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Research Article

Share of rushes in water uptake in shallow lakes in eastern Poland

Joanna Sender[1,*], Monika Różańska-Boczula[2] and Antoni Grzywna[3]

[1] Department of Hydrobiology and Protection of Ecosystems, University of Life Sciences in Lublin, Dobrzańskiego 37, 20-262 Lublin, Poland
[2] Department of Applied Mathematics and Computer Science, University of Life Sciences in Lublin, Poland, 28 Głęboka Street, 20-950 Lublin, Poland
[3] Department of Environmental Engineering and Geodesy, University of Life Sciences in Lublin, Leszczyńskiego 7, 20-069 Lublin, Poland

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Abstract – The intensity of transpiration depends on many environmental factors including light, temperature, wind, and air humidity. By eliminating the variation of these factors under laboratory conditions, an attempt was made to indicate the intensity of this process among different species of helophytes and are there any factors limiting this process. We performed a field study of some shallow lakes to answer the question: what is the role of emergent macrophytes in evapotranspiration in lakes with different trophy and surface. Field works were carried out in the shallow littoral at the peak of the growing season. Under laboratory conditions five species were analysing in respect of water uptake. Under laboratory conditions, the width, length and number of leaves as well as the mass and diameter of the stems of respective species had the most significant effect on the uptake of water by helophytes. The length of the plant was a characteristic with the least significant impact on water uptake. The presence of inflorescence was highly negatively correlated with the amount of water taken up by the plants. This phenomenon may slow down the process of water uptake by plants. Among the analyzed factors affecting the uptake of water in the shallow lakes of the Łęczna-Włodawa Lake District, the most important effect was the area of rushes, their density and lake trophic type. In contrast, the type of lake supply, surface of the lake and the variety of helophytes proved to be irrelevant to the amount of water uptake. Helophytes play a significant role in the uptake of water. The share of *Typha* rushes significantly increases transpiration.

Keywords: emergent macrophytes / plant transpiration / lake / factors

1 Introduction

Dry regions of the Earth occupy almost one quarter of the continents, and permanent shortage of fresh water is observed in more than a half of the continents area. Precipitation and water resources are not distributed evenly. In some European countries, *e.g.* Norway, Slovenia, Great Britain, annual total precipitation exceeds 1000 mm. However, for example in Hungary or Poland precipitation rate is approx. 600 mm (Michalczyk and Sposób, 2011). Poland is included in the group of countries with the lowest water resources (approx. 1500 m^3 per capita per year), while the average value for Europe is 4.500 m^3 per year (Ciepielowski, 1999).

Water resources of the specific region are directly dependent on the natural environment factors such as climatic conditions, geological structure, relief, soils, and land use. Climatic conditions are shaped by solar energy reaching the surface of the Earth, as well as by distance from seas or oceans. They determine the amount of precipitation, evapotranspiration and outflow. Since 1976, the global average temperature has risen at a rate approximately three times faster than in the 20th century (almost 0.6 °C). Mean precipitation rate is increasing in Northern Europe and decreasing in Southern Europe (Ivanova and Yanchev, 2015).

The Łęczna-Włodawa Lake District, despite apparent abundance of surface water, is actually an area with large water deficits resulting from low atmospheric supply and naturally small retention capacities (Michalczyk *et al.*, 2017). Water is a crucial component of high environmental values of the Łęczna-Włodawa Lake District – a lake and peatland region,

*Corresponding author: joanna.sender@up.lublin.pl

and its ability to self-regulation. This area has been subject to transformation for many years due to economic activities, especially irrigation works and intensification of agriculture, exploitation of groundwater, coal mining and use of the land for recreational purposes. Effective protection of the natural values of the Lake District as an area with unique environmental features on a European scale requires rational management of water resources in this area and undertaking protective measures.

The water regime in the area is shaped by terrain and climatic factors, mainly soil permeability, formation, precipitation and evaporation. Climatic conditions, shaped by incoming air masses, determine water poverty resulting from low supply and high water consumption for evapotranspiration. The average annual amount of precipitation, in the analyzed area, reaches about 560 mm, and in respective years its values range from about 400 to 900 mm. The average rate of evapotranspiration is approximately 450 mm, and potential evaporation exceeds 600 mm (Szajda, 1989). The given values indicate the occurrence of periodic water deficits, especially during summer periods, i.e. during the high water needs of vegetation (Wojciechowski, 1965).

Evaporation from the free surface of water is widely described in literature (Crundwell 1986; Chmal, 2008; Nowak, 2009, Grabowska *et al.*, 2016). An integral part of each water body are macrophytes, which often occupy a significant area. The influence of plants on water circulation in hydrogenic habitats, due to their adaptation to the conditions in which they occur, is much larger than that of terrestrial plants. Depending on the water conditions of the habitat, various plants develop in it. Macrophytes affect the physical, chemical and biological character of lakes, and are affected by a suite of factors such as lake morphometry, water chemistry, and biotic interactions (Carpenter and Lodge, 1986; Lacoul and Freedman, 2006; Hudon *et al.*, 2000; Lavrova and Koumanova 2008; Onaindia *et al.*, 2005). Their role largely depends on their qualitative and quantitative structure (Pieczynska and Ozimek, 1977; Sender, 2012; Kłosowski *et al.*, 2011). Evaporation of water through the emergent parts of plants inhabiting the shallow littoral zone of the lake is called transpiration. It is one of the important life processes of plants, consisting in uptake and transport of water containing dissolved nutrients (Kopcewicz, 2012).

In connection with the progressing process of lakes eutrophication in the Łęczna – Włodawa Lake District, and thus increased vegetation succession (Sender, 2009, 2018), it seems reasonable to undertake studies to highlight the role of helophytes in functioning of lakes, especially in the transpiration process. There is no literature data in this area analyzing this process. There is also little data on the participation, in transpiration, of different species of helophytes colonizing the lake littoral zone. Most studies focused primarily on wetlands (Anda *et al.*, 2015; Sánchez-Carrillo *et al.*, 2004, Yano *et al.*, 2017; Milani *et al.*, 2019), or selected species of helophytes (Królikowska, 1971; Grabowska *et al.*, 2016).

Transpiration of aquatic plants can far outweigh evaporation from the free surface of water (Grabowska *et al.*, 2016; Yano *et al.*, 2017). The intensity of transpiration depends on many environmental factors including light, temperature, wind, and air humidity. By eliminating the variation of these factors under laboratory conditions, an attempt was made to indicate the intensity of this process among different species of helophytes. Are there any factors limiting this process?

Furthermore, we performed a field study of some temperate lakes to answer the question: what is the role of emergent macrophytes in evapotranspiration in shallow lakes with different trophy and surface? We also hypothesized that different species of macrophytes have a diverse share in this process, depending on the area and density.

2 Material and methods

The Łęczna-Włodawa Lake District, also called as Łęczna-Włodawa Plain (Kondracki, 2002) is located between the middle course of the Wieprz and Bug rivers (eastern Poland). In the Lake District there are currently 63 lakes, representing all trophic types. It is estimated that over the last 50 years five or more lakes from 68 have disappeared or been overtaken by rush communities. The study included seven eutrophic lakes.

Water uptake by various species of emergent macrophytes occurring in the shallow littoral zone of Łęczna-Włodawa lakes was studied. The following species, occurring in the littoral zone, were analyzed: *Phragmites australis, Typha latifolia, T. angustifolia, Glyceria aquatica, Scirpus silvaticus*.

Field works were carried out in 7 studied lakes in 4 transects in the shallow littoral zone (totally 28 transects), at the peak of the growing season (July, August), when the transpiration rate is the highest. Due to the fact that in the analyzed lakes the rushes zone occurred along almost the entire shoreline, and the buffer zone was natural, the transects were located in the main geographical directions (north, south, east and west of the lakes). In each of the studied lakes the species composition of emergent macrophytes, their density, and range (maximum depth) of occurrence were determined. Furthermore, the following features of the analyzed macrophyte species were determined: shoot length and diameter, inflorescence length (if present), number, width and length of leaves, as well as the mass of the above-ground part of collected plants (Królikowska, 1971). Moreover, due to the dominance of the Phragmitetum community in the studied lakes, an analogous number of samples of *Phragmites australis* growing on the shore (land) was taken for analysis. The number of plants collected for analysis from each of the four transects ranged from 30 (in Lake Gumienko) to 75 (in lakes Uscimowskie and Zienkowskie).

Under laboratory conditions at constant temperature of 20 °C and humidity of 50–70%, measuring cylinders were filled with 200ml of water. Next, the emergent part of the plant was placed in each cylinder and secured with Parafilm to eliminate evaporation from the water surface. Each species was represented by 15 specimens in which the following were analyzed: length of the stem, number of leaves, leaf width and length, stem diameter and weight, as well as (length of) inflorescence, and water level. The measurement period commenced on the day the material was sampled from the site and ended at the moment of stopping the water uptake and the loss of plant weight (from 7 to 11 days). A total of 630 measurements were made.

In order to characterize emergent macrophyte coverage, photointerpretation analyses were made based on orthophotomaps from 2015 with ground resolution of 0.5 m. Particular

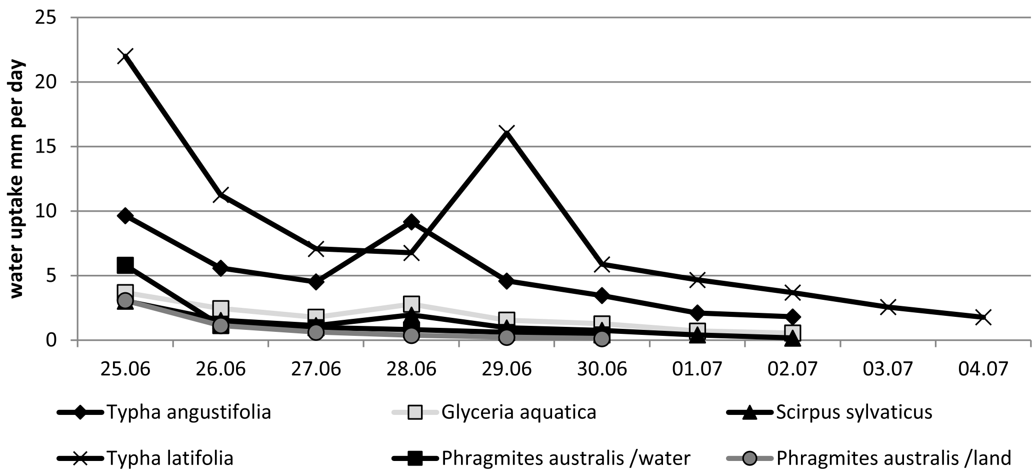

Fig. 1. Daily transpiration of individual species under laboratory conditions.

phytocenosis cover was located by means of field GPS measurements (Trimble GeoXT). On-screen vectorization of a digital orthophotomap was carried out using ArcGIS 10.5.1. software.

Evaporation from water surface was calculated by means of Ivanov's (1954) formula in the form:

$$Ej = 0.0018 \cdot (100\% - f)(25 + t)^2$$

where *Ej*, evaporation from the lake surface, mm; *f*, relative humidity of the air, %; *t*, air temperature, °C.

The monthly evaporation values (*Ej*) were calculated on the basis of monthly average temperature values and relative air humidity determined for the UMCS meteorological station in Wola Wereszczyńska.

The arithmetic mean and standard deviation (SD) of individual shoots of studied helophyte species were determined. The transpiration (daily) was presented on the figure in box plot with regard to the factor studied. A square shows mean, a box corresponds to the mean ± standard error, whereas "whiskers" above and below the box show the locations of the maximum and minimum. Although Shapiro-Wilk test not rejected the normality of the transpiration distribution ($p >$ 0.05), non-parametric Kruskal-Wallis test was used to verify the hypothesis about uniform transpiration for species. This was because the Levene test rejected homoscedasticity. To check whether transpiration is significantly different during the study, a non-parametric Friedman test was performed.

The principal component analysis (PCA) was used, which allowed for determining the potential sources of transpiration. PCA was applied to standardized data to avoid misclassification arising from different parameter units (Czerepko, 2006). The whole statistical analysis were made with the use of Statistica 13.1 package.

3 Results & discussion

Under (permanent) laboratory conditions, the water absorption process proceeded at different rates and time, depending on the species. For all species, the most intense water uptake occurred in the initial period of measurements; then, also the mass of plants was the highest. Throughout the measurement period the largest water uptake was recorded for *Typha latifolia* (22.01 ml/day). At the same time, the process lasted the longest (10 days) in that species (Fig. 1). The lowest amounts of water from the analyzed species were taken by *Phragmites australis* (1.1 ml/day on the 2nd day of measurement) and *Scirpus silvaticus* (0.94 ml/day on the 4th day of measurement) (Figs. 1 and 2).

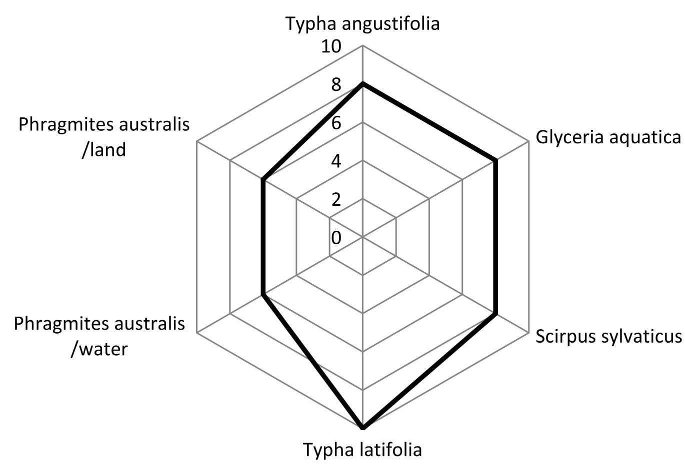

Fig. 2. Number of days in which studied species took water under laboratory conditions.

In addition, common reed, both growing in water and on land, stopped taking up water the soonest, that is, on the sixth day from the start of measurements (Fig. 2).

The Kruskal–Wallis test showed a statistically significant effect of the species on transpiration ($p < 0.0001$). Friedman's test showed that transpiration varies significantly between species. The transpiration of *Typha latifolia* ($p = 0.0024$) does not differ significantly from the transpiration of *Typha angustifolia* ($p = 0.0014$).

Table 1. Water uptake by helophytes in different time periods.

Species/unit	From one plant per day		Standard deviation (*SD*)	Min	Max	From one plant per month	
	ml	l	l	l	l	ml	l
Typha angustifolia	22.833	0.023	0.019	0.004	0.064	684.985	0.685
Glyceria aquatica	12.394	0.012	0.010	0.001	0.045	371.820	0.372
Scirpus sylvaticus	8.919	0.009	0.005	0.002	0.017	267.562	0.268
Typha latifolia	59.073	0.059	0.042	0.002	0.183	1772.179	1.772
Phragmites australis/water	8.867	0.009	0.004	0.001	0.016	265.996	0.266
Phragmites australis/land	6.990	0.007	0.004	0.002	0.015	209.690	0.210

Table 2. Mean values of analyzed features of emergent macrophytes (*SD* – standard deviation).

	Length (cm)	Inflorescence length (cm)	Number of leaves (no)	Leaf length (cm)	Diameter (cm)	Width of leaf (cm)	Mass of plant (gfresh)
Typha angustifolia	80.8	17	5	82	1.26	1.02	24.23
SD	9.76	1.4	0.8	2.8	0.11	0.10	7.13
Glyceria aquatica	60.2	14	7.4	48	0.92	1.22	4.41
SD	4.24	3.7	0.88	2.9	0.07	0.07	1.12
Scirpus sylvaticus	57.00	12.4	11.40	41	0.70	0.96	7.27
SD	2.4	4.7	1.68	3.5	0.12	0.09	0.93
Typha latifolia	111.5	28.1	5.9	98	18.67	2.29	59.49
SD	19.8	7.3	1.8	6.7	1.11	0.19	23.17
Phragmites australis/water	85.9	29.6	6.5	48.4	2.39	3.23	14.09
SD	10.3	6.6	0.8	2.0	3.26	0.26	12.93
Phragmites australis/land	44.2	0	4.2	25.2	0.85	2.10	10.42
SD	34.9	0	3.0	23.2	0.07	2.28	2.70

The studied species of helophytes, under laboratory conditions collected from 0.21 l (*Phragmites australis* inhabiting the coastal zone) to 1.77 l (*Typha latifolia*) of water per month . Daily uptake ranged from 0.007 l to 0.059 l respectively in the analyzed species (Tab. 1).

Due to the large diversity of the studied species, the values of the measured features differed significantly. As a rule, the highest values were achieved by Typha (except density), while the lowest by Phragmites growing on land (except mass) (Tab. 2).

Analyzing the characteristics of selected species of helophytes based on the principal component analysis, it turned out that the most important impact on the uptake of water was the width, length and number of leaves as well as the mass and diameter of respective plants. Among the least significant factors affecting water uptake, under laboratory conditions, was the length of the plant. The presence of an inflorescence was highly negatively correlated, which may slow down the water uptake process (Fig. 3).

Field studies were conducted in 7 lakes with different trophic state from slightly eutrophic to hypertrophic. The lakes differed considerably in the area extending from 4.2 ha Lake Gumienko to 477.5 ha Lake Wytyckie. Those lakes differed by the type of supply: from the flow through the outflow and the inflow to surface waters supply only. The common features of the studied lakes were: very similar depth, lack of stratification and the shape of the littoral bottom, which created similar possibilities for colonization by helophytes (Tab. 3).

The area inhabited by rushes was varied in the analyzed lakes. Rushes occupied the smallest surface in slightly eutrophic lakes – about 7% of the lake surface, and the largest in eutrophic lakes – constituting about 30% of the lake surface. The densities were the largest in the most fertile lakes – Zienkowskie (42 ind/m^2) and Uscimowskie (39 ind/m^2) (Tab. 3).

In terms of species composition, rushes of the studied lakes showed little diversity and numerous similarities. The reed and Typha rushes developed in each of the studied lakes. Rushes created by *Scirpus silvaticus* appeared only in two most fertile lakes. However, manna rush did not occur in poorly fertile lakes (Tab. 4).

Analyzing the surface, density and mean values of water uptake by respective species, the transpiration capacity of rushes on the studied lakes was determined. The share of Typha rushes had the greatest impact on the amount of water uptake by plants. Rush consisting of Typha species collected from 36.3 l per month (*Typha angustifolia*) to 578.9 l per month (*Typha latifolia*). Rushes which mainly comprised Phragmites collected from 61.1 l of water per month in Lake Gumienko to 215.9 l per month in Lake Wytyckie. The highest transpiration rate in litres was recorded for rushes in Lake Wytyckie 325997.9 l/month and in Lake Uscimowske

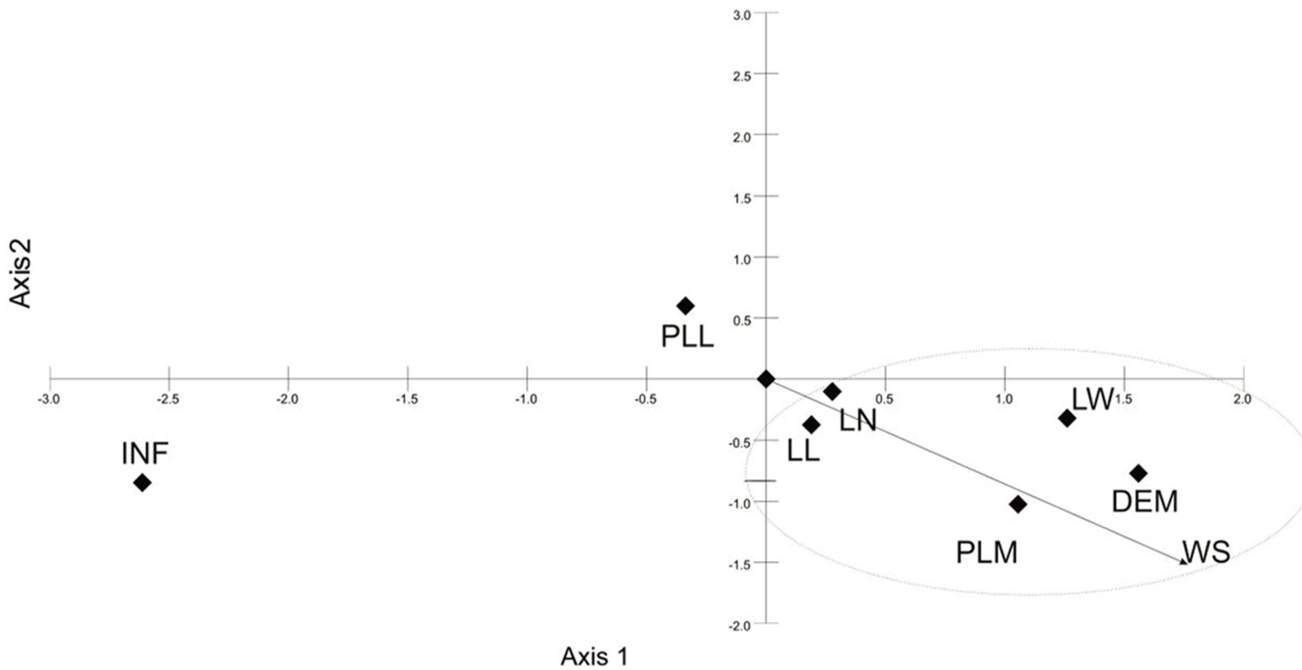

Fig. 3. Principal component analysis (PCA) for investigated features of helophytes and some variables under laboratory condition : WI – water intake; LW – width of the leaf; PLM – plant mass; DEM – diameter; LL – leaf length; LN – leaf number; INF – inflorescence; PLL – the length of the plant.

Table 3. Characteristics of the studied lakes and the rushes areas (TW – transpiration rate, TR – atmospheric precipitation; H –hypertrophic lake, E – eutrophic lake, LE – light eutrophic lake).

Lake	TSI crl	Depth [m]	Numer of helophytes	pH	Secchi disc (SD) (m)	Density ind/m^2	Type of power supply	Max depth of helophytes occurrence (m)	Lake surface	%	Rushes surface	TW	TR
Zienkowskie	H	4.9	10	8.5	0.6	42	P	1.2	6.3	27	1.7	3.49	1.12
Us cimowskie	H	4.4	9	8.5	0.4	39	D	1.3	68.3	22.5	15.4	1.92	0.62
Gumienko	LE	4.3	6	8.4	0.5	27	P	1	4.2	7.1	0.3	3.20	1.03
Rotcze	LE	4.3	5	8.2	0.6	25	B	1.3	43.9	7.06	3.1	2.06	0.66
Koseniec	E	4.2	8	7.3	0.8	21	P	1.3	23.5	33.6	7.9	1.41	0.45
Wytyckie	E	4.2	7	7.4	2.1	35	O	1.3	477.5	25.4	121.2	1.61	0.52
Cycowe	E	4.1	7	8.1	0.7	37	P	1.3	8.7	29.3	2.55	2.69	0.86

Table 4. Area inhabited by particular types of rushes in the lakes studied (ha).

Lake	Rushes				
	Typha angustifolia	*Typha latifolia*	*Phragmites australis*	*Glyceria aquatica*	*Scirpus silvaticus*
Zienkowskie	0.25	0.3	1.1	0.12	0.025
Us cimowskie	1.63	0.55	12.7	0.48	0.1
Gumienko	–	0.23	0.11	–	–
Rotcze	0.99	0.28	1.91	–	–
Koseniec	0.6	0.8	6.5	0.02	–
Wytyckie	10.7	1.02	89.4	0.16	–
Cycowe Komorowskie	0.41	0.25	1.7	0.15	–

Table 5. Monthly transpiration of water through the lake rushes.

l/month/m^2	*Typha angustifolia*	*Typha latifolia*	*Phragmites australis*	*Glyceria aquatica*	*Scirpus silvaticus*	Litters per month from rushes surface
Zienkowskie	133.49	414.44	109.81	34.78	5.21	12530.9
Uścimowskie	86.61	75.61	206.58	13.84	2.08	59513.5
Gumienko		578.94	61.06			2176.0
Rotcze	177.18	129.65	104.64			13123.5
Koseniec	36.31	125.27	120.43	0.66		22393.9
Wytyckie	84.42	20.82	215.92	0.69		325997.9
Cycowe Komorowskie	137.39	228.51	142.24	30.19		13902.4

Table 6. The ratio of evaporation from the free surface of lakes to the surface covered by rushes.

	Typha ang. rushes	Typha lati. rushes	Phrahmites rushes	Glyceria rushes	Scirpus rushes
Evaporation from the surface of the rushes in relation to open water	3.277	6.6162	4.8034	0.4008	0.03645

59513.5 l/month, while the lowest value, i.e. 2176 l/month, was observed in Lake Gumienko (Tab. 5).

Comparing the monthly amount of water evaporated by the emerged plant communities with monthly (July, August) atmospheric precipitation (TR), in the analyzed area the influence of rushes on the lake water balance was significant in these months. Plants on every square meter covered by rushes evaporated from 0.45 (Lake Koseniec) to 1.12 (Lake Zienkowskie) times more water than received from precipitation (Tab. 3).

The relative transpiration rate (TW) determining evaporation from the surface covered by rushes was higher by 1.41 (Lake Koseniec) to as many as 3.5 times (Lake Zienkowskie) in relation to evaporation from the open surface of the lake (Tab. 3). Rush created by *Typha latifolia* exceeds the evaporation rate from the free surface of the water more than six times. Reed composed of *Scirpus silvaticus* had the smallest influence on water uptake (Tab. 6).

According to the principal component analysis factors affecting the uptake of water in the studied lakes, the most important one was the area of rushes, their density and the trophic type of the lake. The type of water supply, the surface of the lake and the diversity of helophytes proved to be irrelevant (Fig. 4).

4 Discussion

Helophytes are usually rooted in the substrate, and the stems grow above the surface of the water. The raised parts of the plant, especially leaves and green stems, carry out the transpiration process. It is an important life process of the plant, consisting in taking up and transporting water along with dissolved nutrients. This physiological process is complex depending on ecological factors present in the water (light, temperature, wind, air humidity). Our study identified significant relationships between aquatic plant cover and transpiration.

The study confirmed that after elimination of the main factors affecting transpiration intensity such as: light, temperature, water vapour deficiency and wind, the process of taking up water by different species of helophytes proceeded at different rates and times. *Typha latifolia* was a species that carried out the process most intensively and for the longest time, while the uptake of water by *Phragmites australis* was the smallest. Therefore, the share of respective species in lake coverage has an important role in water circulation. In the studied shallow lakes of the Lake District, Phragmites rushes were predominant.

Among the analyzed helophyte features, the transpiration process was influenced by length, number and width of leaves, as well as plant mass. These dependencies are also confirmed by studies conducted by Królikowska (1971) on the intensity of common reed transpiration. However, the presence of inflorescence reduced this process. In most helophytes the inflorescence develops between July and September, and the flowers are pollinated by the wind. They reproduce mostly vegetative, are perennial plants and often form age-diverse populations. This in turn affects the different rate of production of inflorescence (Hara, 1984; Podbielkowski and Tomaszewicz, 1996). According to a study by Nowak (2009), the length of the plant, the diameter of its stems, under natural conditions, is also an essential feature because it increases the transpiration area. However, stable conditions such as the lack of waveforms significantly reduce this process even to zero.

Lakes evolve very slowly but constantly. One of the symptoms of lake evolution is trophy growth, followed by overgrowth. This is often manifested by a higher share of helophytes in the lake's phytolittoral. Based on the study conducted on 893 lakes in the northern part of Poland, there is a clear tendency of increasing the area inhabited by rushes vegetation in lakes at the expense of reducing their area by about 0.27% (Skowron and Jaworski, 2017) on average. In addition, increasing helophytes coverage can significantly boost the transpiration process and thus increase the loss of

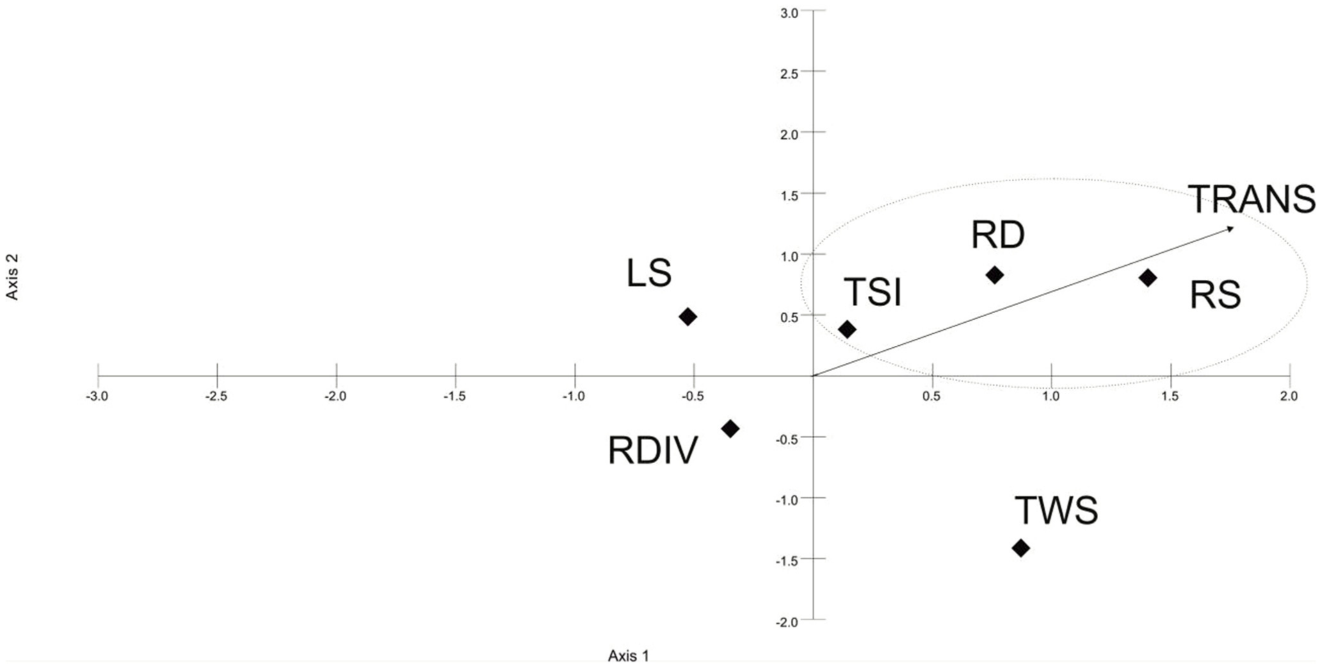

Fig. 4. Principal component analysis (PCA) for investigated features of helophytes and some lake variables: TWS – type of power supply; RD – density; RDIV – rushes diversity; LS – lake surface; TSI– trophy type; RS – rushes surface; TRANS – transpiration.

water, compared to the evaporation of the open lake mirror. Studies by Sánchez-Carrillo *et al.* (2004), conducted on semi-arid wetlands, as well as studies of Timmer and Weldon (1967) for water hyacinth, confirmed that the increasing coverage of macrophytes does not reduce evaporation from the open surface of water but it does increase the rate of transpiration.

Among the analyzed factors affecting the uptake of water in the shallow lakes of the Łęczna-Włodawa Lake District, the most important one was the area of rushes and their density, the same observation were made by Grabowska *et al.* (2016) in Kashubian Lakeland and Anda *et al.* (2015) in Kis-Balaton wetland for *Phragmites australis* studies.

Studies on 7 shallow lakes of different trophic type of the Łęczna-Włodawa Lake District showed varied participation of helophytes in their littoral and very similar qualitative structure. *Typha* and *Phragmites* rushes were found in all lakes. The share of Typha rushes, especially *Typha latifolia*, significantly influenced the intensity of the water uptake process in respective lakes. It can transpire 59.1 ml daily, which in Lake Gumienek gives even 6950 kg/m^2 in a year.

According to Otis (Gessner, 1959; Bernatowicz and Wolny, 1974), the *Phragmites australis* community can evaporate 1304.9 kg/m^2 annually. In the studied shallow lakes *Phragmites* rushes can take up from 732.72 kg/m^2 (Lake Gumienko) to 2591.04 kg/m^2 (Lake Wytyckie) of water.

Atmospheric precipitation for the analyzed months was on average 650 mm, the impact of plants on water balance in the studied lakes was from 0.45 (Lake Koseniec) up to 0.96 (Lake Zienkowskie) times greater than that of rainfall. It is worth mentioning that these months have the highest precipitation values for this region (Harasimiuk *et al.*, 1998). Total water loss to evapotranspiration is up to 3.5 times larger from the water zone inhabited by reed beds than from the surface of the lake (Grabowska *et al.*, 2016). According to Anda *et al.* (2015), reeds transpire more water than deciduous forests.

These studies confirmed that helophytes play a significant role in the uptake and circulation of water in lakes. Probably the predominance of *Typha* rushes would increase those values.

These studies also confirmed that reed from land sites has lower transpiration capacity than it has in water, which is supported by the results of studies carried out by Królikowska (1971). The probable cause is lower biomass values and the number of leaves on land reeds. These are the features that affect transpiration intensity the most. Reeds with unlimited access to water are not protected against its excessive loss, while the presence of inflorescence significantly reduces the transpiration process in all helophytes.

In the Łęczna-Włodawa Lake District, it seems very important to monitor lakes for their colonization by emergent macrophytes. Lowering of water levels, dry summers, human activities (mine, intensive recreation, buildings, etc.) contribute to their overgrowth and, consequently, to their disappearance. Therefore, the assessment of coverage by helophytes can be an effective tool in assessing the water balance of lakes.

5 Conclusions

Helophytes play a significant role in the uptake of water. The share of *Typha* rushes significantly increases transpiration.

Under laboratory conditions, the width, length and number of leaves as well as the mass and diameter of the stems of respective species had the most significant effect on the uptake of water by helophytes. The length of the plant was a characteristic with the least significant impact on water uptake. The presence of inflorescence was highly negatively correlated with the amount of water taken up by the plants. This phenomenon may slow down the process of water uptake by plants.

Among the analyzed factors affecting the uptake of water in the shallow lakes of the Łęczna-Włodawa Lake District, the most important effect was the area of rushes, their density and lake trophic type. In contrast, the type of lake supply, surface of the lake and the variety of helophytes proved to be irrelevant to the amount of water uptake.

Phragmites inhabiting land sites, due to lower values of the analyzed features, affecting transpiration, were characterized by lower water uptake capacity.

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