GROUNDWATER FLUCTUATION OF THE BALTIC COAST IN THE SLOWINSKI NATIONAL PARK AND ITS EFFECT TO LOCAL DIVERSITY

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Abstract. The Slowinski National Park is one of the two coastal national parks in Poland. It is situated in the central Polish Baltic coast. The natural values of the Park are determined by the different ecosystems that operate in conjunction with surface waters and ground waters. The water surface area reaches 47.4% in the Park. The largest area is occupied by Gardno and Łebsko lakes. Around the lakes it is possible to follow the model belt arrangement of vegetation: from typically water biotopes, through marshy and waterlogged ones to typically land ones. This paper presents the preliminary results of the studies on shallow groundwater fluctuation and their implications for the environment, particularly for biodiversity. The shallow groundwater level monitoring data were collected in Łeba Barrier area in northern part of the Slowiński National Park. The piezometers were situated between the Baltic Sea and Łebsko Lake. Groundwater monitoring was conducted in the area of the coastal dunes, in the pine forest zone and on the marshy area, which extends in the vicinity of Łebsko Lake.

Keywords: groundwater fluctuations, Baltic coast, biodiversity.

Rezumat. Fluctuaţiile apei freatice de pe coasta baltică a Parcului Naţional Slowinski şi efectele sale asupra diversităţii locale. Parcul Naţional Slowinski este unul dintre cele două parcuri naţionale principale din zona de coastă a Poloniei. Este situat în partea centrală a coastei baltice poloneze. Valorile naturale ale parcului sunt determinate de diferitele ecosisteme legate de apele de suprafaţă şi subterane. Apele de suprafaţă acoperă 47,4% din suprafaţa parcului. Cea mai mare suprafaţă revine lacurilor Gardno şi Łebsko. În jurul acestora, vegetaţia se dezvoltă sub formă de centuri: de la biotopurile tipic acvatice, la cele caracteristice mlaştinilor şi zonelor cu exces de umiditate, urmate apoi de cele tipic terestre. Lucrarea prezintă rezultatele preliminare ale studiilor privind fluctuaţiile pânzei freatice şi implicaţiile acestora asupra mediului, în special asupra biodiversităţii. Monitorizarea pânzei freatice a fost făcută în zona barierei Łeba, în partea de nord a Parcului Naţional Slowiński. Piezometrele au fost amplasate între Marea Baltică şi Lacul Łebsko. Monitorizarea apei freatice s-a făcut în zona cu dune costale, în pădurea de pini şi în arealul mlăştinos care se extinde în vecinătatea Lacului Łebsko.

Cuvinte cheie: fluctuaţiile apei freatice, coasta baltică, biodiversitate.

INTRODUCTION

Water ecosystems: rivers, lakes, marshlands and wetlands constitute an essential element of the landscape in the majority of the national parks and are habitats for valuable plant associations and fauna concentrations. Adverse changes in the level of groundwater are one of the greatest threats to the protected biotic environment. This applies both to the excessive rise in water table and excessive lowering of water levels, which leads to dry land.

The Slowinski National Park is one of the two coastal national parks in Poland. It is situated in the central part of the Polish Baltic coast. The Slowinski National Park is the northern part of the Lowland Gardnieńsko-Leba, which was formed after the last glaciation (ROTNICKI, 2008). At the beginning of the Holocene, the lowland occupied a spilway of the Reda-Leba, which was the area of the Baltic transgression later (ROTNICKI, 2009). The transgressions affect the swamps and bioaccumulation processes. In the past, the groundwater level was much higher and the plain was covered with swamps. At the end of the eighteenth century, the anthropogenic drainage was initiated in the lowlands and the canals were built. This process has triggered a significant reduction in water levels (SZALEWSKA, 2003) and changes in vegetation. The original natural peat bogs have been converted into meadows.

On this small part of the Baltic Coast the sea, lakes, rivers, dunes, forests, peat bogs and meadows border on each other to form a diversified mosaic of environments and thus also of microclimates and biocoenoses. Around the lakes it is possible to follow the model belt arrangement of vegetation: from typically water biotopes, through marshy and waterlogged ones to typically land ones. This reflects not only the effect of change in water conditions on the structure of plant communities but also the stages in the turning of water regions into land. The composition of ecosystems and the absence of human interference in the processes many of which are subject to, makes the whole a very interesting, living natural museum. In 1977, the park was recognized by UNESCO as a World Biosphere Reserve. Due to the presence of particular importance of wetlands the park was included in the list of Ramsar Convention in 1995.

In the Slowinski National Park, the water surface area covers 47.4%. The largest area is occupied by lakes: Gardno Lake and Łebsko Lake arose as a result of sand bars gradually cutting off the former lagoons (ROTNICKI, 2009). It is the largest coastal lake and the third largest lake in Poland. Its total area is 7 020 ha. Its depth only at some sites reaches 4-6 m. Łeba Barrier separates the lake from the Baltic Sea. The groundwater of the spit is in contact with the waters of the lake and the Baltic Sea.

The article presents the nature of the changes of the groundwater level in Leba Barrier, which are particularly important for the functioning of ecosystems found there (Figs. 2; 3; 4).

MATERIAL AND METHODS

Groundwater is found in the study area in permeable sediments of fluvio-glacial, marine and river origin. Groundwater level is usually at a depth of 1 to 5 m, and in Leba Barrier even below 15 meters (LIDZBARSKI, 2004). An important element in the protection of ecosystems and groundwater, its existing and potential threats is the monitoring. The continuous systematic observations of the groundwater level started under the project on groundwater dynamics in August 2008. The shallow groundwater level monitoring data were collected in the Łeba Barrier area in northern part of the Slowiński National Park. The piezometers were positioned between the Baltic Sea and Łebsko Lake (Fig. 1). Groundwater monitoring was conducted in the area of the coastal dunes, in the pine forest zone and on the marshy area, which extends in the vicinity of Łebsko Lake (Figs. 1; 2; 3). The electronic recorders - DIVER (Schlumberger Water Service) were installed in the piezometers and in Łebsko Lake. The water level and temperature were measured every two hours. The measurements of sea level on the Polish coast, rainfall and air temperature were conducted by the Institute of Meteorology and Water Management.

RESULTS AND DISCUSSIONS

This summarizing article presents the results of observation of water levels by six piezometers located in the belt of coastal dunes (piezometers: B-1 and B-2), in the pine forest belt (B-3 and B-4) and in the marshy belt (B-7 and B-8). One piezometer B-4 (6.3 m asl) is located higher above the sea level in places, where groundwater is flowing in two directions: into the sea and the lake. The piezometers closest to the sea are located at heights of 2.0 m asl (B-2) and 1.7 m asl (B-1). The lowest are the piezometers in the marshy area: 0.04 m asl (B-8) and 0.5 m asl (B-7). The average depth to groundwater, calculated for the period October 2008 - September 2010 is varied in each piezometer. The shallowest groundwater occurs in the marsh area. In the piezometer B-8, the average depth was 16 cm and the groundwater were about 16 cm under the sea level. In the piezometer B-7 the average depth of groundwater is 20 cm. Shallow water level in this zone is related to the impact waters of Lake Łebsko and outflows of groundwater from the dunes of the spit. The lowest level of groundwater was located in the pine forest zone, as the piezometer B-4 indicated a depth of 95 cm. Relatively low depth of groundwater in the entire period of study was also observed in the area of the coastal dunes in piezometer B-1 - 86 cm. This was mainly caused by marine conditions of the Baltic Sea. The average level was 504 cm in the Baltic Sea, with the maximum water level 604 cm during a storm in October 2009. Storm Surges ($H \geq 570$ cm) along the central coast during the analysis period occurred very rarely. The largest fluctuation occurred in the groundwater piezometer B-8, located near Lebsko Lake. The difference between the highest and lowest water levels reached 111 cm. Groundwater is in contact with the waters of the lake. The large fluctuations in groundwater levels are related to the dynamics of surface waters of the lake. Its hydrological regime is conditioned on one hand by the inflow of water from rivers, alimenting it on level 80-90%, on the other hand by changing hydrodynamic conditions between the lake and the Baltic Sea (CHLOST & CIEŚLIŃSKI, 2005). The present lake water level is often below sea level. The lowest lake water levels reached 55 cm below the sea level. Łebsko Lake is connected to the Baltic Sea and its water is brackish (CZERNIAWSKA & SPYCHALSKI, 2010). The data showed that the sea level changes had a direct and very fast effect on the level and salinity of the Lebsko Lake. This was particularly evident during the storm in September 2009 (CZERNIAWSKA, 2011). In addition, the lake occupies a large area and is shallow and represents a unique natural ecosystem. The lake surface reflects the impact of wind on water dynamics. The average water level of Łebsko Lake was 11 cm asl. and was higher than the average water level in the piezometer B-8. A drop in water level is observed in winter months when the lake level is lower than the groundwater (piezometer B-8). On this basis, it can be concluded that throughout the year, groundwater is being supplied by lake waters. Brackish waters of Łebsko Lake are important for functioning of the protected halophytic plant communities that occur in the vicinity of the southern part of the lake. In other research locations, fluctuation of groundwater ranged from 65 cm (B-7) to 98 cm (B-3).

Periods of the minimum and maximum water levels throughout the year can be observed on the basis of the calculated average monthly groundwater fluctuation data. The performed analysis shows that fluctuations of the groundwater conditions of Leba Barrier are not synchronous. This clearly shows the results for 2009 and 2010. In the area of the dune distribution, the minimum groundwater level occurred in May 2009. In the pine forest belt, the minimum conditions of groundwater were observed in June 2009. The lowest water level in the marshy area (piezometer B-8) also occurred in May 2009 and until August 2009 (piezometer B-7). The maximum values of the groundwater levels in the forest area occurred in March 2009 and in the zone of dunes and marshy area in October 2009. The increase in groundwater level in spring was caused by snow melting and by a storm in the Baltic Sea in fall (October), causing also an increase in water levels of Lake Łebsko. Different dynamics of groundwater levels were observed in 2010. The minimum conditions of groundwater occurred in the belt of sand dunes and the forest area in February. A reduction of water was caused by very low temperatures, which lasted since January and caused ground freezing. The average temperature for January 2010 was -5.5°C (minimum -18.4°C) and -1ºC in February. In the marshy area, the lowest groundwater levels were observed only in July and were due to very high temperatures (average temperature of +19.9ºC, and maximum temperatures > +30ºC). The impact of high air temperatures in July 2010 was marked by a clear ground water reduction as observed in all piezometers. The highest water levels that year occurred in

March at the belt of marshland and in other areas until September after a significant rainfall. In September 2010, a total of 152.1 mm of rain fell in the study area, representing the most intensive rainfall during the whole observation period. The research results indicate the need for follow-up of groundwater fluctuations.

The resulting data show large variations of groundwater fluctuations in time and space along the central Polish Baltic coast. Extreme events like storms on the Baltic Sea, very high and low temperature as well as heavy rainfalls, all have major impacts on the dynamics of groundwater. Occurrence of these phenomena makes it difficult to identify closed-system trends and changes in the groundwater conditions in the coastal zone of the Slowinski National Park. Rapid increases in high summer temperatures are a threat to the pristine natural swamp belt, where they can cause degradation of the wetland ecosystems. High sea levels directly affect the ingression of saline water into surface waters and groundwater. Studies of groundwater chemistry have shown that the most vulnerable to the encroachment of saline wetlands are the places located in the vicinity of Łebsko Lake (CZERNIAWSKA & SPYCHALSKI, 2011). An exceedingly high level of groundwater poses a serious threat to local pine forests. The continuing high groundwater level in the second half of 2010 initiated a slow degradation of the stand of Leba Barrier. This has also negative effects on Klucki Forest reserve and its natural biotopes (CHRZANOWSKI & KLUCZYŃSKI, 2004).

CONCLUSIONS

This summary paper presents the results of the systematic pilot studies on a shallow groundwater fluctuation and sea-coastline geo- and ecosystem dynamics and its implications for environment, including local biodiversity. The research implications are of major relevance for the protection and environmental management of the Slowinski National Park. A long-term groundwater monitoring is particularly essential to biodiversity, especially for observations of changes in vegetation cover. For future ecology studies based on a multidisciplinary approach, it is necessary to determine the scale, scope and frequency of potential risks of groundwater fluctuations to local ecosystems, particularly to plant species and their communities established on sand dunes, and in the coastal pine and mixed forests as well as the peat bog / marshland biotopes. The collected data should be used for the modelling of seasonal groundwater changes and forecasting of environmental shifts in the Slowinski National Park. It should be stressed that changes in the coastal groundwater hydrogeological conditions are closely inter-linked to other environmental changes in the Polish Baltic coastal zone with the observed accelerating rate of effects to the progressing coastal erosion (DZIADZIUSZKO & JEDNORAŁ, 1987; ROTNICKI & BORZYSZKOWSKA, 1999). These natural processes are presumably associated with global climate change and the corresponding ocean / Baltic Sea levels rise (ROTNICKI et al., 1995).

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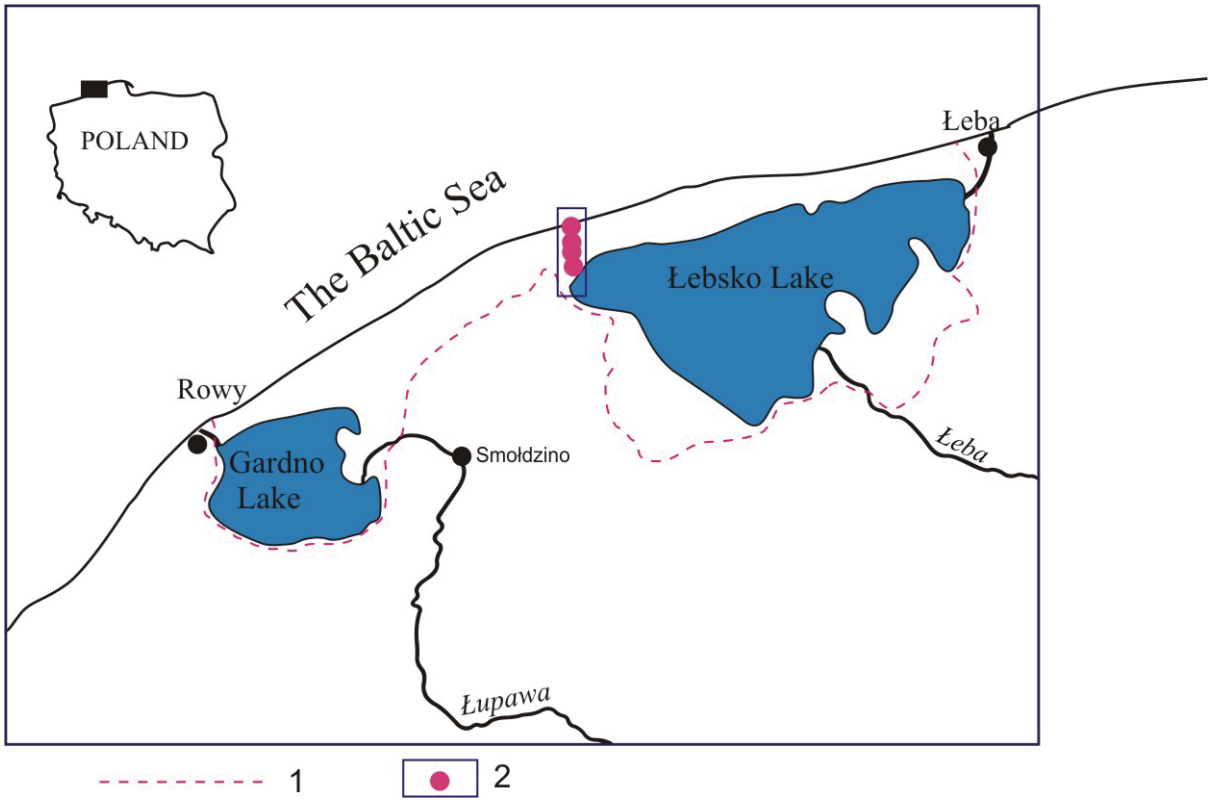

Figure 1. Location of the study area and piezometers. 1 – border of the Slowinski National Park; 2 - study area (the piezometer transect).
Figura 1. Localizarea zonei de studiu şi a piezometrelor. 1 – limita Parcului Național Slowinski: 2 – zona de studiu (linie piezometrică) (original).

Figure 2. The belt of coastal sand dunes in the Slowinski National Park (with *Carex arenaria*). A piezometer location.
Figura 2. Dune de nisip în zona de coastă a Parcului Național Slowinski (cu *Carex arenaria*). Localizarea piezometrelor (original).

Figure 3. The peat bogs occupy the shore areas of the Lebsko Lake, the Slowinski National Park.
Figura 3. Turbăriile ocupă arealele de pe ţărmurile lacului Lebsko, Parcul Naţional Slowinski (original).

Figure 4. The alder carr (*Carici elongatae-Alnetum*) which develops along the shore of Lebsko Lake, The Slowinski, National Park.
Figura 4. *Carici elongatae-Alnetum* care se dezvoltă de-a lungul ţărmurilor Lacului Lebsko, Parcul Naţional Slowinski (original).

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