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Effect of changes in groundwater levels on selected wetland plant communities

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Abstract

Wetland areas maintain a high level of moisture at all times and experience flooding at regular intervals. High groundwater levels help create wetland areas, as does a relative lack of surface water loss. The paper bases on the hypothesis that wetland areas are characterized by seasonally high water levels and drought. These changes in water content markedly affect the presence of rare plant communities. The purpose of this paper is to determine the effect of changes in the level of groundwater on selected plant communities in wetland areas. The paper also aims to determine if any other determinants affect these plant communities: (1) relief, (2) climate conditions (precipitation, temperature), (3) human impact. Furthermore, the paper provides a detailed hydrographic analysis of wetland areas including information on water migration pathways, water recharge systems, and sources of water loss. The study area consists of Piaśnickie Łąki – a protected natural area in northern Poland, close to the Baltic coastline. It is also a designated "Nature 2000" area, and it is abundant in rare plant communities such as reed grass (*Molinietum medioeuropaeum*), which thrives in variable moisture areas. The majority of the research work consisted of literature analysis and fieldwork, which included the installation of a groundwater monitoring system, groundwater and surface water level gauging, and discharge gauging for larger streams found adjacent to the study area. The fieldwork was done in the period 2014 – 2015. The collected research data indicate that groundwater levels did vary during the study period. These conditions helped produce a high rate of plant growth and an increased rate of evapotranspiration across the surface of the study area, which then helped decrease the level of groundwater. One basic condition for the functioning of variable-moisture reed grass communities (*Molinietum medioeuropaeum*) is a specific pattern of variability in groundwater levels. Small depressions in the studied nature reserve offer the best conditions for the occurrence of reed grass communities.

Keywords: *wetland, groundwater, habitat, plant communities, reed grass*

Rezumat. Efectul schimbărilor nivelului apei subterane asupra comunităților de plante alese din zone umede

Arealele cu zone umede mențin un nivel ridicat de umiditate a solului în orice moment şi sunt inundate la intervale regulate de timp. Nivelurile ridicate ale apelor subterane ajută la crearea unor zone umede, ceea ce face o relativă lipsă a pierderilor apei de suprafață. Articole importante admit ipoteza că zonele din zonele umede sunt caracterizate de un nivel sezonier ridicat de apă și secetă. Aceste modificări ale conținutului de apă afectează semnificativ prezența comunităților de plante rare. Scopul acestei lucrări este de a determina efectul variației nivelului apelor subterane asupra comunităților de plante selectate în zonele umede. De asemenea, lucrarea își propune să evalueze dacă alți factori determinanți afectează aceste comunități de plante: (1) relief, (2), condiții climatice (precipitații, temperatură), (3) impactul uman. Mai mult decât atât, lucrarea oferă o analiză detaliată hidrografică a zonelor umede, inclusiv informații privind căile de migrare a apei, sisteme de reîncărcare a apei, precum și sursele pierderilor de apă. Zona de studiu este format din Piaśnickie Laki - o arie naturală protejată din nordul Poloniei, aproape de coasta Mării Baltice. Aceasta, a fost desemnată sit "Natura 2000" și este bogată în comunități de plante rare, cum ar fi stuful (*Molinietum medioeuropaeum*), care se dezvoltă în zone de umiditate variabilă a solului. Cea mai mare parte a activității de cercetare a constat în analiza literaturii și lucrul în teren şi au constat în instalarea unui sistem de monitorizare a apelor subterane, staţie hidrometrică pentru monitorizarea nivelului apelor subterane şi de suprafață, stației hidrometrică pentru debitele de apă curse pe râurile mari din apropierea zonei de studiu. Activitățile de teren au fost realizată în perioada 2014 - 2015. Cercetarea datele colectate indică faptul că nivelul apelor subterane a variat pe parcursul perioadei de studiu. Aceste condiții au ajutat la producerea unei rate ridicată de creștere a plantelor și a unei rate crescute a evapotranspiraţiei zonei de studiu, care a contribuit la reducerea nivelului apelor subterane. Ca o condiție de bază pentru funcţionarea variabilă a umidităţii solului, comunități erbacee (*Molinietum medioeuropaeum*) sunt un model specific de control a variabilității nivelului apelor subterane. Micile depresiuni din zona studiată asigur rezervația naturală studiată oferă cele mai bune condiții pentru apariția comunităților de stuf.

Cuvinte-cheie: *zone umede, ape subterane, habitat, comunități de plante, stuf*

Introduction

Wetland areas are characterized by a permanently high water content. Such areas can be flooded periodically or permanently swampy due to high groundwater levels and reduced surface water runoff. Wetland areas include swamps and bogs as well as moist areas found in the valleys of slow-flowing rivers and streams affected by the horizontal movement of water. These areas are particularly valuable to the natural environment due to their ability to retain water and affect local hydrology in a number of ways (Oertli et al., 2005). Many wetland areas and their catchments form isolated patches of geographic space. At the same time, both natural changes and anthropogenic changes may cause wetland areas to form complete hydrographic systems in conjunction with any adjacent hydrographic entities (Tiner, 2003).

The natural environment of wetland areas is characterized by the highest levels of biological production in the world along with very high species diversity and very high number of living organisms. Variable moisture moor grass (*Molinietum medioeuropaeum*) is of particular importance in wetland areas. Moor grass was, in fact, quite commonly observed across Western Europe until the early 20th century (Van der Hoek & Sykora, 2006). Habitats such as these are important in the effort to preserve biodiversity across lowland areas, river valleys, and land depressions (Nowak, 2015). Many habitats of this type have been designated protected natural areas, which serve as a natural living space for valuable species of animals and plants. (Liira et al., 2008). Therefore, there exists a need to protect moor grass as well as other species from decline (Shmeller, 2008); however, this requires an assessment of water circulation patterns in the study area.

The definition of wetlands most often used in the scientific literature is that found in the Ramsar Convention (1971). This definition states that wetlands are areas of swamp, mud, or bog. Wetlands may include natural and manmade bodies of water, some of which may be permanent and some may be periodic. Some wetlands may possess standing water and some flowing water. Wetlands may consist of freshwater, brackish water, or saltwater. Even marine water can be classified as a wetland area if its depth does not exceed six meters at low tide, which is considered to be a boundary line between coastal wetlands and the open sea (Farrier & Tucker, 2004). Therefore, it appears that the most important criteria for classifying wetland characteristics are geographic location and local hydrology including changes in groundwater levels (Szogi & Hunt, 2001). Human impact remains a relevant wetland factor (van der Kamp, 1999), which affects water circulation patterns and general hydrologic change in these areas (Huhta et al., 2001; Huhta & Rautio, 2005). Both positive and negative effects can be observed in wetland areas affected by human impact for example, mowing meadows or regulation riverbed (Michalska-Hejduk & Kopeć, 2012).

The hypothesis adopted in this paper presumes that wetland areas are characterized by seasonally high water levels and excessive desiccation. These changes have a profound effect on rare plant habitats. The primary purpose of the study was to determine the effects of changes in groundwater levels on selected plant habitats in wetland areas. The secondary purpose was to identify any additional factors affecting plant habitats including relief, temperature, amount of precipitation, and human impact. The third purpose was to create a detailed hydrographic map of the study area, which would also cover water flow directions, recharge pathways, and water loss pathways.

The study area consists of the Piaśnickie Łąki nature reserve in northern Poland, close to the Baltic Sea. It is also a designated Natura 2000 area. The study area stretches across an ancient muddy coastal plain situated between a coastal belt of sand dunes and a moraine-type postglacial upland. The current area of the Natural Reserve "Piaśnickie Łąki" is 56.23 hectares and is part of the 1,085 hectare Natura 2000 area of the same name. The terrain is rather flat with a maximum height of 3.75 m located in the southern part of the reserve. For non-forest communities growing on the reserve "Piasnica Meadows" include fluctuating Molinia meadows (Molinion), which is covered admittedly small area of the reserve, but among the other non-forest communities dominated by surface. Molinia occur in depressions located above separating parts of land covered by forest.

Materials and methods

Data

The research consisted mostly of fieldwork, field data analysis, and library research. In terms of field measurements, the study lasted from February 2014 to February 2015.

A network of measurement sites was established in the course of fieldwork. Seven piezometers were mounted along two transects – north-south and east-west (Fig. 1). The p1, p3, p5, p6 and p7 piezometer formed the north-south transect running through the middle part of the studied nature reserve. On the other hand, the p2, p3, and p4 piezometers formed the east-west transect running relatively close to the center of the study area. The p1 piezometer was mounted at the southern end of the study area in a small hollow in the middle of a meadow.

The p2, p3, and p6 piezometers were mounted in a meadow area that experiences high water stages from time to time. The p2 piezometer was mounted farthest to the west relative to all the other piezometers. On the other hand, the p4 piezometer was mounted farthest to the east in a meadow-type area. The p5 piezometer was mounted on a hill in the central part of the nature reserve. The p7 piezometer was mounted at the northern end of the study area. This last piezometer was fixed close to the Białogórska Struga River whose waters tend to spill over across adjacent areas at high water stages. These small floods also reach the p7 piezometer.

Maps of isobaths contours made with using ArcGIS on the basis of the measurement results. Tools ArcGis was possible to obtain an image retention groundwater table including barriers in the form of rivers and drainage channels

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The paper identifies two distinct time periods – a dry period and a wet period. The two periods were identified based on the amount of water present in the studied nature reserve. A reference value of 46.7 cm was used in the study or the mean annual depth at which water can be found in the study area. Months with a mean exceeding this reference value were classified as wet, while months that did not exceed this reference value were classified as dry.

Two sites were established on the Piaśnica River designed to measure discharge every quarter (Fig. 1) using an electromagnetic current meter produced by Valeport. The first site is situated at a location before the river enters the nature reserve. The second site is located only 50 meters ahead of the mouth of the river at the Baltic Sea. The study also covers water levels in the Piaśnica and Białogórska Struga rivers (Fig. 1) via data from three measurement sites. River water levels were measured using a reference point – the lowest beam of a bridge. The distance from a reference point to the river channel was also measured. For the bridge near the mouth of the river, this value equaled 181 cm. For the bridge located before the river enters the nature reserve, this value equaled 176 cm. The latter site was named Piaśnica II. The site on the Białogórska Struga River produced a corresponding distance value of 149 cm.

Operating data for four pumps at the Dębki II pump site, situated on the Białogórska Struga Canal in the north-western part of the nature reserve, were also obtained (Fig. 1). The date were used to analyze the effects of the extra water available in the nature reserve due to the work of the pump sites. The study also covers atmospheric precipitation data and air temperature data obtained from the Institute of Meteorology and Water Management measurement site at Wierzchucino for the period November 2012 to February 2015. Snow cover data were analyzed in terms of snow layer thickness, maximum duration, and number of days with snow in the period 2011 – 2015.

Data on snow cover were obtained from the Łeba measurement site, as listed by the Internet portal TuTiempo.net.

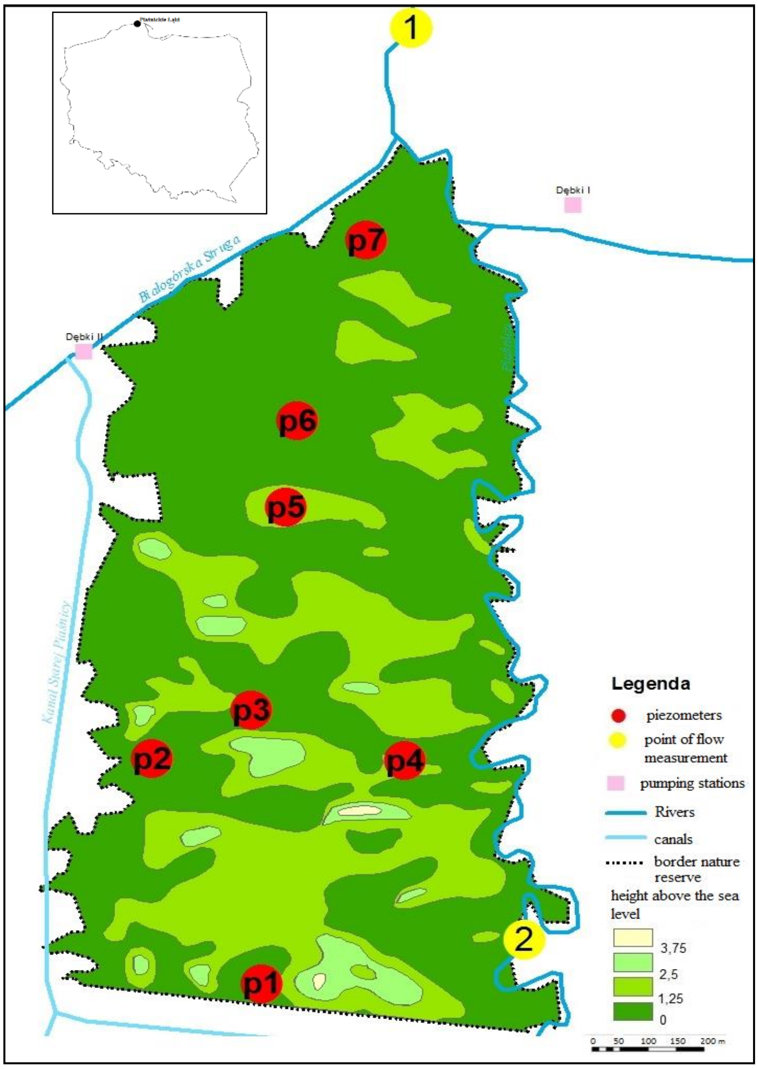

Fig. 1: Landsat scenes used in this analysis and their acquisition date

Results and discussions

Precipitation in the study area was found to be below average (monthly totals) in the study period. The annual precipitation total was found to be 546 mm, compared with a mean of about 600 mm. Precipitation varied substantially from month to month (Table 1). Moreover, high air temperatures during the study period most likely reduced groundwater levels below the local average. Low groundwater levels were also affected by small amounts of snowfall (Piętka, 2009). The number of days with snow in the winter of 2014/2015 was 19, while the maximum thickness of the snow cover did not exceed 15 cm.

For the winter period of 2012/2013, the corresponding values were 61 days and 26 cm (Table 2). This resulted in low groundwater levels in the spring at about 61 cm below ground. Precipitation in the summer did not offset low groundwater levels in the spring. The amount of precipitation in the summer was also not very high at 180 mm for the summer period. The mean groundwater level in the nature reserve stood at 46.7 cm below ground. The maximum groundwater level was 14.6 cm below ground. Despite the short duration of the study period and the non-average conditions in the study area, it was possible to determine seasonal change patterns in groundwater levels.

Table 1: Monthly atmospheric precipitation totals recorded at the IMGW measurement site in Wierzchucin from February 2014 to February 2015 and number of operating hours for pumps at the Dębki II site for the period February 2014 to February 2015 (Office of Water Management of Pomorskie Province, Gdansk office, Puck branch)

Month	Precipitation (mm)	Number of hours of pumps
February 2014	14	0
March	18	12
April	37	51
May	52	0
June	37	0
July	32	0
August	67	57
September	46	64
October	38	85
November	23	9
December	107	380
January	71	622
February 2015	4	270
Sum	546	928

Table 2: Snow cover data for the period 2011 – 2015 acquired at the Łeba measurement site (TuTiempo.net)

Period		Maximum snow cover thickness (cm)	Longest uninterrupted period with snow cover (days)	Number of days with snow cover
Winter 2011/2012		19	29	34
2012	January	8	7	12
	February	19	22	22
	December	26	19	19
Winter 2012/2013		26	22	61
2013	January	8	19	20
	February	13	22	22
	December	5	2	2
Winter 2013/2014		6	18	22
2014	January	6	15	17
	February	5	3	3
	December	15	6	6
Winter 2014/2015		15	9	19
2015	January	4	2	5
	February	13	8	8

Research has shown that winter months are the wettest months of the year in the study area – both February and March 2014 and from December 2014 to February 2015 (Fig. 2). In short, the winter months were characterized by the highest levels of groundwater. The lowest groundwater levels were noted in March at less than 70,7 cm. The dry period in the study area is noted between April and November. Low groundwater levels in the summer months are partly due to high air temperatures and the peak of the vegetation season. Higher evapotranspiration produced by the surface of the bog along with low amounts of atmospheric precipitation help result in a lower groundwater level (Hałas et al., 2008).

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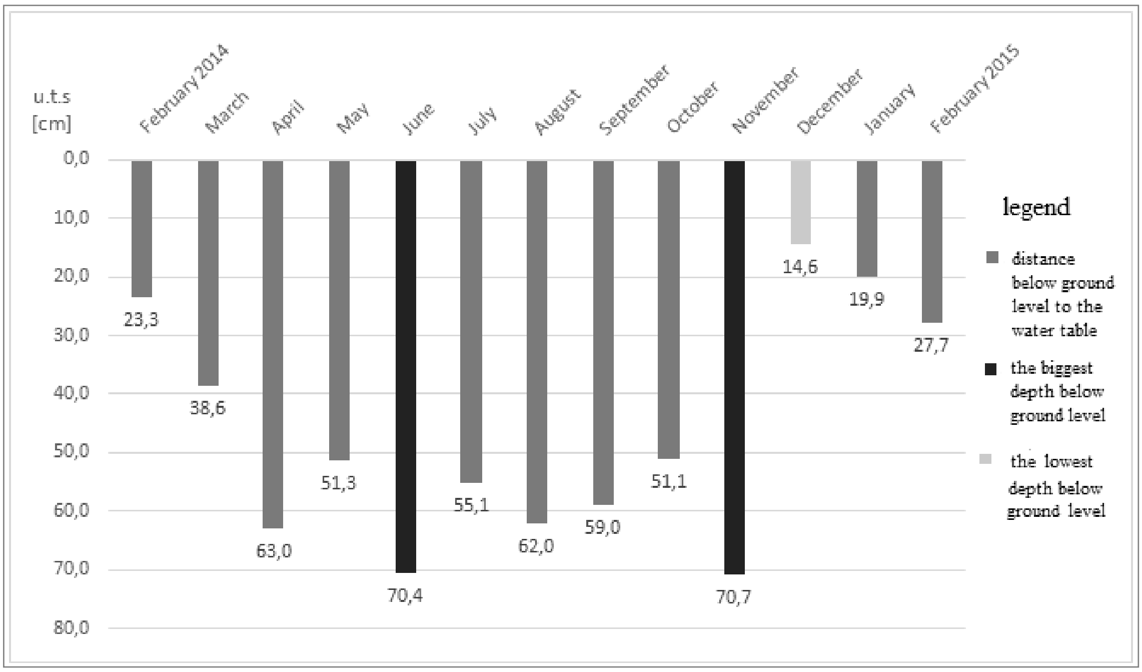

Fig. 2: Mean monthly groundwater level in seven piezometers in the Piaśnickie Łąki nature reserve from February 2014 to February 2015

The dry period lasted eight months in the study area, which was much longer than the wet period. The large disproportion in the number of dry and wet months is the result of low atmospheric precipitation totals as well as high mean and maximum air temperatures over the study period (Fig. 3).

Hałas et al. (2008) studied the effects of meteorological conditions on the fluctuation of groundwater levels and confirmed that maximum air temperature as well as mean daily temperature constitute key factors affecting groundwater levels. At low levels of relative air humidity, high air temperatures prompt accelerated evaporation of groundwater and water found on plants, which further leads to decreased groundwater levels.

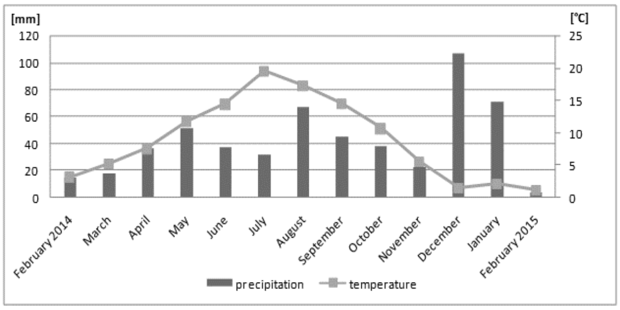

Fig. 3: Mean monthly air temperature and mean monthly atmospheric precipitation measured in the site at Wierzchucino from February 2014 to February 2015 (Source data: TuTiempo.net)

The highest groundwater levels measured by piezometer p1 (southernmost piezometer) were noted in February 2014 and January 2015 (Fig. 4). No water was found in piezometer p1 in June, August, and November. At the same time, piezometer p1 was characterized by the least amount of fluctuation in groundwater levels. Piezometer p2 was mounted along the east-west transect, and was characterized by high water levels in the winter months. In February 2014 and January 2015, water levels exceeded the terrain level (Fig. 4). This was due to the presence of excess water on the surface of the area around piezometer p2. The presence of ice in January around piezometer p2 also contributed to this excessively high water level.

The lowest water level for this piezometer occurred in April when it was found to be dry. A lack of water was also observed in June, August, and November. Other piezometers in the same line as p2 were piezometers p3 (west) and p4 (east). The highest water levels in p3 and p4 were noted in December. In p3 the water level was at ground level at the time, while in p4 the water level was only 3 cm below ground level. The lowest water level in p3 was noted in November at 86 cm below ground. Piezometer p3 was characterized by the largest changes in water levels relative to all remaining measurement sites (Fig. 4).

In p4 the lowest water levels were noted in June and August. Piezometer p5 was fixed atop a hill. Its lowest water levels occurred in October and November (no water). Its highest water level was recorded in January. Piezometer p6 was mounted in a hollow along the north-south transect between p5 and p7.

Its lowest water level occurred in November (Fig. 4), with no water at all. The same zero water level was noted from the previous June until October. On the other hand, the highest water level at piezometer p6 was noted in February 2014 (13 cm above ground level). Piezometer p7 was mounted in the northern part of the nature reserve at a site where the Białogórska Struga River broadens its channel. The highest water level at this site was noted in January at 7 cm above ground level. The lowest water level occurred in June (Fig. 4).

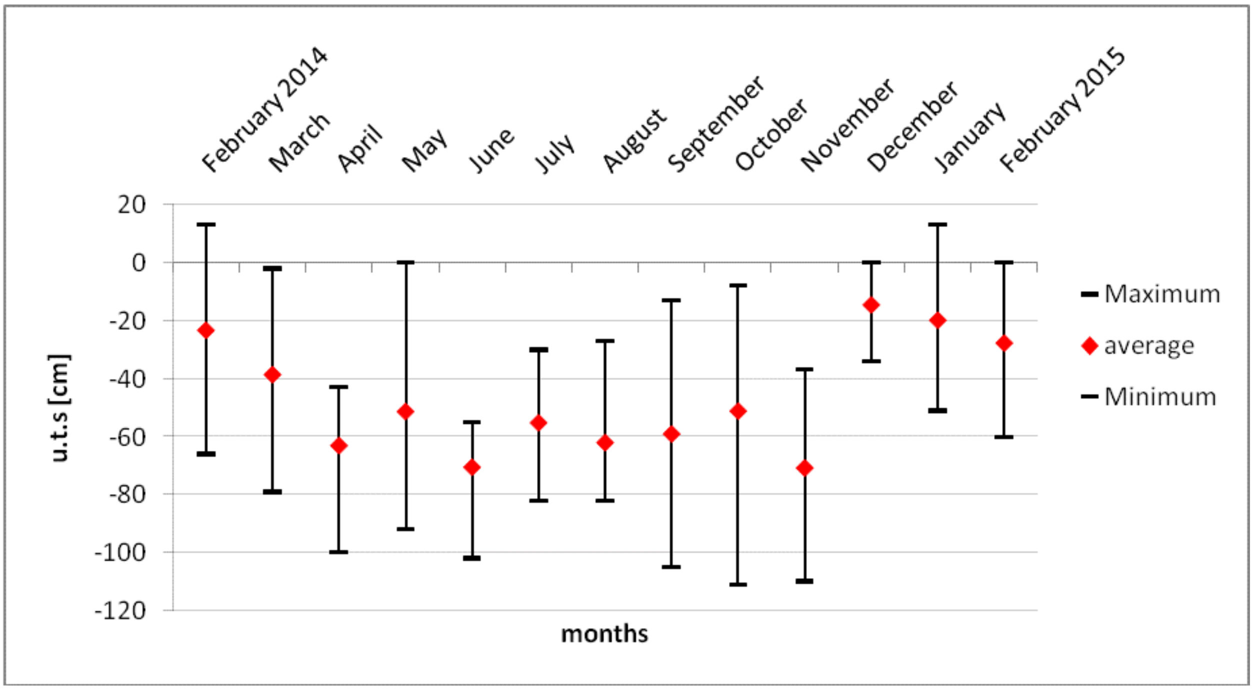

Fig. 4. Mean annual groundwater levels in the study area

Discharge was measured in the Piaśnica River in order to better understand the local hydrology in the study area. The highest readings were obtained in October (Table 3).

Table 3: Discharge in the Piaśnica River at selected gauging sites

Date of measurement	10.03.2014	05.06.2014	17.10.2014
Number of measurement site	Flow ($m^3 \cdot s^{-1}$)		
1	1,87	1,86	5,19
2	0,92	0,96	4,85

This was due to high precipitation totals in September and October. Two other readings produced quite similar values at both gauging sites. This was also due to atmospheric precipitation totals for the analyzed months. Another important pattern was also observed – discharge at Site 1 (river mouth) was higher for every month relative to discharge at Site 2. This was due to the influx of river water from a left-bank tributary – the Białogórska Struga River – upstream of Site 1.

It is likely that the quantity of water transported by the Piaśnica River may affect groundwater levels in the eastern part of the nature reserve. The river may serve as a drainage outlet for this part of the study area.

Surface water levels were found to be the highest at the Białogórska Struga River site. A minimum reading of 34 cm was noted in June (Table 4). The highest level was noted at 84 cm in November. The highest water levels at the two remaining gauging sites on the Piaśnica River were noted in November (no. 1) at 38 cm and December (no. 2) at 7 cm.

The pump operation times, suggest that the wettest months were from December 2014 to February 2015. Fewer operating hours were noted from August to October 2014. Pump operations did not occur at all in February 2014 and from May to July 2014. This may be explained via low precipitation totals at the time. The largest number of pump hours were noted in January 2015, which was almost double that for the second wettest month or the month of December 2014. The months with the largest number of pump hours or December 2014 and January 2015 were also months with the highest atmospheric precipitation, which helps

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explain the increased drainage rate for the local polder. At the same time, water levels in piezometers were also the highest during these months. This also suggests that water pumped out by the Dębki II pumps recharges groundwater aquifers in the studied nature reserve.

Research in the study area has shown that groundwater level isobaths, in most cases, follow an east-west pattern. There were three exceptions – February 2014, April 2015, and November 2015 (Fig. 5).

Table 4: Water levels (cm) at gauging sites on the Piaśnica and Białogórska Struga rivers in the study period.

Data	06.04.2014	12.05.2014	05.06.2014	08.08.2014	06.09.2014	25.11.2014	29.12.2014	23.01.2015
Piaśnica	1	9	0	0	35	38	29	0
Białogórska Struga	50	53	34	61	60	84	81	59
Mostek(Piaśnica II)	3	0	0	0	0	6	7	0

The most shallow groundwater was noted at the northern fringe of the nature reserve at piezometer p7. The height of the groundwater table decreases gradually in the southern direction in the studied nature reserve. The deepest groundwater was found at piezometer p1. It is also possible that river water from the Piaśnica is entering the area of the nature reserve and recharging groundwater aquifers.

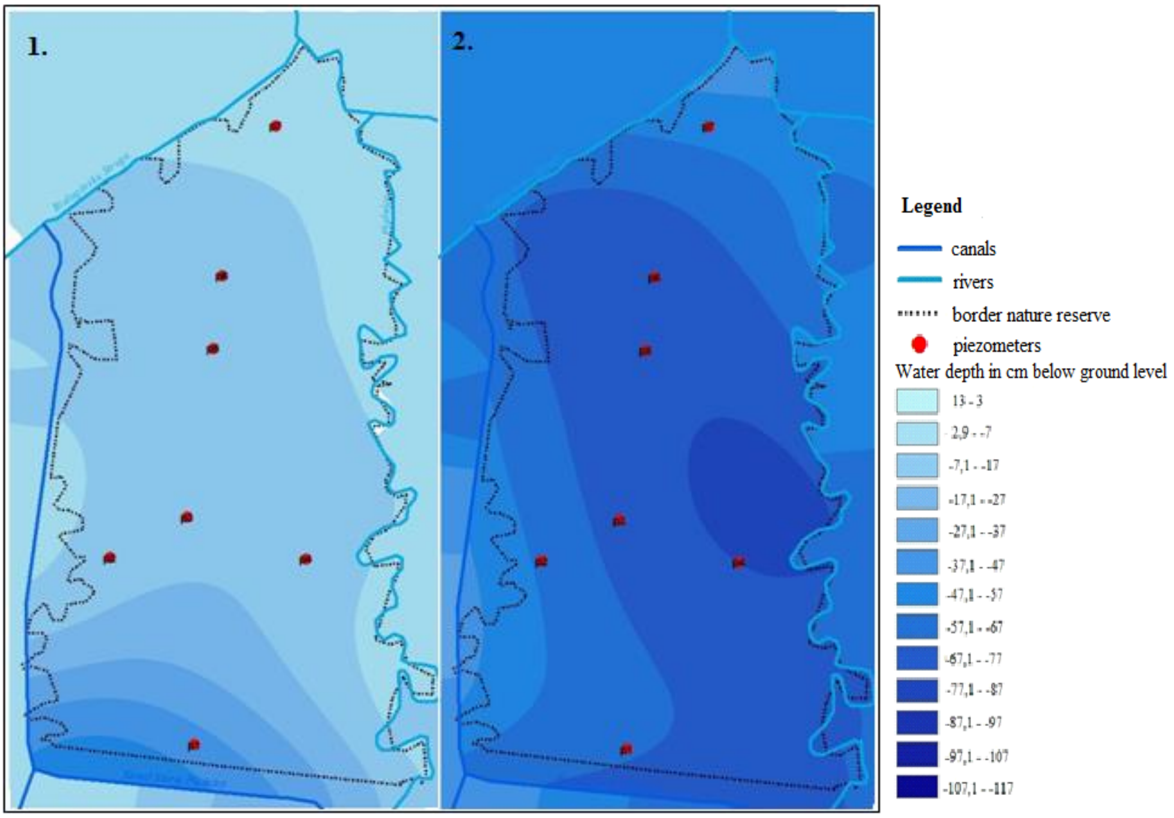

Fig. 5: Groundwater level isobaths in the month 1-most humid (December) and 2 driest (November)

The western boundary of the nature reserve consists of a levee, while its southern edge is formed by a canal. A drainage system prevents water exchange within the nature reserve. It is possible to confirm this via the lowest water levels near the eastern boundary of the reserve and higher water levels near the western boundary. This pattern may be explained by unique local terrain characteristics.

The western boundary runs along a levee, which facilitates water collection in a depression that used to be a channel of the Piaśnica River. This is most likely further facilitated by the frozen soil in the wintertime. The eastern boundary of the reserve is formed by the Piaśnica River, which serves as an excellent drainage base for groundwater. High groundwater levels were detected for the longest period of time in the northern part of the nature reserve as well as near watercourses and hollows and depressions, which in addition served as habitats for environmentally valuable vegetation.

Discussion

According to Sharitz (2003), changes in groundwater levels are now the major cause of environmental change in wetland areas. Water levels may change seasonally or in the long term from complete inundation to full drought, which is why wetland habitats need to adapt to hydrologic conditions that often change in unpredictable ways. In addition, the groundwater supply and changes therein occurring across geographic space and over time play a key role in the very existence of wetlands. Furthermore, Piniewski et al. (2012) believe that increasing demand for groundwater is the main threat to water and mud ecosystems today. Degradation of plant habitats occurs due to the gradual lowering of groundwater tables. High fluctuations in the groundwater supply in the study area illustrate the significance of water in the life and decline of selected plants.

Many bogs that appear to remain untouched by drainage and agriculture experience an array of dispersed side effects associated with changes in the natural environment caused by human impact. This includes atmospheric deposition of nitrogen (Kleinebecker et al., 2010).

According to Kleinebecker et al. (2008), species diversity in bog areas exhibits a strong linear correlation with peat chemistry. A general regression model in this case is produced mainly by three environmental variables that explain a total of 76% of variance. The three variables are changes in groundwater levels, nitrogen content, and dissolved calcium content. What is important is that the most fundamental factor driving change in plant habitats is always water and more specifically changes in its supply. This is why every change in water supply and the changes in water supply pathways in wetland areas affect the lifecycle of wetland plants. Peat deposit drainage is believed to be the most important driver of change in swampy habitats.

The existence of wetlands and the species composition of the plants found therein are closely linked with water resources and water circulation patterns. Hence, it is vital to identify and reconstruct the water balance in a study area. This makes it possible to analyze changes in the natural environment of wetland areas (Leider et al., 2013). However, excess human impact has dramatically reduced the surface area of wetland areas throughout the world, which has in effect perturbed water circulation patterns on a local, regional, and global scale (Rijsberman, 2006). This is often due to man’s desire to use wetland areas for agricultural purposes (Muller et al., 2013). Main environmental problems in wetland areas include excessive drying as well as eutrophication and acidification. Environmental impacts include both positive and negative effects of renaturalization efforts (Lamers et al., 2002).

This finding is also confirmed by Frieswyck and Zedler (2007) who believe that the most important change agent in wetland areas is the groundwater supply. This results from the fact that water is an integral part of the structure and functioning of wetland areas, which also results in a strong relationship between plant life and changes in water levels. Another factor that plays a key role is the introduction of invasive species that stabilize the water level. Given that the stabilization of the water level yields a change in the established vegetation cycle, the above researchers wonder if similar changes will occur if the water level is not stabilized. In their study, Frieswyck and Zedler (2007) used historical aerial photographs of three wetlands in the vicinity of Lake Michigan in the United States to show that invasive species prompted the elimination of wetland meadow habitats, which the researchers explained in terms of a significant decrease in the local water supply. In addition, wetlands characterized by standing water are threatened by the expansion of reed communities.

Papastergiadou et al. (2008) studied wetlands around Lake Cheimaditida in northern Greece and discovered that the surface area covered by reed increased 19% over a period of 50 years. On the other hand, the surface area of open waters and open bogs decreased 99.5%. Certain features that impede the accurate identification of changes in water levels are caused by local topography or properties of sediments (Hudona et al., 2006). According to Boudreau and Rouse (1995), local characteristics of various types of wetlands including parent material, hydrographic conditions, and biotic properties help determine the water balance for different types of study areas.

The identification of water circulation patterns helps in the drawing of conclusions on the most optimal environmental conditions for valuable species found in a given study area. In addition, it is important to perform long-term observations of many different bodies of water in order to capture the nuances associated with the unique nature of each study site. Reference papers include works on bodies of water in the Netherlands, where researchers attempted to understand how periodic drying and variable water supply pathways can affect the deposition of nutrients across variable-moisture meadows. Certain types of meadow, such as *Molinietum medioeuropaeum*, need nutrient-poor soils to thrive (Willems, 1983; Van der Hoek & Sykora, 2006).

The quantity of nitrogen and phosphorus ions may be also regulated by water recharge in wetland areas. Groundwater recharge yields fewer nutrients than does surface recharge. In certain situations, this may change. One such situation is when dead plant remnants litter the meadow surface and eventually transform into layers of peat. This is why mowing is deemed to be such an important way to maintain variable-moisture moor grass habitats, as it removes excess vegetation (Van der Hoek & Sykora, 2006; Ilmarinen et al., 2009). Mowing was used as a research step in this study, and it was a first step designed to help protect variable-moisture meadow communities. The work was done in 2014 and 2015 in select areas using a mowing schedule. Areas were selected for mowing based on the type of vegetation present. Most of the mowed areas were covered with variable-moisture meadow. Some meadows were mowed both in 2014 and 2015. The total mowed area was 9.98 ha in 2014 and 10.95 ha in 2015.

Researchers from various areas of inquiry agree that human impact is a main factor in the preservation of biodiversity and the loss of habitats. Certain steps are necessary to provide an environment where variable-moisture moor grass can function. These include fertilization to some extent, extensive animal grazing, and the mowing of meadows (Huhta et al., 2001; Huhta, Rautio, 2005; Van der Hoek, Sykora, 2006; Zelnik, Čarni, 2008). However, the effects of human impact can also be negative, taking the form of drainage, irrigation, river regulation, fires, and increases in soil chemicals content in adjacent areas (Willems, 1983).

Research on decreases in biodiversity has been performed on a variety of habitats in France, Germany, the Netherlands, Belgium, the Czech Republic, Estonia, and Switzerland. These particular studies were performed as part of the European Union program GREEN VEINS (Liira et al., 2008).

Research has shown that intensive agriculture and mechanized agriculture do not help in the preservation of protected plant habitats. Another study on this subject was performed in the Netherlands. The study focused on the effects of agriculture, animal grazing, and mowing on the preservation and decline of plant habitats in calcium-rich soils. Variable-moisture moor grass habitats are most commonly found in north-western Europe, and especially in southern England.

Research has shown that mowed areas and areas subject to grazing are characterized by the presence of more plant species protected by environmental law. In effect, one group of species does not dominate other groups of species in these geographic areas (Willems, 1983).

Conclusion

The data collected as part of this study do show that fluctuations in groundwater levels can be detected in the study area, which is a precondition for the proper functioning of plant habitats such as those of *Molinion medioeuropaeum.*

The lowest water levels were detected in June in the middle part of the studied nature reserve (north-south transect). Water levels were found to increase in the direction of the Piaśnica River, which serves as a boundary line for the reserve, and it is also the largest watercourse in the study area. In addition, higher water levels were detected in the northernmost part of the studied nature reserve.

June was characterized by low atmospheric precipitation totals (37 mm) and high air temperatures. This caused rapid plant growth and increased evapotranspiration from the land in the study area, which in turn led to a decline in the groundwater level. Peak groundwater levels were noted in December and lasted until the end of the study period. The reason for this was the highest precipitation of the study period (107 mm). February of 2014 was the month with the highest amounts of precipitation. Hydro-isobaths for February follow a north-south pattern, unlike that for all other months, where the set pattern is east-west. The height of the groundwater table decreases gradually towards the southern part of the studied nature reserve.

The necessary precondition for the proper functioning of variable-moisture moor grass meadows (*Molinietum medioeuropaeum*) is a proper pattern of change in groundwater levels. Hollows and depressions are excellent places for moor grass to thrive. Protective measures such as systematic mowing of meadows as well as not regulating watercourses in the near vicinity may be pursued to help moor grass meadows thrive.

These measures would help these areas flood seasonally – an important part of moor grass ecology. On the other hand, human impact is also a key factor in the decline of moor grass meadows. Drainage practices as well as the drying of wetlands yield forced vertical water movement in these areas. In summary, it may be argued that human impact in wetland areas has altered change patterns in groundwater levels.

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