

INFLUENCE OF HYDROLOGICAL CONDITIONS ON THE STATE OF SELECTED PLANT HABITATS IN THE SŁOWIŃSKI NATIONAL PARK (NORTHERN POLAND)

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Abstract

The Słowiński National Park (SNP) extending between two large coastal lakes – Gardno and Łebsko, is very characteristic for the Polish coastal zone of the southern Baltic Sea. This is a place where human pressure on water relations is observed for over 200 years. In the other hand attempts to protection of biotic and abiotic environment are also carried out there. The overall objective of the park is to preserve all existing there lakes, swamps, bogs, meadows brackish, coastal forests and sandspit with unique in Europe moving dunes. Słowiński National Park is located in northern Poland, on the coast of the southern Baltic. It is a hydrographic unit that differs from the rest of Poland in terms of hydrological conditions. Permanent wetlands perform a particular task in the system of water circulation, especially water retention, in this area. They are created by peat bogs, which genesis refers to climate-plant change during the period of Holocene. The main objective of this paper is to determine the hydrological conditions, particularly changes in the water table, that prevail in the area of SPN and to determine their impact on the selected plant habitat, both forest and non-forest. The main work consisted in query and development reference material. Data concerning groundwater levels variations were obtained from the Słowiński National Park Leadership and the National Geological Institute under the MONBADA program, while the volume of rainfall and water levels in the main lakes and coastal rivers were obtained from the Institute of Meteorology and Water Management. Halophilic vegetation, that occurs in SPN in a residual state, creates a valuable and rare habitat. A piece of land between the eastern shore of Lake Łebsko and a causeway, on which the road runs, is the only place where it is now established. It is represented by halophytes from *Agropyro-Rumicion crispus* group. In conclusion, hydrographic conditions (including the water cycle, periodic retention, sea water intrusion and groundwater level fluctuations) have relevant, or rather crucial importance for occurrence of specific types of plant habitats. As a result of human pressure natural habitat conditions have been disrupted, through which the growth of certain plant species was suppressed. Consequently, at this moment, SPN's protection tasks seek to restore natural water relations in order to optimize the development of selected hydrogenic habitats. The study covers the current state of water relations and plant habitats in the SPN.

Keywords: The Słowiński National Park (SNP), hydrogenic habitats, ground water level changes, hydrological conditions

INTRODUCTION

The Słowiński National Park (SNP) extending between two large coastal lakes –Gardno and Łebsko, is very characteristic for the Polish coastal zone of the southern Baltic Sea (Fig.1). It is one of 23 parks that rank in Poland and also the second located in the coastal zone. Its primary task is preservation of biotic and abiotic environment occurring here in rare scale. The overall objective of the park is to preserve all existing there lakes, wetlands of various origin, coastal forests and especially sand spit with unique in Europe moving dunes.

Słowiński National Park is dominated by one of the components of the natural environment, which is water. It covers almost 80% of the Park area. Within the SNP the water and its circulation determine the presence of hydrogenic habitats, with the whole spectrum of differentiation: from the marine ecosystem through the lake ecosystems, the peat-bog ecosystems, riparian, swamp forests, and more. Each of these habitats is characterized by a diverse range of flora and fauna, of which vegetation is the most sensitive indicator of changes taking place in the environment.

Particular task in the circulation system, especially the retention of water in the SNP, are the coastal lakes which are the last natural receiver of water flowing from the inland. Beside the lakes, the hydrogenic terrestrial ecosystems which cover over 25% of the SNP fulfills a similar role. They are formed of peatbogs which genesis refers to the climate and plant changes during the period of Holocene (Tobolski et al., 1997). The peatbog ecosystems occurring in the SNP are characterized by an advanced degree of degradation which manifests as peat mass supuration and mineralization which consequently leads to settling of the entire deposit. The observed process is the result of intense drainage work lasting over 200 years, carried out in order to regulate and adapt water relations to the agricultural needs and peat exploitation. Despite keeping large areas covered with peat-forming plant communities, human pressure caused that the process of forming peat does not occur there.

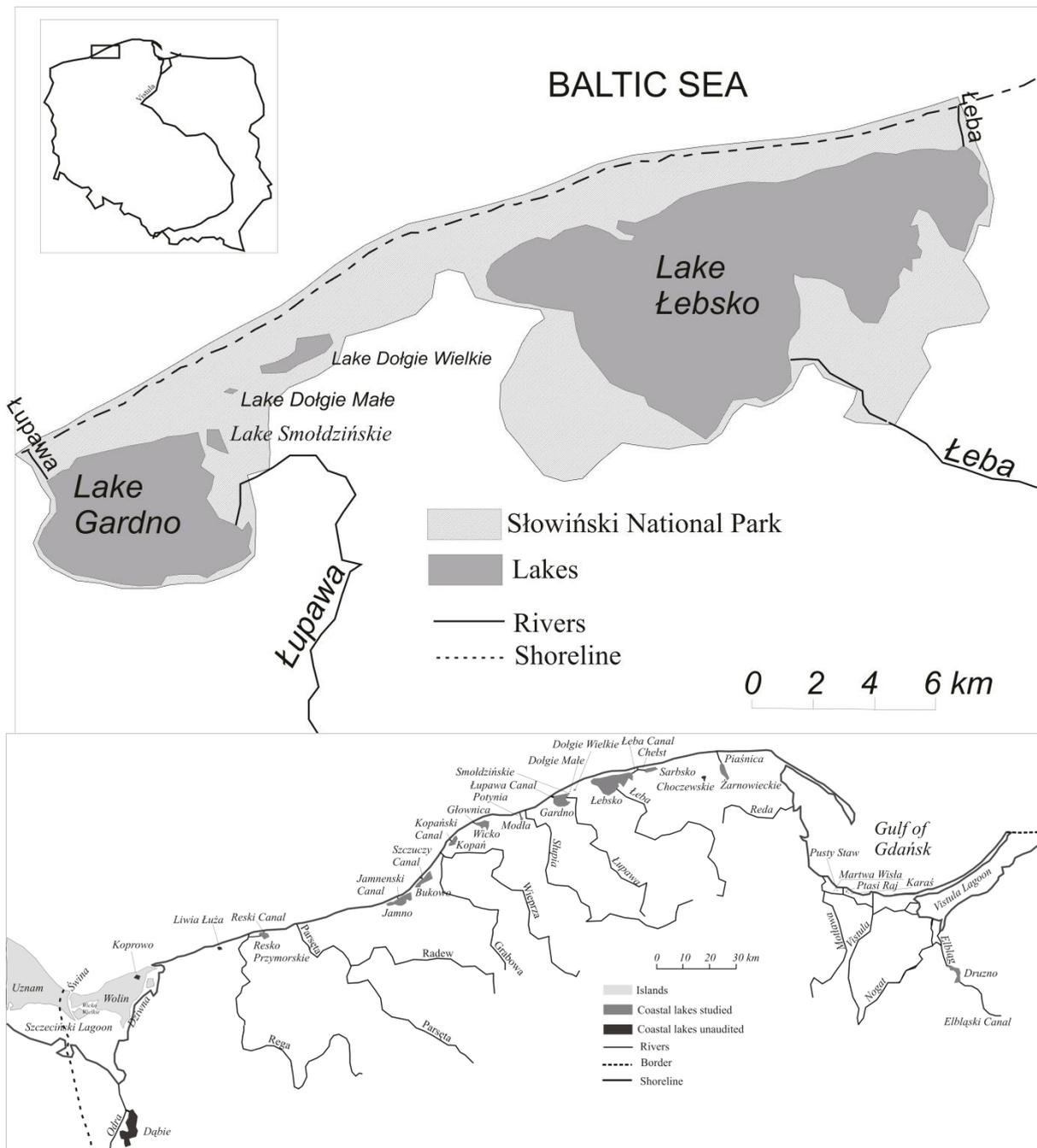


Figure. 1 Słowiński National Park on the background of hydrographic network of the Polish coast of the southern Baltic Sea

The main objective of this work is to determine the current hydrological conditions prevailing in the selected forest and non-forest ecosystems, where water is the most important element that determines the biological processes. Interpretation of changes in groundwater levels and determination of their impact on the development of selected plant habitats takes particular importance in this field.

Among terrestrial hydrogenic habitats of SPN the largest areas are occupied by forests, represented by: swampy coniferous forest, swampy mixed coniferous forest, moist mixed coniferous forest, moist coniferous forest, swampy mixed forest, moist mixed forest and alder forest (Fig. 2). Reed-meadow vegetation in varying degrees of succession also occurs in the area of SNP. Additionally halophilous vegetation, found in SNP in the rudimentary state, creates valuable and rare habitats. The only current place of halophilous vegetation presence is the piece of land on the eastern shore of Lake Łebsko. It is represented by the halophyte such as *Agropyro-Rumicion crispi*.

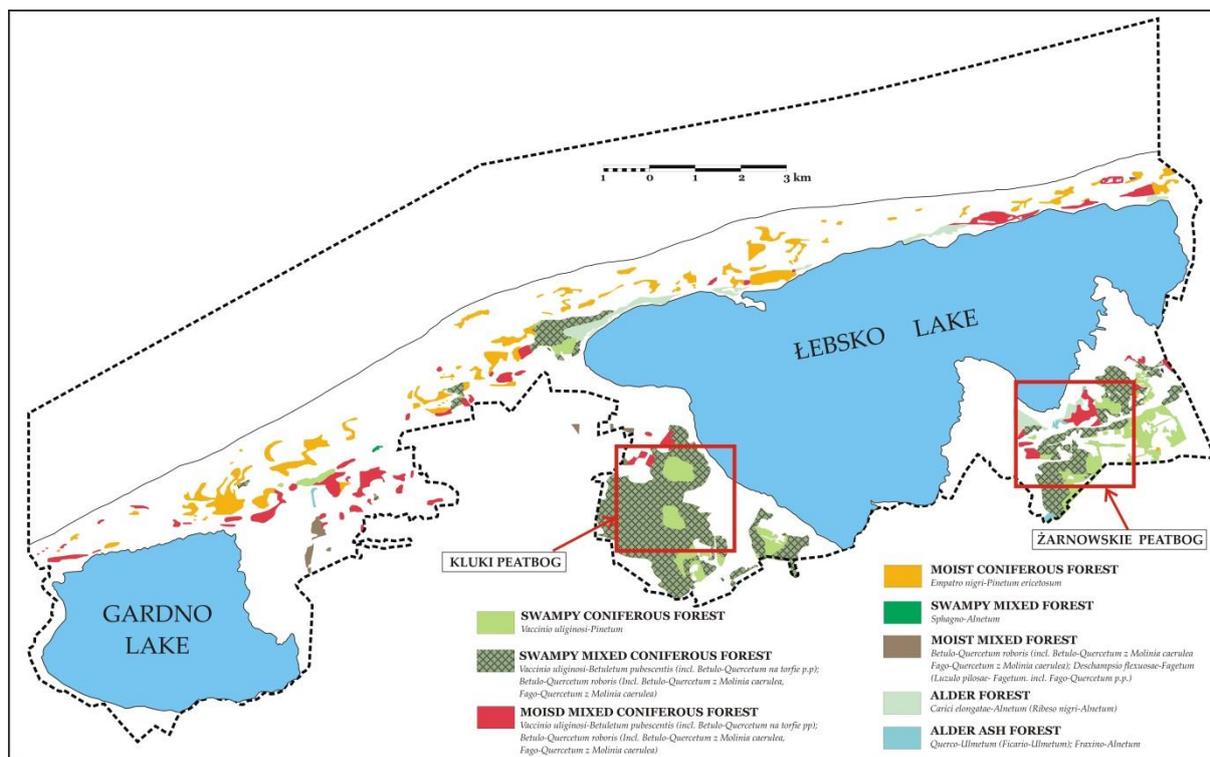


Figure. 2 Forest habitats in the SNP

METHODS

The research involved making a patrol hydrographic charts of selected habitats, in order to register anthropogenic changes and obtain a static map of objects, water phenomena and hydrotechnical devices. Information collected during the field work has been completed on the basis of the source materials query. Among materials, the most important included data concerning groundwater levels variations carried out by the monitoring cell of Słowiński National Park. Total precipitation and water level observed in the main coastal lakes were obtained from the Institute of Meteorology and Water Management. These data have been developed graphical and analysed in terms of clarify the current state of water conditions prevailing in the habitats. Due to the limited framework of the publication, the following are the results of research carried out on the two Baltic types surfaces of a peat-land moss communities: peatbog Żarnowskie and peatbog Kluckie. These surfaces differ in the way protective actions carried out there. Both peat bogs are located in the catchment of the Lake Łebsko and have uplifted central highland with the falling slopes of dome, surrounded by highly marshy ecotone where a swampy forest *Vaccinio uliginosi-Pinetum* is forming.

OBTAINED RESULTS AND DISCUSSION

Swampy coniferous forest is a habitat associated with the occurrence of bogs, which form on endoreic areas, basins or on the outskirts of overgrown lakes. Under natural conditions, hydrological regime of such bogs, is characterized by constantly high groundwater level resulting from that the water is derived entirely from precipitation. It follows that even in periods of dry summer half-year, groundwater level does not fall below 0.5 m from the ground surface, and during the winter half-year it often remains on the ground. Consequently, the variability of groundwater level is low and also is characterized by small amplitudes of fluctuations during the year. In connection with the soil-forming bog processes occurring in the water, pH of the water is very acidic and often falls <4.0 pH. Due to the supply way, peatbog Żarnowskie and peatbog Kluckie are termed ombrotrophic (rain-fed), while in due to the phytosociological terms thereon occurs similar to the natural vegetation *Erico-Sphagnetum medii* which is one of the rarest and vanishing peatbog in Poland, dominated by protected cross-leaved heath *Erica tetralix* (Jasnowski 1990).

The studied peatbogs are objects whose proper functioning has been imbalanced as a result of interference in the water relations caused by the artificial groundwater level lowering by the system of drainage ditches. The presence of *Cladonia* lichens, common heather *Calluna vulgaris* and tussock cottongrass *Eriophorum vaginatum*, resulting in disappearance of characteristic clump-valley habitat

structure, indicates the peat bogs domes overdrying. In addition, there has been a withdrawal of oligotrophic peat forming vegetation, among others, peatmosses as *Sphagnum magellanicum*, *Sphagnum rubellum*. Lowering the water level caused a change in habitat conditions and foster the possibility of scots pine *Pinus sylvestris* and downy birch *Betula pubescens* (also known as moor birch) which initiated the spread of bog forest and replacement vegetation with the dominance of common heather *Calluna vulgaris* and purple moor grass *Molinia caerulea* on depleted excavations.

Protective treatments were carried out within the peat bog Żarnowska in 2006-2007. These consisted in installing valves in the girdling ditches abstaining uncontrolled water runoff and excision of tree stands whose function was to reduce transpiration from the surface of peat bog (Braun & Chlost 2008). In total, 24 valves were built. Furthermore, 30 hectares of pine volunteer from the central part of peatbog dome were excised. Similar protection methods have been successfully implemented on other bogs in the northern part of Poland (Herbichowa et al. 2007), as well as in the Nordic countries (Komulainen et al., 1999). Currently, the entire protective area of peatbog Żarnowska covers 300 hectares, the western part of which is occupied by the peat excavations. After removing the drainage facilities, excavations filled with water and took the form of reservoirs named: Lake Babidół Great, Babidół Small and Jelenie (fig.3).

As part of monitoring 8 manual piezometers are installed in the peatbog Żarnowska. Data from these piezometers are read once a week. Piezometers are disposed in pairs (deeper and shallower) in such a way as to form transect passing through the center of peat bog. Piezometers PŻ1-PŻ2, PŻ3-PŻ4 and PŻ5-PŻ6 form pairs located on the peatbog dome. Among these piezometers PŻ1, PŻ3 and PŻ5 are longer, and extend to approximately 180 cm depth to the abiotic part with peat strongly hydrated, but also more compacted.



Figure. 3 Location of piezometers on peat bog Żarnowska

Piezometers labeled with even numbers (PŻ2, PŻ4, PŻ6) are shorter and installed at the base of acrotelm, characterized by loose and porous peat, which hydration is dependent on the current atmospheric conditions. Piezometers PŻ7 and PŻ8 are located in the edge part of the peat bog. It should also be noted that the piezometers PŻ1-PŻ2 and PŻ8 extend over the area where the peat layer has been exploited to a depth of approximately 1 m.

Furthermore, there are 2 automatic limnigraphs with one-hour storing data time step located on the peatbog. Limnigraph No. I records fluctuations in water level in the border area of the peatbog and also is located near girdling ditch. Limnigraph No. II records water level fluctuations on the peatbog dome.

From the analysis of monthly average groundwater level fluctuations on a peatbog Żarnowska during the period 2006-2011 data it follows that variability regime refers to the ocean characteristics (Chelmicki 1991). This means that the water level changes in the seasonal system in such a way that the high levels recorded during the winter half-year (from November to April), when the water remains on the ground, while

during summer half-year groundwater level does not fall below 0.5 m from the ground surface. Minimum usually falls on months of July and August (Fig. 4). Then also occur the highest sums of precipitation, which nevertheless do not compensate for losses due to evaporation and transpiration.

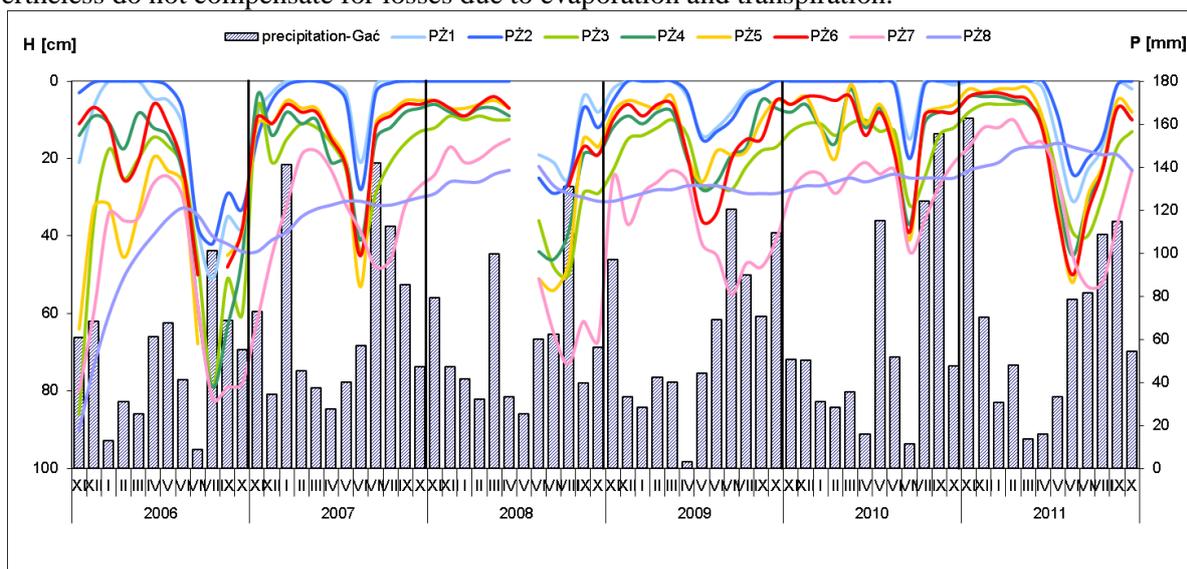


Figure. 4 Average monthly fluctuations in groundwater levels on a peatbog Źarnowska for 2006-2011

Over the years, a gradual increase in the average water level caused improvement in water relations and retention state of the peatbog. During the period 2006-2011 the average annual groundwater level increased from about 1.0 cm (PŽ1, PŽ6) to approximately 0.5 cm (PŽ8) per year. The high groundwater level resulted in falling out of unwanted tree stand (mostly pine and birch). This demonstrates the positive impact of conservation measures applied there. However, a very significant impact of hydrometeorological conditions (for the period or year) to fluctuations in water level, is also noticeable there. One example of that is cold and prolonged winter and extremely hot and dry July in 2006 (Braun & Chlost 2008), which in effect caused that from the entire observation period 2006-2011 the lowest water levels were recorded then.

High synchronicity in shaping groundwater levels fluctuations with rain-fed in the short- and long-time cycle was also found there. This means that the groundwater level is sensitive to temporary changes in hydrometeorological conditions, but its response to precipitation is appropriately delayed and has a different range depending on the size of the precipitation. This delay may last from a few days (PŽ2, PŽ4 and PŽ6) to the month and longer (P8), and it is a result of the peatbog construction and the depth of installed piezometers. In the first case, these are shallow piezometers, located in the acrotelm porous layer which is responsible for the water distribution in the peatbog. In the second case, the delay is caused by pluvial water infiltration through the settled, dense structure of peat.

Observations carried out in years 2006-2011 show that the level of summer retention in peatbog, corresponds to the size of spring retention more than to the size of the atmospheric supply. If in the spring (April-May, and even June), the water level as a result of hydrometeorological factors is maintained at a high level or even the water remains on the ground, then in the summer, even with a relatively small rain alimentation, the water level does not drop below 0.5 m from the ground surface. An example of this might be the July in year 2010, when total precipitation accounted for only 11.4 mm.

It is important to preserve the water level in the peat bog cross-section. On the basis of the variation of water level in manual piezometers it was found that the largest amplitudes of fluctuations occur in dome part of the peatbog and reach even 1.0 m in piezometers PŽ5-PŽ6. On the other hand, the rhythm of fluctuations recorded by limnigraphs, shows large amplitudes in both the central and border part of the peatbog. These divergent results are caused by different location of manual and automatic devices. However, it should be noted that the level recorded in automatic ones practically does not fall below the limit of 0.5 m from the ground (Fig. 5).

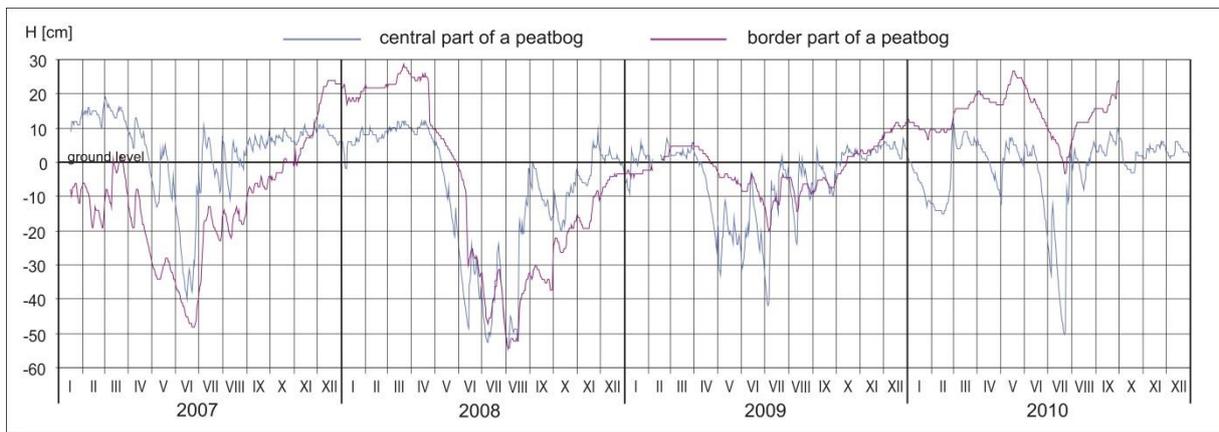


Figure. 5 Daily variations in groundwater level on the peatbog Żarnowska in 2007-2010

Slightly different water conditions prevail in the swamp forest on the peatbog Kluckie. It should be noted that no protective treatments were performed here, as it was in the case of the peatbog Żarnowska. Observations of groundwater level are performed in six manual piezometers, distributed as follows: pair PK1-PK2 - on the edge of peat bog by the road, then PK3 and PK4 - in the central part and PK5 and PK6 - near the channel C9.

Fluctuations in average monthly record of the water level shows that groundwater level in most piezometers remains below 0.5 m from the ground surface (Fig. 6). This applies especially to the summer half-year. The weekly readings in some piezometers recorded declines of up to 1.5 m, and in extreme weather conditions in the summer, piezometers of underground length from 1.0 to 1.6 m, are drying up. These are piezometers No. 6 and 5, located near the channel C9. They are located in the part transformed by human activity and located on the substrate, where the spoils from the construction of the channel C9 has been accumulated, causing it to become the highest part of the peatbog.

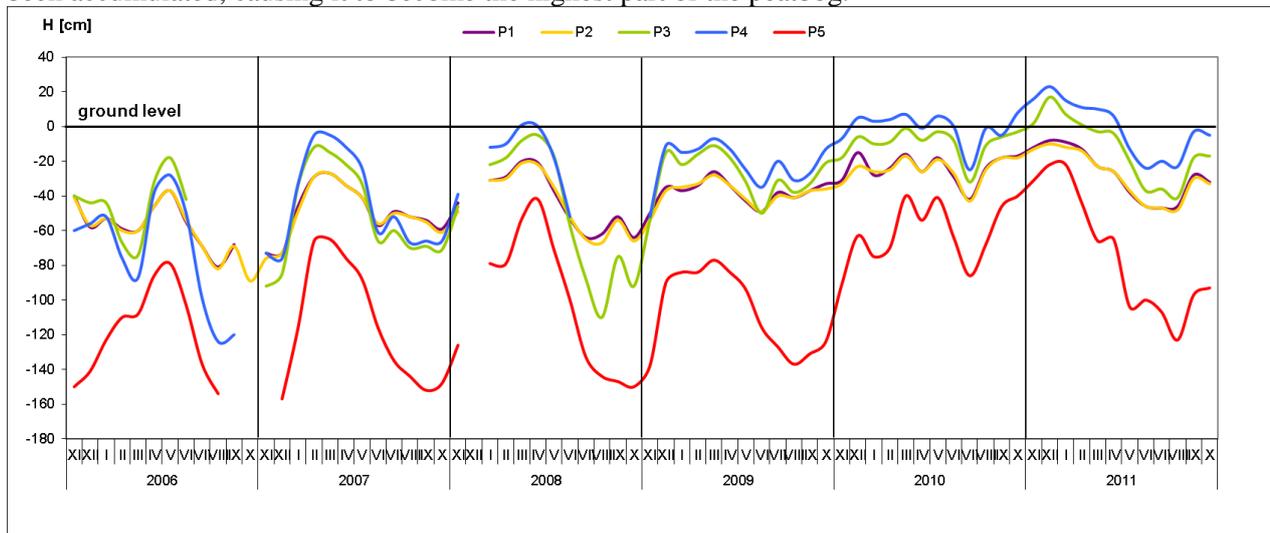


Figure. 6 Average monthly variations in groundwater levels on the peatbog Klucki for 2006-2011

Concurrency of groundwater levels fluctuations on the peatbog Kluckie with the channel C9, is readable in the fluctuations of variability level of almost all piezometers (Fig. 7). It should be noted that the variability of the water level in the channel C9 depends on two factors: the activities of beavers and purification of the channel by the Drainage Water Management in Slupsk. After mechanical recanalisation, water levels in the channel fall into the 60-70 cm, while the activity of beavers raises the water level to 100 or more centimeters.

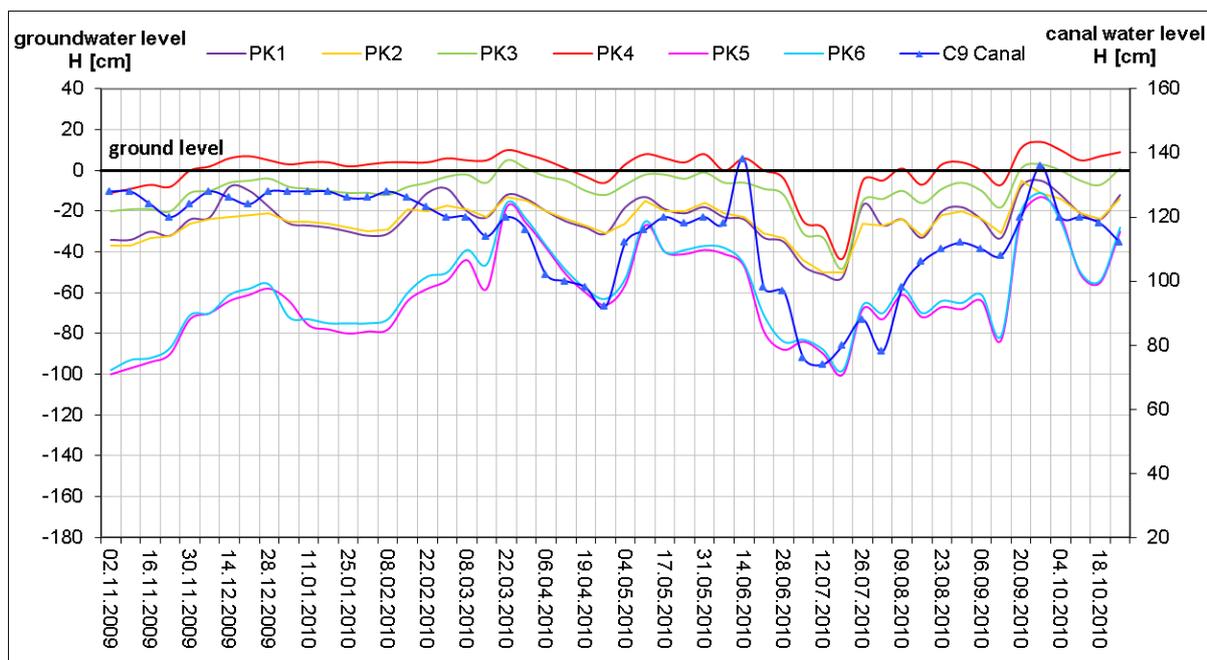


Figure. 7 The relationship between fluctuations in groundwater levels on the peatbog Kluckie and channel C9 on example of 2010 hydrological year

Piezometers PK1, PK2, PK3 and PK4 are installed on part of the peatbog that is not transformed by human activity. In the first two piezometers, the average groundwater level from the period of 2006-2011 remained at depth of 40 cm below the ground surface. The largest decreases (less than 0.5 m) were recorded from June to October, and sometimes even December. The highest water levels usually occurred from January to April. There was found no water stagnated on the surface of the ground. The reason for this might be the location of piezometers near the road, along which drainage ditches extend. The road was built on a natural sand dune belt that crosses the peat bog from west to east. Drainage ditches are used to hedge the road by flooding during high water levels periods.

Piezometers PK3 and PK4 are located in the lowest part of the bog, on its dome, which settled as a result of draining of. Here are registered the shallowest ground water levels. Seasonally water appears on the ground surface, usually in a wet time of the year, especially in January and February and during snowmelt in March and April.

Location of the peatbog in close proximity to Lake Łebsko, resulting in hydraulic contact between the objects (Fig. 8). The connection marks primarily by affecting the level of the lake on the formation of the groundwater level, but it is legible only in extreme increases or decreases situations in the level of the lake. It should be noted that the variability of the lake water level is very dynamic and determined by the rhythm of variation in the Baltic Sea. The correlation coefficient of fluctuations of both basins stands at $R^2 = 0.9$ (Chlost 2012).

CONCLUSION

Contemporary strategy of the SNP concerning renaturalization of the bogs extends in two ways: either includes attempts to active protection, aimed at improving the water conditions (the peat bog Żarnowska) or confined to maintain the natural environment unchanged (the peat bog Kluckie).

As carried out analyzes show, protective treatments applied to the peatbog Żarnowska bring tangible results. First of all, retention of the complex increased. Fluctuations in water levels are low, and the groundwater level, even in extreme hydrometeorological conditions, does not fall below 0.5 m from the ground surface. Experiment carried out on discussed peat bog brought promising evidence in this matter. The experiment consisted in peat reintroduction in excavation voids filled with water, in order to initiate the development of bog vegetation. Peat adopted and began slowly but spontaneously grow occupying larger areas.

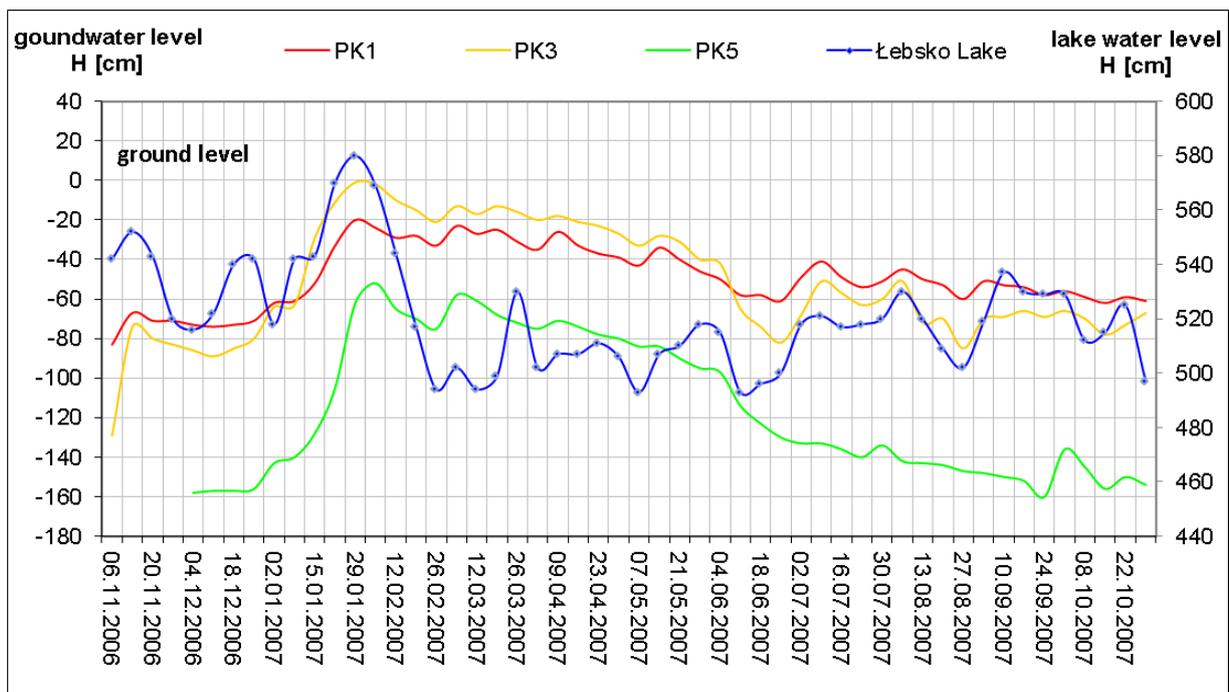


Figure. 8 Fluctuations in groundwater levels on the peatbog Kluckie and Lake Łebsko on example of 2007 hydrological year

Passive protection method is a consequence of the formal and legal reasons arising from settled land use in areas adjacent to the SNP. The park is located at the lowest point of a larger wetland complex of wide alluvial plains called Lowland Gardneńsko- Łebska, with agricultural land use. This unfavorable location causes that most of the ditches and irrigation channels begins outside territory of the SNP, and flows into the coastal lakes within the park. Therefore it is not possible to liquidate them or install valves, because this can cause raising the water levels in meadows adjacent to the park. First of all, there is a conflict between environmental protection and the functioning of the transit drainage channel C9. Because of it, peatbog has too large amplitude of groundwater levels fluctuations, resulting in its overdrying and in the further consequences the succession of trees and shrubs, which are the main risk here. Significant fluctuations may also result from the hydraulic connectivity between peatbog waters and the Lake Łebsko. In the case of peatbog Żarnowska this connection is very reduced, due to the isolation of peatbog from the lake by a belt of inland dunes.

REFERENCES

- Braun M & Chlost I., 2008, Funkcjonowanie systemu torfowiskowego Żarnowska [w:] E. Jekatierynczuk-Rudczyk, M. Stepaniuk, M. Mazur, Współczesne problemy geografii polskiej-geografia fizyczna. Dokum. Geograf. Nr 37, PAN, IGiPZ Warszawa, s. 122-128.
- Chełmicki W., 1991, Reżim płytkich wód podziemnych w Polsce, Rozprawy Habilitacyjne, Wyd. UJ, Kraków, 218, s. 136.
- Chlost I., 2012, Geograficzne uwarunkowania stosunków wodnych Niziny-Gardneńsko-Łebskiej. Rozprawa doktorska, maszynopis Katedra Hydrologii UG, ss. 233.
- Herbichowa M., Pawlaczyk P. & Stańko R., 2007, Ochrona wysokich torfowisk bałtyckich na Pomorzu, Wydawnictwo Klubu Przyrodników, Świebodzin, s.147.
- Jasnowski M., 1990, Torfowiska województwa słupskiego. Stan, zasoby, znaczenie, zasady gospodarowania, ochrona, Akademia Rolnicza w Szczecinie, *Wojewódzkie Biuro Planowania Przestrzennego w Słupsku, Szczecin* s. 84.
- Komulainen V.-M., Tuittila E.-S., Vasander H. & Laine J., 1999, Restoration of drained peatlands in southern Finland: initial effects on vegetation change and CO₂ balance, *Journal of Applied Ecology*, 36, 634-648.
- Tobolski K., Mocek A., Dzięciołowski W., 1997, Gleby Słowińskiego Parku Narodowego w świetle historii roślinności i podłoża, Domini, Bydgoszcz – Poznań, s. 183.