on ten specific principles (GRUMBINE 1994), including: data collection, monitoring, adaptive management, interagency cooperation, organizational change, humans embedded in nature, and the establishment of values. In order to successfully implement this approach, there is a need to support applied research on this subject matter (UNDERWOOD 1995).

According to SIMM et al. (1995, p. 147), beach management is the "the process of managing a beach, whether by monitoring, simple intervention, recycling, recharge, the construction and maintenance of beach control structures or by some combination of these techniques, in a way that reflects an acceptable compromise in the light of available finance, between the various coastal defence, nature conservation, public amenity and industrial objectives".

Another crucial factor for the system of management to consider are the needs of potential customers seeking a wide-range of services offered by beaches and recreational centers (BRETON et al. 1996). The primary needs of tourists enjoying their leisure time on beaches include pro-health activities, entertainment and consumption. Each of these needs may generate income for recreational centres with beaches. Therefore, the survey results of our research should be considered a valuable comparative material for other observations in this field throughout the world. The respondents' answers reveal a number of characteristic trends in their attitudes, views, and needs which can be applied in practice.

The geographic location of the permanent place of residence determines the use of beaches by the surveyed women only in the case of those living 5–10 kilometers from the nearest beach. However, the majority of study subjects resided less than 5 kilometers away. A survey conducted by DUTTON (2001) revealed that nearly 40% of human population live at a distance of up to 100 kilometers from the shore and that this can be considered an attractive distance for tourist business which involves beaches. Ironically enough, nearly 19% of the respondents, none of whom live further than 10 km from the beach, stated that the distance (too far) was a factor negatively influencing their beach attendance. Such discrepancies in the answers lead to the assumption that the analyzed students were simple "looking for excuses" rather than identifying a legitimate problem.

Another interesting fact that seems to contradict the research subjects' opinion is the aspect of water cleanliness. According to the Report on the Condition of the Natural Environment in the Warmia and Mazury voivodeship in 2010, the ecological and chemical condition of lake water in this region was found to be good with the exception of the Vistula Lagoon (SMOTER et al. 2011) This would indicate that the students' answers regarding this factor were not true and should be interpreted rather as the lack of interest in this manner of spending leisure time.

A serious concern arises from the fact that fewer than 11% of the respondents confirmed their swimming skills, and hardly anybody reported other forms of physical activity that can be done at the beach (only a small number of women reported using kayaks and water bicycles). Thus, it seems that 19–20 year old women spending their leisure time at the beach are not interested in physical activity (a health aspect) but enjoy entertainment and consumption aspects such as sunbathing, drinking alcohol, eating, and dancing at the disco, many of which can have detrimental effect on health.

A considerable percentage of respondents preferred aqua parks to beaches, which might be explained by bad weather, cold water or a poor infrastructure of the beaches in Warmia and Mazury (the primary reasons indicated).

The climate typical of this region of Poland is a crucial factor reducing the attractiveness of beaches. Owing to a short summer period (June – September) and frequent weather changes, tourist opt for aqua parks and spas offered by hotels and recreational centers.

The majority of respondents gave a low ranking of the standard of beaches The responses of the detailed evaluation varied greatly but were far from promising. This should serve as motivation for beach management to improve their standards, and attract more people.

Conclusion

The survey revealed good accessibility to beaches in the Warmia and Mazury region which however, did not increase their attractiveness. Despite the easy access to beaches, over half of the surveyed women did not frequent them and those who did, didn't do so often. The primary reasons for not spending leisure time at Warmia and Mazury beaches included unwillingness and a low standard of their infrastructure. The majority of respondents who reported going to beaches sought consumption and entertainment as opposed to outdoor physical activity.

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LAKES UNDER PRESSURE: DATA ON THE DEVELOPMENT OF LAKE TOURISM IN HUNGARY

***Bulcsú Remenyik*[1], *Géza Tóth*[2], *Lóránt Dávid*[1], *Csaba Szücs*[1], *László Vasa*[3], *Gulmira Uakhitova*[4]**

[1]Institute of Tourism, Regional Development and Foreign Languages
Károly Róbert College in Gyöngyös, Hungary
[2] Central Statistical Office, Budapest, Hungary
[3] Faculty of Economics and Social Sciences
Szent István University in Gödöllö, Hungary
[4] Department of Tourism
L.N. Gumilyov Eurasian National University Astana, Kazakhstan

K e y w o r d s: lake tourism, tourism ecology, ecotourism, culture tourism, natural tourism.

A b s t r a c t

The present study, which compares and contrasts the tourism and visitor-based economic development at major lakes in Hungary aims at describing how roles have changed and opportunities have presented themselves in the lake tourism sector. In the western part of Central Europe (Germany, Switzerland, Austria and Slovenia) lake tourism has grown to be a leading tourism product since the 1960s. Hungary saw a boom in its lake tourism in the mid 1960s as leaders of its centralized, planned economy changed their stance on tourism in an effort to generate income and counterbalance the possible siphoning-off of western tourists by Romanian and Bulgarian seaside resorts. Lake Balaton, Lake Tisza and Lake Velence were the recipients of state investment and and emerged as the most popular lake tourism destinations.

Address: Dávid Lóránt, Károly Róbert College, 3200 Gyöngyös, Mátrai u. 36, Hungary, phone +36 3751 83 74, e-mail: davidlo@karolyrobert.hu

JEZIORA POD PRESJĄ ANTROPOGENICZNĄ: DANE DOTYCZĄCE ROZWOJU TURYSTYKI JEZIOROWEJ NA WĘGRZECH

***Bulcsú Remenyik*[1], *Géza Tóth*[2], *Lóránt Dávid*[1], *Csaba Szücs*[1], *László Vasa*[3], *Gulmira Uakhitova*[4]**

[1] Instytut Turystyki, Rozwoju Regionalnego i Języków Obcych
Wyższa Szkoła im. Karola Roberta w Gyöngyös, Węgry
[2] Centralne Biuro Statystyczne w Budapeszcie, Węgry
[3] Wydział Nauk Ekonomicznych i Społecznych
Uniwersytet im. Szenta Istvána w Gödöllö, Węgry
[4] Katedra Turystyki
Euroazjatycki Uniwersytet im. L.N. Gumiłowa w Astanie, Kazachstan

S ł o w a k l u c z o w e: turystyka jeziorowa, ekologia w turystyce, turystyka kulturowa, turystyka przyrodnicza.

A b s t r a k t

Celem tego opracowania, w którym porównano rozwój ekonomiczny związany z turystyką wokół najważniejszych jezior na Węgrzech, był opisanie, w jaki sposób zmieniły się role i jakie nowe możliwości pojawiły się w sektorze turystki jeziorowej. W zachodniej części Europy Środkowej (Niemcy, Szwajcaria, Austria i Słowenia) turystyka jeziorowa rozwijała się począwszy od lat 60. XX w., by ostatecznie stać się jednym z głównych produktów turystycznych. Na Węgrzech przeżywała ona okres gwałtownego rozwoju w połowie lat 60. XX w., gdy decydenci planowej, scentralizowanej gospodarki zmienili w tej kwestii swoje stanowisko, upatrując w turystyce jeziorowej szansę osiągnięcia dochodów. Jeziora Balaton, Tisza i Velence otrzymały państwowe inwestycje, stały się konkurencyjne dla nadmorskich kurortów Bułgarii i Rumunii.

Introduction

The objective of this paper is to present the changes in the tourism roles of lake tourism and their development possibilities. There were a number of objectives set in connection with our research. On the one hand we intended to examine whether lake tourism was in a favourable or unfavourable situation in Hungary and also to observe the similarities and differences among lake-side settlements. On the other hand it was our task to compare lakes and measure them against national averages. Furthermore, we also wanted to find out whether these lake-side settlements were totally different or whether they showed some similarities.

In 1964 the foreign exchange and customs regulations were simplified, the visa issuing procedure was accelerated, visa free travel was introduced with a number of countries and the foreign exchange supply of travellers was also improved. The New economic mechanism starting in 1968 also considered the development of tourism as of highest priority thus lake tourism together with holiday tourism became a leading tourism product in Hunhgary. By the beginning of the 1980s the shores of Lake Balaton started to be saturated, developments started to focus on Lake Velence and Lake Tisza, though which

the lightenening of the burden on Lake Balaton was meant to be achieved. During the 1990 a number of national parks were established at wetland habitats (Fertö-Hanság National Park, a Balatonfelvideki National Park, a Duna-Ipoly National Park), the national parks started to supervise areas that were valuable for them. In 1999 the Hortobágy National Park was elected among World Heritage sites and as a result the Bird Sanctuary of Lake Tisza received World Hewritage protection. The Fertö-Hanság National Park had an important role in making Lake Fertö as cultural landscape a World Heritage site in 2001 so the development of eco- and natural tourism came into prominence in connection with further development of lake tourism. Further possibilities in the development of Lake Balaton, Lake Tisza, Lake Velence and Lake Fertö are presented by the fact that strategic Pan-European routes pass through these areas.

The delimitation and analysis of the lake area settlements

The analyses of the four lakes (Lake Balaton, Lake Fertö, Lake Tisza, Lake Velencei), similarly to other surveys, can run into difficulties. The reason is that it is utterly difficult to match geographical borders with administrative boundaries. Therefore, in order to dissolve this problem, we decided to use a spatial informatics software (ArcView 9.3.1.) to define settlements whose administrative area includes even a 1 square kilometre area that belong to the lake itself. Thus we ignored settlements situated further away from the lake. These of course can enjoy the benefits of a nerby lake but in this way we could avoid having to arbitrarily determine a distance within which settlements

Table 1

Lake area settlements by population (2010)

Categories by settlement size	Number of settlements	Distribution [%]	Population of settlements	Distribution [%]
–199	2	2.7	267	0.1
200–499	13	17.3	4 706	1.8
500–999	9	12.0	6 402	2.4
1 000–1 999	24	32.0	33 491	12.7
2 000–4 999	18	24.0	58 156	22.1
5 000–9 999	4	5.3	29 979	11.4
10 000–19 999	2	2.7	24 389	9.3
20 000–49 999	2	2.7	45 394	17.2
50 000–99 999	1	1.3	60 755	23.1
Total	75	100.0	263 539	100.0

Source: Hungarian Central Statistical Office, edited by the authors

should be included in the surveys as this distance varies from case to case (Table 1).

During the survey 75 settlements were delimited more than half of which had a population of between 1000 and 2000 or between 2000 and 5000. In relation to the total population the importance of these two categories is somewhat smaller, and thus the only settlement of the examined area with a population of over 50000, Sopron, can come to the limelight. All in all it can be stated that lake area settlements are mainly fragmented ones.

The current state of lake tourism

In the following section some of the indicators – that we consider important – of lake area settlements will be examined. However, it must be noted that although the settlement themselves can be comapared, it is impossible to explain the current development or processes of their socio-economic phenomena solely on the basis of tourism. Although we believe these phenomena are interconnected thei background is much more complex (Table 2).

Table 2

Relevant statistical data of lake area settlements

Lakes	Population, 1 January 2011	Population (2000 = 100)	Migration balance by 1000 people, 2000–2010	Unemployment rate, 2010	Per capita income, 2010 (national average = 100)
Lake Balaton	146 708	100.8	3.4	7.7	97.6
Lake Fertö	65 828	110.5	10.4	2.6	90.2
Lake Tisza	28 055	87.5	–8.0	16.8	74.5
Lake Velence	22 948	118.2	23.0	6.3	116.0
Country total	9 985 722	97.9	–	8.9	100.0

Source: Hungarian Central Statistical Office, edited by the authors

According to the most up-to-date data almost 147 tousand people lived in the 51 settlements around Lake Balaton, 66 thousand lived in the 7 settlements around Lake Fertö, 28 thousand people lived in the 12 settlements of Lake Tisza, while the 5 settlements of Lake Velence were inhabited by 23 thousand people on 1 January, 2011. These areas show a diverse picture in respect of population changes. While there has been an explicit increase in population in case of Lake Velence and Lake Fertö compared to 2000, but the population around Lake Balaton has been stagnating, and at lake Tisza there ahs been a decrease in population. The area of Lake Velence and Lake Fertö is characterised by significant migration, the settlements of Balaton are characterised by moderate migration, while in the area of Lake Tisza the population

has been definitely migrating from the area. The Tisza Lake area is in an unfavourable position considering two more basic indicators, namely the unemployment rate and per capita income. The unemployment rate there is above the national average, while the specific income lever is lower. The most favourable situation in respect of unemployment is observable at Lake Fertö, while in respect of income it is at Lake Velence.

It is worth further considering per capita income in detail because they indicate the most important development tendencies of the areas. Of the four examined regions the most advanced area is Lake Velence and the astest development is observable there (+15.2 percentage point). Although the area of Tisza Lake is the least developed of the examined region, its development almost reached that of Lake Velence between 2000 and 2010 (+14.7 percentage point)! Lake Balaton shows a rather stagnating tendency (+3.7 percentage point), while at Lake Fertö the there has been a significant decrease reaching 17.6 percentage point! The fact that Szekesfehérvár, which is one of the economic centres of Hungary, is situated nearby plays an important role in the fast improvement of Lake Velence. The other reason of the outstanding development was that it was defined as a "retro-lake" until the end of the 1990s, then from the early 2000s two settlements, Gárdony and Velence, started to develop rapidly and these settlements demonstrably increased the number of toursist arriving from Budapest. The unfavourable performance of Lake Fertö is due to the fact that the accessibility of the lake has not changed, the attraction developments finaced from EU sources were finished only this year (visitor centre, reconstruction of Fertöd) and they hav not made their effectrs felt. The development of Lake Tisza has been facilitated by the fact that it was declared to be a priority holiday destination in 1998 then a separate tourist region was organised in its area, and a well considered accommodation and attreaction development also took place (Eco-centre in Poroszló, Robin Adventure Park in Tiszafüred). The ratio of the growth of commercial accommodation reached 70% in average. Of the different types of accommodation facilities pensions grew in the fastest rate while campsites grew only at a 25% rate. The number of holiday houses and hotels doubled since 2000 whereas the share of tourist hostels and youth hostels did not reach 4% combined in 2010. The question is what regional differences prevail behind these development tendencies. In this research the Hoover-index, which is often used in Hungarian literature, has been applied, which expresses on a 0–100% scale what percentage of one of the examined indicators (in this case the income from which income tax is calculated) should be regrouped among the settlements of certain sections so that its distribution could punctually equal with the distribution of the other indicator (in this case population) among the settlements. Since settlement groups of different sizes were examined we tried to measure the distribution changes per unit areas for the sake of comparability. Its formula is:

$$h = \frac{\sum_{i=1}^{n} x_i - f_i}{2n}$$

where:
x_i and f_i – two distribution rates (in our case the population and income share of the ith settlement from the total population and total income within the study area), for which the following two formula hold true: $\Sigma x_i = 100\%$ and $\Sigma f_i = 100\%$; n is the number of settlements in the study area.

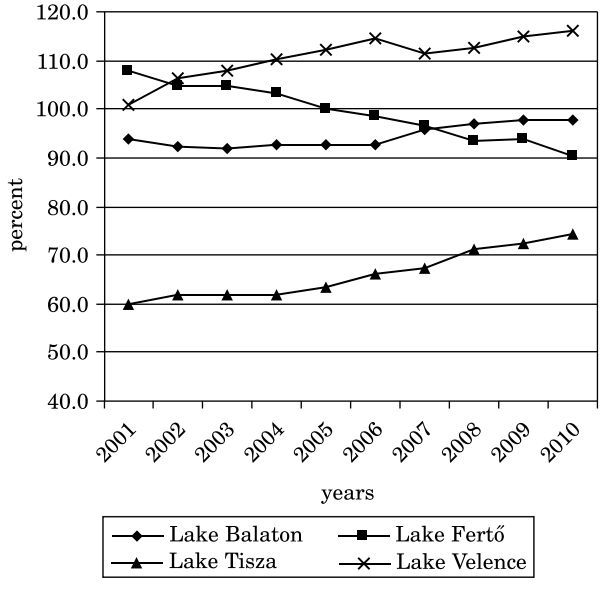

Fig. 1. Per capita income of lake area population relative to Hungarian national average (percentage), 2001–2010
Source: Hungarian Central Statistical Office, edited by the authors

The degree of the per settlement regional differences is the highest at Lake Tisza and Lake Velence and what is more the tendency is expressly positive in both cases (Table 3). On the other hand, in the case of Lake Fertö the tendency of the relatively minor differences is negative. Of the four areas Lake Balaton shows the least regional differences whose rate has not changed significantly in the past few years. The significant differences observed at Lake Velence can be explained by the rapid development of Gárdony and Velence, whereas at Lake Tisza the differences were caused by strengthening of the four large settlements in the area (Tiszafüred, Abádszalók, Kisköre, Poroszló) and the dominance of Poroszló and Tiszafüred was further enhanced by eco-tourism developments. At Lake Fertö the differences among the settlements are continuously diminishing due to the implementation of attraction developments.

Table 3

The Hoover-index of lake areas, 2001–2010

Lakes	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Lake Balaton	0.22	0.23	0.23	0.22	0.21	0.21	0.21	0.20	0.21	0.20
Lake Fertö	0.55	0.52	0.54	0.47	0.43	0.41	0.42	0.35	0.33	0.27
Lake Tisza	0.84	0.92	1.02	1.11	1.17	1.17	1.19	1.13	1.05	1.00
Lake Velence	0.73	0.79	0.63	0.76	0.86	0.94	0.88	0.90	1.11	1.01

Source: Hungarian Central Statistical Office, edited by the authors

Considering the turnover of commercial accommodation facilities of the examined areas, Lake Balaton rises above the others as one fifth of all guest nights were spent there (Table 4). This order of magnitude is not surprising if capacities are taken into consideration as more than one fourth of all the national accommodation facilities can be found there. Compared to 2000 the number of accommodation facilities grew only at Lake Tisza while the most significant setback occurred at Lake Fertö.

Table 4

Visitor related data of public accommodation establishments in the lake areas

Lakes	Guest nights, 2010	Guest nights, 2010 (2000 = 100)	Capacity, 2010	Capacity, 2010 (2000 = 100)
Lake Balaton	18.9	78.2	26.2	94.2
Lake Fertö	2.8	121.1	1.4	76.6
Lake Tisza	0.5	106.5	2.4	135.3
Lake Velence	0.9	110.5	2.0	86.3
All settlements	100.0	106.5	100.0	99.6

Source: Hungarian Central Statistical Office, edited by the authors

Between 2000 and 2010 the guest nights of commercial accommodation facilities decreased only at Lake Balatonnál, while the other areas experiend some growth. The most significant increase is observable at Lake Fertö (Figure 2). The dramatic decrease at Lake Balaton can be explained by the decreasing number of foreign guests. The decrease mainly affected the camp sites (–68%) and the holiday houses (–56%) but compared to 2000 youth hostels also received fewer foreign guests. The other types of accommodation facilities have seen an increase, the most significant increase is connected to pensions (+180%).

In 1990 almost half of all foreign visitors chose to stay in camp sites whose share in 2010 was only 24%. Hotels increased their ratio from 45% to 68% while pensions did the same from 1% to 3%. Holiday houses experienced

a decrease so only 5% of the foreign guests choose them. The combined ratio of youth hostels and tourist hostels did not reach 1% in 2009.

The number of domestic guests changed from 139 thousand to 895 thousand during the examined period. The average six-and-a-half-time increase brought about similar positive processes for all types of accommodation facilities. Hotels have experienced an eleven-fold increase while pensions saw a ninefold increase and even campsites grew in this respect by almost 60%.

In 2000 around 50% of domestic guests chose hotels, this number increased to 70% by 2010.

On the other hand camp sites saw a decrease from 27% to 9% while holiday houses from 15% to 8%. Currently pensions have a somewhat smaller share (6%) than youth hostels (7%) and that of the tourist hostels' is significantly lower (1%).

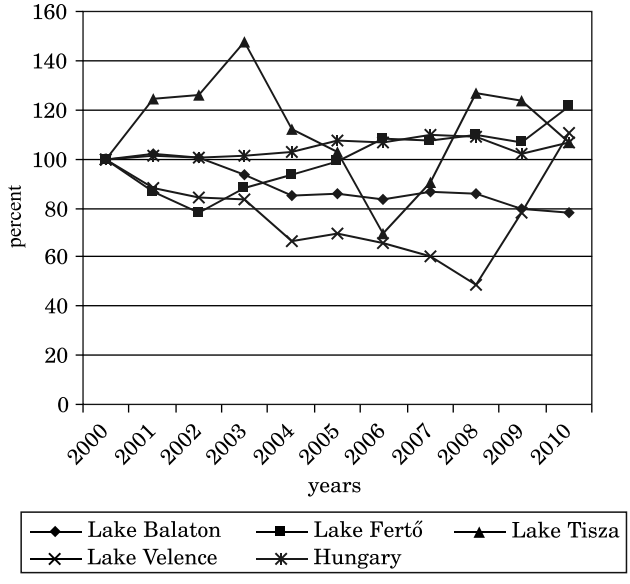

Fig. 2. Number of guest nights at public accommodation establishments
Source: Hungarian Central Statistical Office, edited by the authors

In respect of the category currently called "other" (until 2009 it was referred to as "private") the dominance of Lake Balaton is even more significant. Four out of 10 guest nights are spent there and half of the accommodation capacity can be found there. Compared to 2000 the number of accommodation capacity decreased only here and at Lake Velence while at the two other lakes there has been a significant increase (Table 5). The number of commercial accommodation capacity of the Balaton Region stood at 76 thousand in

2010, which made it number one of the examined regions in the whole examined period. Capacity increased by almost 20% in the region between 2000 and 2010. Only campsites show a decrease, while other types experienced a significant growth. Of the tourist products camp-site tourism lost the most as in 1990 more than 70% of the capacity was in camp sites, this decreased to 32% by 2009.

Between 2000 and 2010 the number of guest nights at other accommodation establishments decreased at Lake Balatonnhl and at Lake Velence, while there has been an increase in the other two regions. The most significant increase is at Lake Tisza (Table 4).

Table 5

Visitor related data of other (private) accommodation establishments in the lake areas

Tavak	Guest nights, 2010	Guest nights, 2010 (2000 = 100)	Capacity, 2010	Capacity, 2010 (2000 = 100)
Lake Balaton	39.7	67.9	50.7	76.8
Lake Fertö	1.0	134.8	0.5	158.3
Lake Tisza	1.2	205.6	2.1	188.2
Lake Velence	0.7	16.4	1.2	85.0
All settlements	100.0	88.7	100.0	102.6

Source: Hungarian Central Statistical Office, edited by the authors

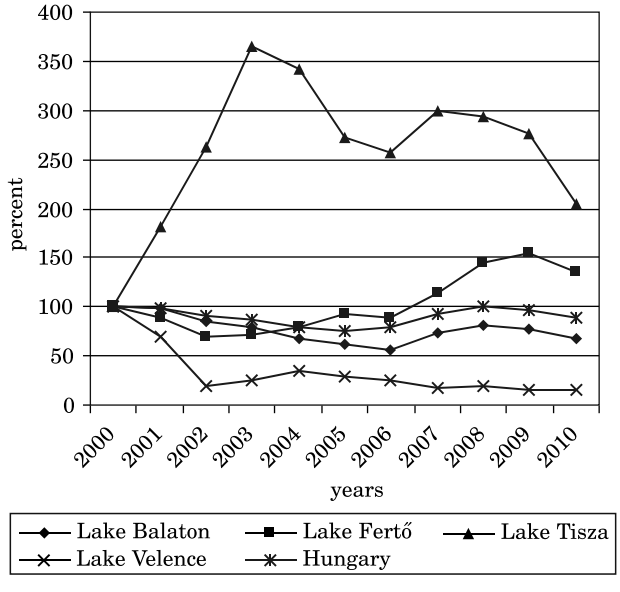

Fig. 3. Number of guest nights at other (private) accommodation establishments (percentage) 2000 = 100

Source: Hungarian Central Statistical Office, edited by the authors

At Lake Tisza there were 21 thousand visitors in 2000 and it remained similar in 2010. The intrinsic structure of the 2% increase was similar to the domestic ones: Campsites suffered signicant – almost 20% – losses, nevertheless hotels had an even worse period as their losses reached almost 25%. The other types show significant increases.

In 2010 almost half of the foreign guests chose campsites followed by hotels. There was a significant increase in connection with the holiday homes as a result of which their ratio currently stands at 13%. The share of other type of accommodation establishments is negligible (Table 6).

The domestic guest nights in the region grew from 123 thousand to 196 thousand, which represent an almost 60% improvement. The greatest, more than double, increase can be observed at hotels, but pensions and holiday homes had a significant increase as well. In 2010 the visitors spent one third of all guest nights at hotels, in 1990 this rate did not even reach 10%. The rate of pensions and holiday homes is similar (24–20%) respectively. In 1990 campsites were in the forst place with 80%, currently their rate does not reach 20%.

Table 6

Distribution of accommodation establishments in the Lake Tisza area

Type	2000		2005		2008		2010	
	unit	capacity	unit	capacity	unit	capacity	unit	capacity
Commercial	67	4 121	91	10 865	90	11 055	89	11 071
Hotel Type	33	1 268	40	2 155	39	2 362	42	2 455
Hotel Type	7	721	15	1 128	13	1 172	13	1 124
1*	1	40	3	191	4	250	2	79
2*	1	106	4	217	3	183	3	166
3*	4	293	7	608	5	643	5	512
4*	1	282	1	112	1	96	2	143
5*	–	–	–	–	–	–	1	224
Pension	26	547	25	1 027	26	1 190	29	1 331
Other type	34	2 853	51	8 710	51	8 693	47	8 616
Tourist hostel	3	139	2	237	3	87	2	67a1’
Youth hostel	1	112	2	168	3	342	2	363
Holiday house	18	505	24	1 155	24	1 150	22	1 020
Camp site	12	2 097	23	7 150	21	7 114	21	7 166
Private	630	3 706	787	5 148	960	6 790	1 014	7 327
Paying guest service	135	656	463	3 053	489	3 599	519	3 990
Rural accommodation	495	3 050	324	2 095	471	3 191	495	3 337
Total	697	7 827	878	16 013	1 050	17 845	1 103	18 398

Source: Hungarian Central Statistical Office, edited by the authors

Conclusions

In the system of tourism ecology lake tourism comprises of nature-, eco-, culture-, and heritage tourism as tourism product (DÁVID-CSOBÁN 2010). Tourism ecology examines lake tourism from three aspects: human ecology focuses on the relations between society and tourism; landscape ecology is a study of how landscape is tructrured and how it is utilised; and settlement ecology examines the relations between urbanisation processes and tourism.

The similarity in respect of development possibilities at all four examined lake areas are cycling tourism and water tourism.

Owing to European Union subsidies bicycle tracks are buing built around the lakes and adjoin the great European tracks (EUROVELO-network), thus cycle tourism may become a key sector of lake tourism. Most cycle tourists spend 3–4 days at a destination near our rivers and participate in cycle tours in a hub-and-spoke way. They mainly make use of hospitality services, which are mostly catering facilities along the shore. A significantly wider range of services are used by them than by angling tourists, although it is also proved that cycling tourists attend a lot less leisure-time and cultural programmes. In their responses the interviewed cycling tourists mentioned that the reason of their visit may be relaxing, uniqueness, cultural sites and programmes, areas near their residence, wine tasting, and the weather. The greatest value for them was the presence of water but they also commended the quality of the newly built bicycle tracks.

The other product that could be further developed is water tourism; the greatest possibilities of shipping lie with excursion boats, event boats, and possibly holiday boats. In water considering angling tourism people may choose from three different options: they may fish from the shore, from a rowing boat, or from a power-boat. Since success may depend on the familiarity of the place most anglers insist on palces they are accustomed to and this may be the reason why angling tourism is characterised by a hub-and-spoke nature. Waterskiing and personal water crafts belong to the sport category. They are usually linked to specific areas where the boats or personal water crafts can be stored ald launched safely.

The third breakout point may be the development of a system of theme parks of which adventures parks are gaining popularity.

The development of lake tourism also comprises of gastro tourism as well as event-, angling-, and equestrian tourism. There are observable differences among the priorities thus cultural and heritage tourism is more significant at Lake Balaton while at Lake Fertö and Lake Tisza the top priority is eco-tourism.

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THE ALQUEVA RESERVOIR IN PORTUGAL: TOWARDS THE DEVELOPMENT OF A NEW LAKE DESTINATION

Ana Isabel Rodrigues[1], *Antónia Correia*[2], *Metin Kozak*[3]

[1] Polytechnic Institute of Beja, Portugal
[2] CEFAGE, Faculty of Economics Algarve University, Portugal
[3] Foca School of Tourism and Hospitality Management
Dokuz Eylul University, Turkey

K e y w o r d s: Alqueva Lake, Lake tourism, lake destination, tourism development, natural environment.

A b s t r a c t

A number of well-known tourism destinations around the world are based on lakes as the main attraction. Although is still difficult to determine the economic significance of lakes, lake tourism has been recognized as a relevant subfield of tourism studies. Based on a PhD investigation related to lake tourism, this paper seeks to reveal and discuss the potential of the Alqueva reservoir as an emerging destination in the Alentejo region in the south of Portugal. This new resource has offered a naturally defined unit for tourism development since the reservoir started to fill up in 2002. Further research concerning destination image applied to the Alqueva Lake as a study area will provide valuable information for positioning and promoting it as a lake-destination in the future. Meanwhile, some of the challenges and contradictions in aligning the Alqueva as a resource with tourism development are highlighted in this paper.

ZBIORNIK ALQUEVA W PORTUGALII: ROZWIJANIE NOWEGO PRZEZNACZENIA W WYKORZYSTYWANIU JEZIORA

Ana Isabel Rodrigues[1], *Antónia Correia*[2], *Metin Kozak*[3]

[1] Instytut Politechniczny w Beja, Portugalia
[2] CEFAGE, Wydział Ekonomii Uniwersytet w Algarve, Portugalia
[3] Uniwersytet w Mugla, Turcja

S ł o w a k l u c z o w e: jezioro Alqueva, turystyka jeziorowa, rozwój turystyki, środowisko naturalne.

Address: Ana Isabel Rodrigues Polytechnic Institute of Beja, Portugal, e-mail: ana.rodrigues@ipbeja.pt

Abstrakt

Wiele znanych ośrodków turystycznych na świecie funkcjonuje w oparciu o jeziora, które stanowią ich główną atrakcję. Choć nadal trudno jest ustalić znaczenie ekonomiczne jezior, turystyka jeziorowa stała się już uznaną dziedziną badań. W oparciu o badania prowadzone w ramach pracy doktorskiej autorzy zaprezentowali i omówili potencjał zbiornika Alqueva jako tworzącego się ośrodka turystycznego na południu Portugalii. Począwszy od 2002 r., czyli od czasu, gdy zaczęto go napełniać wodą, zbiornik Alqueva jest w sposób naturalny określoną jednostką przeznaczoną do rozwoju turystycznego. Dalsze badania dotyczące wizerunku jeziora Alqueva jako miejsca docelowego dla turystów dostarczą cennych informacji pozwalających na ustalanie pozycji i promowanie jeziora w przyszłości. W prezentowanym artykule autorzy podkreślają niektóre z wyzwań i okoliczności utrudniających uznanie jeziora Alqueva za zasób odpowiedni do rozwoju turystyki.

Introduction

Lakes offer a naturally defined core resource for tourism development. There are several examples of lake-based destinations around the world, where regional or local attractions are mainly based on a lake resource. In fact, the potential of Europe in terms of lake destinations is well-recognized, which clearly justifies the adoption of a "lake tourism" concept under the wider concept of "water based tourism" (RYHANEN 2001). Nowadays, lake tourism is considered not only as an important type of tourism of economic value for certain destinations, but also academically as a subfield of tourism studies (HALL and HÄRKÖNEN 2006). Two different types of lakes should be distinguished: natural and artificial. The case of Alqueva Lake, a new artificial reservoir in Portugal since 2002, will be examined. This reservoir fulfils several functions as storage, water supply, hydroelectric and irrigation, considering the fact that this dam is located in Alentejo, the driest and hottest region of Portugal. The construction of the dam was crucial, since severe climate and the lack of infrastructures have blocked this region's development for decades, isolating it from national and European economies. Presently, the Alqueva Lake is a large reservoir in Europe (surface area 250 km^2; maximum depth 99 m; shoreline 1200 km; length 82 km). It is important to highlight that, like natural lakes, the importance of reservoirs for social and economic development has been already demonstrated (DUDA-GROMADA et al. 2010).

According to HALL and HÄRKÖNEN (2006), the idea of lake tourism is underpinned by a certain geographical entity which has arisen because of its particular environmental characteristics. In the case of Alqueva, the establishment of a new reservoir in 2002 has resulted in a lake resource considering the fact that it comprises several recent attractions contained in the nature, culture and community of the lake, generating new possibilities for tourism development. One of the basic elements of a tourism destination is well-defined spatial boundaries. Presently, a territorial delimitation has been conducted,

giving rise to a geographical area of seven municipal areas around the lake, which includes sixteen villages on the lakeshore (named "lakeside villages") spread over seven municipal areas[1] (*PE~AQUA*... 2003).

The tourist and recreational potential of Alqueva is rooted in the Alentejo region where it is located. Broadly, the Alentejo is considered to be an exceptional part of an unspoilt Portugal, full of character, barely touched by tourism and steeped in history. The Alentejo region is marked by nature and heritage, a vast landscape that varies considerably, from the open rolling plains of the south to the granite hills that border Spain in the north-east. With the construction of the Alqueva dam a completely new landscape has appeared since 2002. Where there used to be plains, roads and even villages there is now a considerable body of water known as the "Great Lake", which crosses two countries, Portugal and Spain[2]. New beauty came into being, mostly non-urbanized, characterized by a genuine landscape.

However, to be competitive, destinations must be managed from a strategic point a view. Since destination image is considered to be one of the most important marketing tools for a successful destination, an image study assumes a crucial step, even more so in the case of emerging destinations, such as the Alqueva Lake which is at the very beginning of tourism development. Therefore, framed by a Ph.D research with the purpose of identifying the main image variables of Alqueva as an emergent lake destination in order to develop in the future a reliable and valid scale of image management for this type of destinations, two key themes underpins this paper. First, knowledge of the process through which the Alqueva reservoir has emerged, highlighting some natural, cultural and tourism aspects; this will contribute to the Ph.D research since it provides a richer understanding of how the tourists perceived the Alqueva Lake as an emerging destination. Second, it is believed that the value of examining these elements provides important insights to engage in a discussion of the challenges, contradictions, and directions towards a tourism development as a lake-destination area.

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[1] The municipal areas located in the Portuguese part of the lake are the following: Alandroal, Moura, Mourão, Portel, Reguengos de Monsaraz, Serpa and Vidigueira. The lakeside villages are: Capelins, Juromenha, Póvoa de S. Miguel, Estrela, Luz, Granja, Alqueva, Amieira, Monte do Trigo, S. Marcos do Campo, Campinho, Monsaraz, Telheiro, Mina da Orada, Marmelar and Pedrógão, according to Gestalqueva (PE~*AQUA*... 2012). However, the legislation of the Destination Management Organization of Alqueva (TGLA) in 2008 determined only six municipal areas, excluding Vidigueira and Serpa, and including Barrancos. For more information about the legislation visit http://www.turismoalqueva.pt/media/attachments/24/2/Estatutos-do-Polo-Alqueva.pdf

[2] The Alqueva Reservoir resulted from damming the Guadiana River located on the Portuguese-Spanish border separating Extremadura and Andalucia (Spain) from the Alentejo and the Algarve (Portugal). The Guadiana's course covers a distance of 829 km, and it is the fourth-longest in the Iberian Peninsula, with a hydrological basin extending into an area of approximately 68,000 km/ (see Maia 2000). The Alqueva Reservoir covers the two countries. This paper focus on the Portuguese part of the Lake.

The Dam Construction: Background

The Alqueva dam is located in the Alentejo, a south-central region of Portugal separated from the rest of the country by the Tagus River. The Alentejo is rural and is the most depopulated region in the country. The Alqueva project has a long and well-established history: the Portuguese government decided to invest in water storage facilities to expand irrigation and supply water to the Alentejo region as a result of severe problems of physical and human desertification. This region has one of the lowest rates of rainfall over the whole Portuguese territory, generally varying between 500 and 600 litres per square meter *per annum*. At the same time, the inter-annual distribution of rainfall in the region is extremely irregular, varying between 250 litres/m^2 in dry years and 900 litres/m^2 in rainy years (EDIA 2000). As a result of an extremely irregular water flow, the only way to guarantee the supply of water from surface resources was by building large dams. The first reference to creating a water reserve in the Guadiana River dates back to the beginning of the 20th century. However, the Multipurpose Alqueva Project (MAP) was only implemented in 1957, as a part of the Alentejo Irrigation Plan. At that time the main goal was economic development based on the agricultural sector. The Project was only approved in 1975, with the Portuguese-Spanish Agreement in 1968 on international rivers. After advances and retreats during the 1970s and the 1980s, a *Global Assessment Study* of the project promoted by the European Commission Regional Development Office emerged as the central issue in this process. Portugal joined the European Union in 1986 together with Spain and since then, the financial support of the project by the European Commission (EC) was a key issue for the Portuguese government. As a result of this *Global Assessment Study,* the European Commission agreed to finance MAP only if became evident that it would play a key role for regional development. Finally, in 1995 the Portuguese government decided to proceed with the MAP with or without financial support from the European Union, as a means of setting up a strategic water reserve in this region. Alqueva was considered as a key project of the Guadiana River Basin Plan approved in 2001 (SANCHES and PEDRO 2006). This watershed is regulated on a national basis under a bi-state agreement between Portugal and Spain. On February 8th in 2002 the dam gates were closed and the Alqueva reservoir started to fill up.

In order to manage the whole MAP, a public limited company named EDIA (Alqueva Development and Infrastructures Company) was founded in 1995 by the Portuguese Government with the objective of conceptualizing, building and exploiting the MAP. Also aware of the importance of this project for the social and economic development of the region, EDIA included a business

perspective in its strategy, aiming to promote the development of 20 Alentejo municipalities, which are directly influenced by the MAP (EDIA). Among the various components of this project and as a result of the lake's size, sustainable tourism growth soon became a significant goal.

Natural Environment

The territory adjacent to the Alqueva Lake and its nearest surroundings (mainly located in the southeast) has a Protected Site classified by the European Union, which is part of the Natura 2000 network[3]. This Site is a Special Protection Area (SPA) named Moura/Mourão/Barrancos, which has 84,909 ha characterized by a heterogeneous landscape that varies between open treeless plains for cereal cultivation and *montados*. A *montado* is the agro-silvo-pastoral system specific to the Alentejo region, comprising an open formation of cork and holm oaks in varying densities, combined with a rotation of crops/fallow/pastures (PINTO-CORREIA and MASCARENHAS 1999). Despite the fact that it has been declining in recent decades, the *Montado is* one of the best examples of Mediterranean forest. The type of landscape generated by this agro-silvo-pastoral system is particularly attractive for relaxation and recreation (SUROVÁ and PINTO-CORREIA 2008: 313). Therefore, the typical landscape of the Alqueva Lake should be considered in the future as one of the most important resources for tourism development. Considering biodiversity, the Mourão/Moura/Barrancos SPA is also very important for the conservation of steppe birds as well as for many species of birds of prey (Black Vulture, Golden Eagle, Spanish Imperial Eagle, Bonelli's Eagle). This is the most important overwintering area of the Crane (*Grus grus*) in Portugal. It is also one of the priority areas for the conservation of the Iberian lynx (*Linx pardinus*). As for steppe birds, this SPA is an important overwintering area for the Great Bustard (*Otis tarda*) (LPN 2012).

In addition to this SPA, there are two more Sites classified by the Natura 2000 Network as Sites of Community Importance (SCI) in the terrains adjacent to the lake: a) Moura/Barrancos (43,309 ha) with an appreciable

[3] The Natura 2000 Network is a European ecological network which aims to preserve biodiversity by conserving natural habitats, wild flora and fauna in the European Union territory. The Natura 2000 Network is composed of sites classified as Special Protected Areas (SPA), by the Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds, including the migratory species and the habitats where they occur. Sites of Community Importance (SCI) classified according to the Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and wild fauna and flora which are considered threatened in the EU. For more information visit the website http://ec.europa.eu/environment/nature/natura2000/index-en.htm and also http://www.icnf.pt/ICNPortal/vEN2007/O+ICNB/Rede+Natura+2000/

physiographic and geological diversity, allowing the occurrence of various plant communities; it also includes one of the country's most important havens for bats; b) Guadiana/Juromenha (2,501 ha), very important for endemic flora; the location of the only two populations of *narcissus humilis* in Portugal (ICNF 2012).

Additionally, it should be highlighted that as a consequence of a large-scale transformation in this area, the management for multiple uses of the Alqueva reservoir has determined certain obligations for EDIA, who have recognized since the beginning of this process the environmental responsibility implicit in its action. In order to compensate for the loss of habitats due to the submersion of a very large area, EDIA has acquired the Noudar Nature Park (approximately 1,000 ha), which is representative of a genuine natural environment of this region. This park, located in the southeast area of the Lake, is included in the Natura 2000 network, forming an ecological set with Spanish protected areas. Noudar Nature Park is managed according to the maintenance of biologically diverse silvo-pastoral systems adapted to the necessities of conservation, which will promote the sustainable development of this area, making agriculture, forestry and tourism compatible (PNN). The maximization of the positive effects on biodiversity is at the crux of the management model of this park, which is also well prepared in terms of tourism, including comfortable accommodation for families and a portfolio of outdoor activities.

Another important attraction which has profoundly increased the value of the natural environment at Alqueva Lake is related with its sky. Alqueva was the first site in the world to receive the "Starlight Tourism Destination" certification, awarded to visitable places characterized by excellent quality for the contemplation of starry skies and the practice of tourist activities based on this resource. The Alqueva Dark Reserve is an area of 3000 km^2 and is spread over the lakeside villages. The ideal conditions for an excellent observation of the dark sky are ensured by this site with an average of 286 clear nights a year, a low level latitude (38degN) and minimal light pollution (DARK SKY ALQUEVA... 2012).

Cultural Factors

As has already been observed, the sudden creation of this enormous mass of water massively transformed the landscape. Sixteen villages are now located on the lakeshore, and underwent a profound transformation. Hence, the cultural and historic attraction of the lake is interweaved with this new territory that defines the Alqueva Lake as a lake-destination area. Despite the fact that these villages are not well prepared for tourism, they preserve and

value the history and living experiences of the local people over the centuries. As Cooper states "*local community is a key consideration on the cultural appraisal of lakes as a recreation and tourism resources*" (2003: 29). Regardless of their lack of infrastructures, their potential for tourism was already identified and recognized (*PE~AQUA*... 2012). In general they attract the visitor's attention with similarly-shaped white houses, framed in a deep blue, grey or yellow colour. Hence, the peaceful atmosphere surrounded by a rural landscape is worthy of interest.

Nevertheless, it is reasonable to remark upon some significant cultural attractions located alongside the lake. The medieval town of Monsaraz is one of the oldest Portuguese settlements of southern Portugal, occupied since prehistory, where visitors can walk and feel the atmosphere with a view over the lake. Also, there is a considerable number of castles spread over the surrounding area from the 13th and 14th centuries (Castles of Moura, Mourão, Terena, Alandroal, Portel, Noudar, Monsaraz)[4]. Additionally, northwest of the lake it is important to highlight the Juromenha Fortress (Alandroal) where the original fort was built in 1167 by the founder of Portugal in order to protect the area from the Moors and rebuilt in the 14th century. Despite its historical and cultural importance the fortress remains in bad condition requiring a programme of conservation.

Along with this heritage, a particular reference should be made to the remarkable process involved with the settlement of a new village ("Luz Village") totally built when the original village was flooded by the Alqueva dam. The procedure of relocation of the village was unique and has been pointed to as an example of how ethical values can be conciliated with the necessity of constructing a dam. In order to share this legacy, the Museum of Luz was founded in 2003 with the purpose of promoting and safeguarding the tangible and intangible heritage of Alqueva in the context of the Alentejo region, becoming one of the village's "memory buildings". From a small window in one of the museum's rooms, it is possible to identify exactly where the old Luz village once stood. A final consideration goes to the city of Évora which, despite the distance from the Lake (about 60 km from Monsaraz, Alandroal or Amieira), can be easily reached by car. Évora has been classified by UNESCO as World Heritage since 1986, preserving the remains of over a thousand years of history under Celtic, Roman, Visigoth and Arabian influences. This city is one the main touristic attractions in the Alentejo region.

[4] For more information about Portugal and Alentejo visit to the promotional websites of Portugal at http://www.visitportugal.com and Alentejo at http://wwwvisitalentejo.pt.

Tourism Infrastructures

As previously observed, the Alqueva Lake is a new resource for tourism in the Alentejo region. The evolution of tourism is intertwined with the evolvement of destinations, which go through a cycle similar to a life-cycle of a product. In general, destinations go through different stages of development due to their dynamic nature: exploration, involvement, development, consolidation, stagnation (BUTLER 1980). Framed by this well known analytical model applied to the Alqueva Lake, the following considerations might emerge: (a) the delimitation of the physical boundaries of Alqueva as a lake-destination area is very recent, and sometimes is still misleading; b) the type and scale of tourism for Alqueva in particular and the Alentejo in general is being discussed within a recent tourism regional plan; b) the relatively recent foundation of a Destination Management Organization for Alentejo and Alqueva named as "Terras do Grande Lago Alqueva" (TGLA)[5], within the intervention of the public sector in tourism; c) the absence of a clear and well defined image and positioning in the market; d) the implementation of initiatives to promote the destination, and provide the tourism product development such as the Dark Sky certification. Arguably, it could be concluded that Alqueva as a lake-destination area is at the very beginning of the life-cycle, apparently at the "involvement stage".

Therefore, the concept of a life cycle helps to understand how situation-specific life-cycle conditions influence the level of touristic infrastructure development in a particular destination. In the case of the Alqueva Lake and in terms of its supply there is some accommodation, although a qualification process should be implemented. TGLA is in the process of developing and collating information, monitoring the state of the tourism supply on the Alqueva Lake. A preliminary version of the accommodation inventory was undertaken by the TGLA and identified 31 accommodation establishments, mostly classified as rural tourism within the categories of rural hotels and farmhouses, according to the Portuguese legislation. The houses are located in a rural and calm environment, rustic or in old manor houses, in direct contact with nature and local traditions. Some of them provide opportunities for tourists to take advantage of the immense landscape extending through the

[5] "Turismo Terras do Grande Lago" (TGLA) is the Local Management Organization responsible for the management and marketing of Alqueva as a lake-destination area, founded in 2008, according to the TGLA ordinance 1151/2008 de 13 Outubro. However, it must be noted that the Portuguese Government has announced a significant change in the structure of the public administration of tourism, which probably will lead to the integration of TGLA in the current Regional Management Organization promoting the Alentejo as a destination (ERT Alentejo). Presently, (August 2012) the final decision has not yet been announced which, in fact, contributes to some uncertainty related to Alqueva's management as a lake-destination in the future.

plains with various sport activities such as horse riding, cycling, bird watching, canoeing, among others. Most of the accommodation already existed before the rise of this large body of water; however new small projects were then installed after the Alqueva reservoir due to its significant potential. Meanwhile, new major tourism projects are projected on the lakeshore, in accordance with the POAAP (Alqueva and Pedrogao Dam Plan). This territorial planning instrument clearly defines the guidelines for the land-use in the Alqueva area, particularly for tourism.

As destinations are an amalgam of components and experiences, water-based activities are of paramount importance for lake-destinations. On the Alqueva Lake, this type of activities is primarily based on the first major nautical project located in "Amieira village", one of the sixteen "lakeside villages" already mentioned in this paper. The programmes on the Lake consist of scheduled passenger cruises (SPC) and houseboat renting (HBR). In terms of SPC, this service is provided by three cruise boats, stopping at various points of interest located in some of the "lakeside villages", of which three have the capacity for 25 passengers and one for 120 passengers; the HBR consists of a different concept of accommodation offering the ultimate freedom for tourists who love the water, with a plot composed of seven houseboats with a capacity that ranges from 4 to 12 passengers (*Amieira Marina* 2012). Apart from this service, there are five more nautical companies according to the TGLA inventory, mainly small and family projects, focused on sailing and motorboat cruises, with or without crew. It is also noteworthy to mention some infrastructure requirements vital for the development of water-based activities on lakes. Presently, Alqueva Lake has only one marina installed near Amieira village with all the basics, and some small wharfs spread out among the lakeside villages. It is expected that in the future more appropriate infrastructures will come into existence in response to the tourism and recreational potential of the Lake, following the rules established by the POAAP (Spacial Planning of Alqueva and Pedrogão Reservoirs) implemented since 2002.

Discussion and Conclusion

So far the previous sections have provided a description of the Alqueva Lake project as well as its potential for tourism development. There is no doubt that Alqueva is at the very beginning of the life-cycle as a lake-destination area. The purpose of this section is to introduce and briefly discuss, based on a literature review of lake tourism, important issues concerning the Alqueva Lake as a future lake-destination area.

Firstly, an integrated lake management approach should be implemented since lakes are complex destination systems (COOPER 2006). Coordination is essential in all types of destinations, but even more on lakes as open systems. The vulnerability of lakes since they represent fragile eco-systems, the multiple uses of lakes, the level of complexity of coordinating all the different stakeholders involved in the destination, demands a holistic view of the lake. In the case of Alqueva, the large number of organizations implicated in the management of the lake leads to a high level of responsibility fragmentation[6]. Given the difficulty of managing the Alqueva Lake as a single entity due to the fact that this reservoir didn't exist until 2002 and now a new reality has arisen, crossing different territorial boundaries; in the near future it will be useful to implement a specific authority consisting of representatives from the different public sector agents involved in the management of the lake. Additionally, a partnership task force could emerge with public, private sector and community that could provide strategic advice and recommendations in the creation, monitoring and review of policies for developing and managing the Alqueva Lake and any issues related to its future.

Secondly, and in line with the earlier discussion, it will be of a great value if an integrated and specific management plan for Alqueva Lake could be implemented by the government of Portugal. This important planning instrument would be considered as the main driving force for the destination and, simultaneously could aggregate all the multiple stakeholders involved in the management process. According to COOPER (2006) the management of the Lake District in UK and the Great Lakes in North America are two good examples of a holistic management. The former, because there is a particular Development Plan for the Lake District under the supervision of a specific Authority (Lake District National Park Authority); the latter for the reason that each lake of the Great Lakes (five in total) has its own management plan but are still linked, and also because the management programme is subject to an international management agreement between USA and Canada. The same situation happens on the Alqueva Lake, since this is a lake that crosses two different countries (Portugal and Spain).

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[6] The management of the Alqueva Lake involves multiple organizations, each one with a more direct or indirect impact on its development in various fields. These are some examples of the large number of entities involved: IPA (Portuguese Environment Agency) responsible for implementation of the national policy of water resources; EDIA responsible for the management of the Alqueva Dam, already presented in this paper; CCDRA (Coordination Commission of Regional Development of Alentejo) implements the government policy for planning, environment and development in Alentejo; ATTGLA (Association of the Alqueva Evolving Municipal Areas in Portugal and Spain); TGLA (Alqueva Lake Great Lands) responsible for management and marketing Alqueva as a tourism destination; ERT Alentejo (Regional Tourism Organization for Alentejo), responsible for management and marketing Alentejo as a tourism destination.

Thirdly, tourism on lakes takes place in the surrounding area of the lake and not exclusively on the lake itself (HALL and HÄRKÖNEN 2006). Naturally, linked to the definition of lake tourism is the idea that there is a geographical entity with particular environment characteristics. This feature becomes, probably, more evident on natural lakes which always existed in a particular place than on lakes artificially created. Given the background of Alqueva as a new lake that has existed only since 2002, one of the central discussions is the need for a clear delimitation of the territorial boundaries of Alqueva as a lake-destination area. This has been an undefined process considering the fact that there are two different standpoints: (i) the first was established in 2003 (*PE~AQUA*) by EDIA based on the concept of sixteen "lakeside villages" within seven municipalities adjacent to the lake (ii) the second was adopted by TGLA from 2008 more focused on the municipal areas (six), which are not exactly the same as the former. Therefore, it is important and urgent to define a single position towards a geographical delimitation of Alqueva as a lake-destination, which must be assumed by the whole tourism industry. The future marketing planning for this destination is totally dependent on this particular, but fundamental aspect.

Lastly, marketing, product development and promotion are of paramount importance for the development of destinations. Also in lake-destination areas successful marketing is linked to a strong destination image (ERKKILA 2006). Therefore, it is important to continuously understand its formation process (BALOGLU and MCCLEARLY 1999, GARTNER 1993), within a geographical expansion of image studies applied to non-traditional entities (such as lake destinations), over almost forty years of an evolutionary research (RODRIGUES et al. 2012). Since the Alqueva Lake is at the very beginning as a lake-destination, consistent work on water-image formation should be implemented framed by the experience economy as the 21st century's paradigm. Moreover, waterscapes are considered to be a significant challenge for tourism marketing, because of their pleasantness as an environment and attractiveness as a landscape (TUOHINO and PITKÄNEN 2004). An image study will then provide valuable information for positioning, differentiation, and promoting Alqueva as a lake-destination area in the future within a national and a regional marketing strategy.

In terms of product development, the idea of the gateway approach first proposed by GUNN (1979) which GARTNER (2006) explored applied to lake areas, could be implemented in the Alqueva Lake in terms of product development, promotion and distribution. Gateways are seen as consumption centres, which offer products from different service providers in a central location. However, gateways are not only applied in terms of location in a physical space, but nowadays they can be understood in terms of new technologies in tourism.

This idea of gateways, in the case of lake destinations, is of great importance due to the complex destination system as mention before. Presently, the concept of gateways applied to lakes involves the existence of a website as a promotion and distribution tool, providing information from the multiple services providers (e.g. accommodation, activities, events, restaurants) on the lake in an integrated and coordinated model. Alqueva Lake should in the future develop a website, since from a customer point of view destinations are viewed like any other product[7]. In a more developed stage with a considerable level of supply in nautical activities, the adoption of the "Nautical Resort" concept developed in Spain and France for sea water could also be explored on lakes, specifically on the Alqueva Lake. Undoubtedly, this model of "product engineering" development should be rooted in a strong destination image of the lake.

In conclusion, the aim of this paper was to draw attention to a new reservoir located in a rural region of Portugal. The potential of the Alqueva Lake and the adjacent areas for tourism is mainly due to the specific natural environment, typical landscape and cultural resources of an essentially non-urbanized territory. As a lake-destination, Alqueva is at the very beginning of the life-cycle, which leads to the need for a successful marketing approach and action. Further research will contribute to determine the main attributes that should promote the Alqueva Lake for tourism purposes in the near future.

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[7] There are good examples of websites for lake-destinations areas. The website of Lake District in Italy is a good example of product development, promotion and distribution tool of a destination-lake area. For more information visit the http://www.distrettolaghi.it.

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A COMPARISON OF MILLING VALUE OF SPELT WHEAT AND COMMON WHEAT GRAIN GROWN IN ORGANIC FARMING SYSTEM

***Małgorzata Warechowska*[1], *Józef Warechowski*[2], *Józef Tyburski*[3]**

[1] Chair of Fundamentals of Safety
[2] Chair of Process Engineering and Equipment
[3] Department of Farming Systems
University of Warmia and Mazury in Olsztyn

Key words: spelt wheat, common wheat, kernel quality, milling properties, organic farming.

Abstract

The objective of the studies was to compare the milling properties of spelt wheat and winter and spring common wheat kernels. The studies were carried out with winter spelt wheat cv. Schwabenkorn and Franckenkorn and with common wheat: winter variety cv. Korweta and spring variety cv. Bombona. Spelt wheat and common wheat were grown in organic farming systems. The evaluation of kernel milling value was performed based on the physical and chemical kernel characteristics and with a trial laboratory milling. Thousand kernel weight, test weight, vitreousness, hardness and content of total ash in the kernels and flour were determined. The milling efficiency factor *K*, ash number and specific energy for kernel comminution (E_r) were calculated. The granulometric composition of middlings (milling product) was also determined with laser diffraction.

It was shown that spelt wheat kernels had lower milling parameters than common wheat grain. Out of the tested grain samples, spelt wheat – in comparison with common wheat – had a more floury structure of the endosperm and significantly higher ash content in kernels. Less flour was obtained from spelt wheat than from common wheat. The highest volume of flour was produced from spring wheat cv. Bombona. Specific energy input for milling of spelt wheat kernels was significantly lower in comparison with common wheat. The milling of common wheat cv. Bombona consumed the highest amount of energy; it resulted from higher hardness of kernels. The average particle size of the products obtained by common wheat milling was positively correlated with vitreousness of grain.

Address: Małgorzata Warechowska, University of Warmia and Mazury, ul. Heweliusza 10, 10-719 Olsztyn, Poland, phone: +48 (89) 524 56 13, e-mail: gosiaw@uwm.edu.pl

PORÓWNANIE WARTOŚCI PRZEMIAŁOWEJ ZIARNA ORKISZU I PSZENICY ZWYCZAJNEJ UPRAWIANYCH W SYSTEMIE ROLNICTWA EKOLOGICZNEGO

***Małgorzata Warechowska*[1], *Józef Warechowski*[2], *Józef Tyburski*[3]**

[1] Katedra Podstaw Bezpieczeństwa
[2] Katedra Inżynierii i Aparatury Procesowej
[3] Katedra Systemów Rolniczych
Uniwersytet Warmińsko-Mazurski w Olsztynie

Słowa kluczowe: pszenica orkisz, pszenica zwyczajna, jakość ziarna, właściwości przemiałowe, rolnictwo ekologiczne.

Abstract

Celem badań było porównanie właściwości przemiałowych ziarna pszenicy orkiszu z ziarnem ozimej i jarej pszenicy zwyczajnej. Materiał badawczy stanowiło ziarno orkiszu ozimego odmian Schwabenkorn i Franckenkorn oraz pszenicy zwyczajnej: formy ozimej odmiany Korweta i jarej odmiany Bombona. Orkisz oraz pszenica zwyczajna uprawiane były w systemie rolnictwa ekologicznego. Wartość przemiałową ziarna oceniono na podstawie jego cech fizykochemicznych oraz wykonując próbny przemiał laboratoryjny. Oznaczono masę tysiąca ziaren, gęstość w stanie usypowym, szklistość, twardość oraz zawartość popiołu całkowitego w ziarnie i w uzyskanych po przemiale mąkach. Obliczono współczynnik efektywności przemiału *K*, liczbę popiołową oraz określono jednostkową energię rozdrabniania ziarna (E_r). Wyznaczono także skład granulometryczny śruty metodą dyfrakcji laserowej. Wykazano, że ziarno orkiszu cechowało się gorszymi właściwościami przemiałowymi niż ziarno ozimej pszenicy zwyczajnej. Spośród badanych prób ziarna, orkisz w porównaniu z pszenicą zwyczajną cechował się bardziej mączystą strukturą bielma oraz istotnie większą zawartością popiołu w ziarnie. Z ziarna orkiszu uzyskano mniej mąki niż z pszenicy zwyczajnej. Największą ilość mąki uzyskano z pszenicy jarej odmiany Bombona. Jednostkowe nakłady energetyczne na przemiał ziarna orkiszu były znacząco mniejsze niż na przemiał ziarna pszenicy zwyczajnej. Najwięcej energii wymagał przemiał ziarna pszenicy zwyczajnej odmiany Bombona. Wynikało to z większej twardości ziarna. Średni rozmiar cząstek produktów przemiału pszenicy zwyczajnej był dodatnio skorelowany ze szklistością ziarna.

Introduction

Spelt wheat (*Triticum spelta L.*) is one of the oldest species of wheat. In recent years there has been a growing interest in spelt wheat, which is mainly utilized in the milling and cereal industry. This interest may result from the nutritional values of spelt wheat. It is thought (BONAFACCIA et al. 2000, SULEWSKA et al. 2008, BIEL et al. 2010) that spelt wheat grain has a more beneficial chemical composition and better nutritional value in comparison with common wheat grain. It contains more protein with higher nutritional value, lipids, mineral compounds, vitamins and dietary fiber (MARCONI et al. 1999, BONAFACCIA et al. 2000, ABEL-AAL, HUCL 2002, RUIBAL-MENDIETA et al.

2005). Spelt wheat is a very valuable crop for organic agriculture, since it has retained its native characteristics and it is therefore well suited for organic methods of growing. It should be emphasized that the advantage in yielding of common wheat over spelt wheat decreases in sites of less favourable growing conditions (CASTAGNA et al. 1996, LACKO-BARTOSOVA, OTEPKA 2001).

Technological characteristics of spelt wheat, similar to common wheat, are determined based on such parameters as kernel milling value and baking flour value. Physical and chemical parameters and a milling laboratory test constitute the kernel milling value (DZIKI, LASKOWSKI 2005). Kernel parameters influence the milling and quality of flour. According to POSNER (2003), the quality of flour depends in app. 75% on the quality of raw material and in app. 25% on milling technology. The quality of flour is important in the subsequent stages of processing and exerts an impact on the properties of final products such as bread, pasta, cakes, cookies, and other bakery products (KONIK et al. 1992, STEVE et al. 1995, ZHANG et al. 2005).

Since the area of spelt wheat growing is expanding in Poland and around the world, it becomes necessary to evaluate its grain for milling value. Improvement of milling properties is an important aspect of common wheat and spelt wheat breeding programs. It is of particular importance in organic production in which there is a limited capacity for influencing grain quality due to elimination of fertilization with synthetic nitrogen and of synthetic crop protection agents. Therefore, the objective of the studies was to compare the milling properties of spelt wheat and common (spring and winter) wheat grown in organic system.

Materials and Methods

The study was carried out with winter spelt wheat cv. Schwabenkorn and Franckenkorn and common wheat: winter variety cv. Korweta and spring variety cv. Bombona, all grown in organic system. The samples of grain originated from 3 certified organic farms located in Budziszewo (heavy soil), Zgniłobłoty (medium soil) and Łęgno (medium soil) from the harvests collected in 2010. The samples of spelt wheat, each 10 kg, were hulled on a laboratory device LD 180 ST 4 (WINTERSTEIGER). The evaluation of milling value was carried out based on the physical and chemical properties of grain and a trial laboratory milling in a Quadrumat Junior mill (Brabender) equipped with a cylindrical sifter wrapped with a 70GG sieve (PE 236 μm). The humidity of kernels (PN-EN ISO 712: 2009) was determined and then for 24 hours before milling grain was re-moisturized to 14.5% by adding an appropriate volume of water. Thousand kernel weight (PN-EN ISO 520:2011), test weight (otherwise:

bulk density of grains) (PN-EN ISO 7971-3: 2010), kernel vitreousness (PN70/R-74008) and total ash content in grain and in flour (PN-EN ISO 2171:2010) were also determined. Particle size index (PSI) was calculated as the mass percentage of particles smaller than 75 μm in the milled products in accordance with AACC 55-30:2000 method,

$$PSI = \frac{m_p}{m_0} \cdot 100\% \tag{1}$$

where:
m_p – weight of sieved material (d < 0.075 mm) [g],
m_0 – weight of collected sample [g].

The milling efficiency factor K (the quotient of flour yield to the content of ash in flour) and the ash number (the quotient of ash content in flour to the flour yield multiplied by 100000) were also calculated. The results were compared with a 5-degree scale of milling value developed in the Central Laboratory for Cereal Processing and Storage in Warsaw for the Quadrumat Junior mill (SITKOWSKI 2011).

The volume of energy used for comminution was determined based on the measurement of energy supplied to the mill. Comminution time was measured with a stop-watch to an accuracy of ± 0.1 s. The real power utilized by the mill was also measured. The energy necessary for putting the elements of the comminuter into motion was calculated as the quotient of real power of idle running to comminution time. The operation of comminuting a given grain sample was determined assuming that the total energy consumed by the comminuter equaled the sum of energy for comminuting and energy for putting its elements into motion. The specific energy for comminuting E_r (kJ kg^{-1}) was determined with the following equation,

$$E_r = \frac{E_c - E_s}{m} \tag{2}$$

where:
E_c – total energy consumed by feed mill [kJ],
E_s – energy of idle running ($E_s = P_s \cdot t_r$) [kJ],
m – weight of comminuted sample [kg].

The granulometric composition of middlings (milled grain, the milling product) was also determined with laser diffraction analysis (LDA) on a Mal-

vern Mastersizer 2000 analyzer. The results of the measurement were the mean from three subsequent repetitions. The analysis of granulometric composition of middlings (milled grain) allowed us to determine the average size of particle according to the following formula (VELU et al. 2006):

$$d_p = \sum_{i=1}^{n} \varphi_i d_i \tag{3}$$

where:
φ_i – proportion of size fraction i in the tested sample [kg kg^{-1}],
d_i – average size of i fraction particles [μm],
n – number of size fractions.

The sizes of particles corresponding to the level of sieving at 10%, 50% and 90% (d(0.1), d(0.5) and d(0.9), respectively) were determined with the cumulative function of the granule size composition of milled product. The relative width of distribution (SPAN) was calculated with the following formula:

$$\text{SPAN} = \frac{d(0.09) - d(0.01)}{d(0.5)} \tag{4}$$

The results were statistically analyzed. The analysis of variance was performed with STATISTICA® for Windows v. 10 (StatSoft Inc.). The significance of differences between the means was determined with Tukey test. The statistical hypotheses were tested at $\alpha = 0.05$.

Results and Discussion

The results of evaluation of quality parameters in spelt wheat and common wheat grain are presented in Table 1. The tested samples of grain were differentiated in the majority of indirect indices of milling value. The test weight of winter wheat variety Korweta was highest (71.9 kg hl^{-1}) and significantly different from the test weight of tested spelt wheat varieties. The variety Bombona of spring wheat significantly differed in its test weight from the variety Schwabenkorn of spelt wheat. Thousand kernel weight (TKW) is one of the basic indices of sowing potential and commodity quality of cereals; it indicates the ripeness of grain. TKW for the tested spelt wheat grain ranged from 39.0 to 43.5 g and was significantly higher than TKW for common wheat. It is thought (POSNER 2003) that thousand kernel weight corrected to the

constant level of humidity is a good indicator of milling properties, including the milling yield of flour. The main factors that influence the behavior of grain during milling are vitreousness and hardness of kernels (GREFFEUILLE et al. 2007a, GREFFEUILLE et al. 2007b, DZIKI et al. 2011). Among the tested samples, only the kernels of winter wheat variety Korweta had a vitreous structure of the endosperm. The grain of spelt wheat and spring wheat cv. Bombona was floury. The kernels of spelt wheat were less vitreous than common wheat. The hardness of the tested kernels expressed with PSI ranged from 30% for spring wheat cv. Bombona to 64% for winter wheat cv. Korweta. The kernels of Bombona variety were classified as soft, whereas the grain of spelt wheat and common wheat cv. Korweta was categorized as extra soft.

Table 1
Results of the evaluation of physical and chemical parameters of common wheat and spelt wheat kernels

Trait	Common wheat		Spelt wheat	
	Korweta	Bombona	Franckenkorn	Schwabenkorn
Test weight [kg hl^{-1}]	71.9^{c}	67.3^{a}	67.2^{a}	69.6^{b}
Thousand kernel weight [g]	36.5^{a}	36.7^{a}	39.0^{b}	43.5^{c}
Vitreousness [%]	60^{c}	32^{b}	6^{a}	9^{a}
PSI [%]	64^{a}	30^{b}	62^{a}	59^{a}
Ash in grain [%]	1.94^{c}	1.75^{b}	2.07^{a}	2.09^{a}

Explanatory notes:
a, b, c – differences of values in letter (for the given variety) marked with the same letters are insignificant at $\alpha = 0{,}05$

The content of ash in the tested samples of spelt wheat was relatively high: 2.07% for the Franckenkorn variety and 2.09% for the Schwabenkorn variety. A comparable concentration of ash in spelt wheat kernels was reported by CAPOUCHOVA (2001) and MARCONI et al. (2002). Similar to the studies by other authors (KRAWCZYK et al. 2008a, CACAK-PIETRZAK, GONDEK 2010), spelt wheat grain had a higher ash content than common wheat kernels.

Milling yield of flour is used for a direct evaluation of the milling properties of common wheat grain. The yield of flour obtained from spelt wheat grain was significantly lower than the yield of flour produced by milling of common wheat kernels (Table 2). The highest flour yield (69.1%) was recorded for spring wheat cv. Bombona. Numerous studies (ABDEL-AAL et al. 1997, CAPOUCHOVÁ 2001, MARCONI et al. 2002, KRAWCZYK et al. 2008b) have indicated that milling of spelt wheat produces less flour in comparison with common wheat; it indicates its worse milling parameters. This was confirmed in our studies. It is thought (POSNER 2003) that flour yielding is positively correlated

with thousand kernel weight. Our studies revealed a reverse correlation. Together with the increase in thousand kernel weight, the yielding of flour decreased (r = -0.609) (Table 3). According to the data found in the literature (DOBRASZCZYK 1994, HADDAD et al. 1999, TURNBULL, RAHMAN 2002), higher yielding of flour is associated with higher vitreousness of the endosperm and hardness of kernels. It was evidenced by our studies with the correlation coefficients between the volume of flour and the structure of wheat endosperm and between the volume of flour and PSI (Table 3).

Table 2

Results of the evaluation of milling value of common wheat and spelt wheat grain

Trait	Common wheat		Spelt wheat	
	Korweta	Bombona	Franckenkorn	Schwabenkorn
Milling yield [%]	62.5^{c}	69.1d	52.9^{a}	57.2^{b}
Total ash content in flour [%]	0.57^{ab}	0.66^{b}	0.52^{a}	0.55^{ab}
Milling efficiency factor K [–]	111^{b}	105^{a}	101^{a}	105^{a}
Ash number [–]	904^{a}	976^{a}	991^{a}	958^{a}
Energy for comminuting [kJ kg^{-1}]	55^{b}	65^{c}	36^{a}	36^{a}
SPAN	11.482^{c}	2.426^{b}	9.922^{a}	9.207^{a}
Average particle size of milling product d_{Sr} [µm]	129.262^{a}	230.505^{b}	128.764^{a}	141.321^{a}
Assessment of milling value	medium – sufficient	low	low	low

Explanatory notes as in Table 1.

Table 3

Statistically significant values of linear correlation coefficients between the physical and chemical parameters of kernels and the milling parameters

Trait	Milling yield	Total ash content in flour	Milling efficiency factor	Ash number	Energy for comminuting	Average particle size of middlings
Test weight			0.816			
Thousand kernel weight	–0.609	0.729			–0.789	
Ash in grain	–0.922	–0.819			–0.949	
Vitreousness	0.848	–0.894	0.896		0.772	0.920
PSI	–0.777	–0.866			–0.708	–0.993

Ash content in flour is an important index in the evaluation of milling properties. Kernels with low ash content, particularly in the endosperm, are desirable raw materials for the cereal and milling industry. The ash content in flour ranged from 0.52% (spelt wheat cv. Franckenkorn) to 0.66% (common wheat cv. Bombona). A statistically significant difference was detected only between the ash content in flour produced from common wheat cv. Bombona and flour produced from spelt wheat cv. Franckenkorn. Contrary to the results of other studies (CACAK-PIETRZAK et al. 2005, SOBCZYK et al. 2009, CACAK-PIETRZAK, GONDEK 2010), the content of ash in flour was negatively correlated with the content of ash in grain ($r = –0.819$).

Most of the mineral components in grain are concentrated in the layer adherent to the seed cover and within the seed cover. High ash content in wheat grain is reflected in a higher concentration of mineral compounds in the endosperm. Consequently, this results in an increase in the ash content in produced flour (POSNER 2009). However, according to SPIEGEL and KLABUNDE (1995), correlations between the ash content in grain and in the endosperm and the ash content in flour are related to its yielding. If the yielding is below 72%, only the content of ash in the endosperm exerts an impact on the content of ash in flour. If the yielding increases to 80%, the content of ash in the whole kernel influences the ash content in flour.

In order to compare the milling properties of common wheat and spelt wheat, the milling efficiency coefficient K was calculated; it includes flour yield in relation to its ash content. The values of milling efficiency coefficient K ranged from 101 to 111 (Table 2). The highest milling efficiency was detected for the kernels of common wheat cv. Korweta; this result combined with the ash number (904) classifies it as a grain with moderately satisfactory milling properties. Both spelt wheat and spring wheat cv. Bombona were categorized as poor. The comminution of common wheat kernels required higher energy input than that necessary for the comminution of spelt wheat grain. Significant correlations were found between the vitreousness of common wheat and the energy requirement for comminution ($r = 0.772$). Spelt wheat that has a floury structure of the endosperm did not require such high energy input as more vitreous kernels of common wheat. According to PUJOL et al. (2000), differences in the consumption of energy for comminuting common wheat varieties with soft and hard endosperm may amount to 100%. CACAK-PIETRZAK et al. (2009) and CACAK-PIETRZAK, GONDEK (2010) claim that vitreous kernels are more resistant and require higher energy input for comminution. The reason lies in the structure of the kernel. In vitreous kernels, starch grains are deeply embedded in the protein matrix in contrast with the structure of floury kernel which has a loose endosperm structure.

Granule size composition of milled products (flour, crushed cereal meal) is an important parameter of milling value, since it influences further stages of

processing. It determines the properties of flour during dough-making and baking. It also exerts an impact on the water absorption capacity of flour (POPPER et al. 2006). According to PARK et al. (2006), the size of flour particles is one of two most important parameters (after protein content and parameters of flour quality) which influence the porosity of wheat bread. Granule size composition is associated with the volume content of individual components of comminuted kernels that are finally found in different size fractions of milled grain. Milled products are composed of a number of fractions. The multimodal nature of granule size composition of milled cereals grain has also been shown by other authors (DEVAUX et al. 1998).

All tested milled products were highly poly-dispersive. Based on the curves of granule size composition, five fractions are identified (Figure 1) that constitute milled products. The milling of spelt wheat yielded five fractions, whereas the milled products from common wheat cv. Bombona did not contain 1 μm and 100 μm fractions. The fraction composition of milled products obtained from common wheat cv. Korweta approximated that of spelt wheat, but the proportion of 100 μm fraction was significantly smaller (app. 75% of this fraction in comparison with spelt wheat). The granule size composition of milled products from common wheat cv. Korweta included the particles of 200 μm as the basic fraction and the traces of 30 and 4 μm fractions. Two fractions, i.e. 30 and 600 μm, were predominant in the milled products obtained from spelt wheat and common wheat cv. Korweta. The relative width of particle size distribution (SPAN) ranged from app. 2.5 for common wheat cv. Bombona to app. 11.5 for Korweta variety (Table 2). The statistical analysis did not reveal any significant differences between the SPAN determined for the tested spelt wheat varieties; this value amounted on average to 9.5.

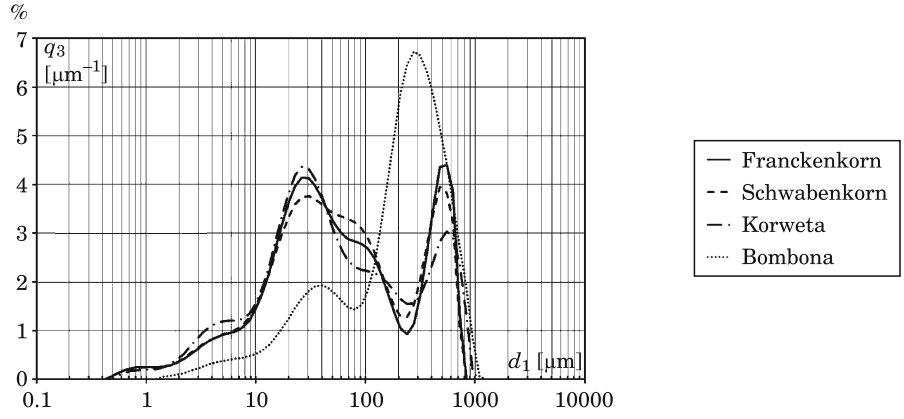

Fig. 1 Granulometric composition of middlings obtained from common wheat and spelt wheat

The average particle size ranged between 130 to 230 μm. Significant differences were found between the average particle size of the milled product obtained from common wheat cv. Bombona and the other tested common wheat varieties. The statistical analysis revealed a high correlation between the average particle size of the milled product and the vitreousness of kernels (Table 3). A significant negative correlation between PSI and the average particle size of milled product obtained from the tested material is explained with a mathematical relation linking these indices.

Conclusions

1. Spelt wheat grain had worse milling parameters than winter wheat kernels.
2. The specific work utilized to comminute spelt wheat grain is significantly lower in comparison with common wheat grain.
3. The average particle size of the milled products obtained from common wheat varieties was positively correlated with the vitreousness of kernels.

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