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CHANGES IN WATER LEVELS OF PROSNA (BOGUSŁAW PROFILE) IN THE YEARS 1973-2017

Summary

The thesis presents long-term changes in water levels of Prosna, one of the main rivers in Wielkopolska, i.e. a region that commonly is considered as one of the least water-rich in Poland.It was found that in the last 40 years, average annual water levels of Prosna were characterized by a downward trend of 7.8 cm·dec^{-1} and werestatistically significant at p=0.05 and also p=0.01.In all months, the water level dropped, although statistically it was significant in seven cases.The largest reduction in monthly average water levels (statistically significant, p = 0.05) was in August and December and it was progressing at a rate of 13.2 and 12.3 cm·dec^{-1}.The consequence of this ongoing trend may be, among others, deterioration of living conditions of ichthyofauna, or worse water quality of Prosna.

Key words: water levels, river, climate change, Prosna

INTRODUCTION

Fluctuations of water levels in rivers are a good indicator of changes in natural and anthropogenic factors that determine the hydrological conditions in the catchment. The first ones include the amount of rainfall and air temperature, which affects the size of the evaporation. The other are all types of hydrotechnical activities, as well as changes in the way the catchment is used and managed. Water levels can be influenced by both factors at the same time, which makes determining the main cause of changes in water levels is often difficult. The amount of water in the river is a key factor shaping the river bed and its valley. Processes

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modelling their form are the result of erosion and accumulation of matters, whose advantage is generally determined by the energy generated by water, changing in direct proportion to the oscillation of fluctuations in water levels. Fluctuations of water levels create specific environmental conditions for the existence of specific species of flora and fauna in these zones. An important issue is also how water level fluctuations in rivers affect human life. Already in antiquity, large cultures were based on river floods, which allowed for irrigation of fields and functioning in unfavourable dry climate zones. The occurrence of low (water deficits for various branches of the economy) and high levels (floods) should be considered unfavourable. Observations of water levels are important in the context of flood risk assessment, which was covered by Ptak [2013]. Determination of the warning and alarm state for a given water level profile activates actions (e.g., protection of floodwalls, evacuation of people, etc.) related to protection against this element. Taking into account the above premisses, it is interesting and even necessary to present the course of water levels based on long (reliable) data strings, on the basis of which it is possible to determine the range of variations of a given river, the trends that these changes are subject to and determining the main reasons for these changes.

The objective of the thesis was to determine the directions and size of changes in the Prosna water levels in the Bogusław profile. In addition, the analysis of directions and size of changes in climatic factors in the context of their future impact on water levels has been made.

MATERIALS AND METHODS

One of the major rivers of Wielkopolska - the region commonly considered as one of the least water-rich - is Prosna (Fig. 1). The river is the left tributary of the Warta River with a length of 229 km and a catchment area of 4924 km^2. According to Kaniecki [1976], its average fall is 0.82 ‰, the catchment's sculpture is transformed by periglacial processes, and the material that forms the floodplain terrace is fine and medium-grained sands. The type of hydrological regime was defined as a medium or highly structured, depending on the location of the water gauge station [Wrzesiński, 2013]. The analysis of water levels was based on measurement data of the Institute of Meteorology and Water Management - National Research Institute (IMGW-PIB) from the Bogusław profile from 1973-2017. The daily water levels formed the basis for determining the values of monthly and annual averages. The analysis was performed in relation to hydrological years. The thesis also uses data on everyday atmospheric precipitation and air temperature from the IMGW-PIB synoptic station in Kalisz, located about 20 km from the Bogusław station.

Analysis of the directions of changes in the water levels of the Prosna River in the Bogusław profile in 1973-2017 on a monthly and annual basis was made using the non-parametric Mann-Kandall test (MK) [Kendall and Stuart, 1968]. The size of monthly and annual water levels changes was determined using the non-parametric Sen test (Gilbert 1987).It was carried out in relation to the minimum (NH), medium (SH) and maximum (WH) levels. The maximum interdiurnal changes in water levels, i.e., increases (+DH) and decreases (-DH) were also analysed.The significance analysis of trends was carried out for four p levels $_{\alpha}$:0.1; 0.05; 0.01 and 0.001. A detailed analysis of the size and directions of changes in air temperature and precipitation was carried out in relation to particular months and hydrological years. The analysis was carried out taking the same procedure as in the case of water levels (Mann-Kendal and Sen tests).

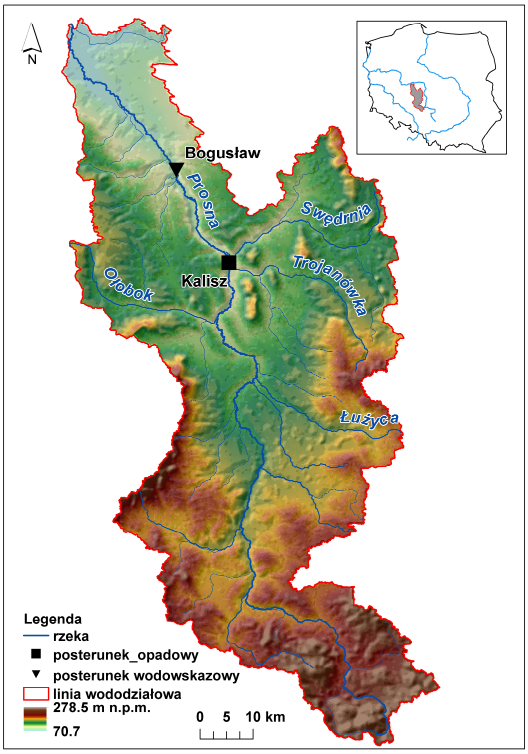


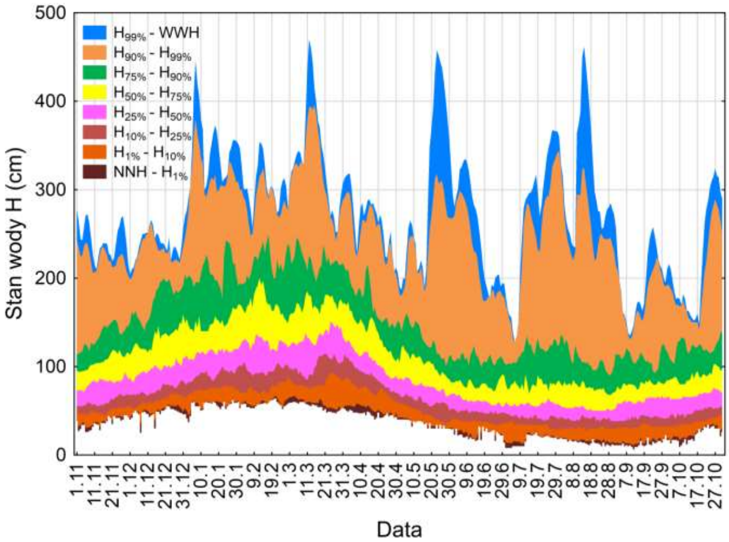
Fig. 1. Location of the research object

RESULTS AND DISCUSSION

The Prosna water levels in the Bogusław profile in the years 1973-2017 varied from 6 cm to 470 cm with an average value of 98 cm (Fig. 2a).In individual years, average annual water levels ranged from 51 cm in 1990 to 154 cm in 1977. With respect to the months, highest levels occurred in March - an average of 146 cm, and the lowest in August and September - an average of 67 cm (Fig. 2a). Figure 2a shows the changes in water levels in relation to particular days of the years 1973-2017 - the lowest and the highest values (NNH and WWH) and the percentiles of 1, 10, 25, 50, 75, 90 and 99 were calculated for each day. The highest levels usually occur in the period from January to March and in May. The levels comparable to the maximum high water levels due to rain, appeared in May, July and August. This occurred most often after heavy rainfall.Low water levels usually occurred in late August and September, and periodically at the beginning of July (Fig. 2a).This is a typical situation for lowland rivers in the discussed region. The March maxima are related to spring melt and difficult infiltration (frozen ground), which affects the generation of the highest water levels and the occurrence of flooding during this period. On the other hand, the lowest levels recorded in late summer result from the depletion of the catchment's water resources. This happens despite the fact that the highest rainfall amounts are recorded in July, and high losses in the water balance are responsible for the observed situation in the distribution of water levels in the river, which are the result of, among others, plants vegetation or high evaporation.

The highest variability of water levels in the analysed period was found in July and August (on average 67 and 77%) and the lowest in April (39% on average) - Fig. 2b.

a)



b)

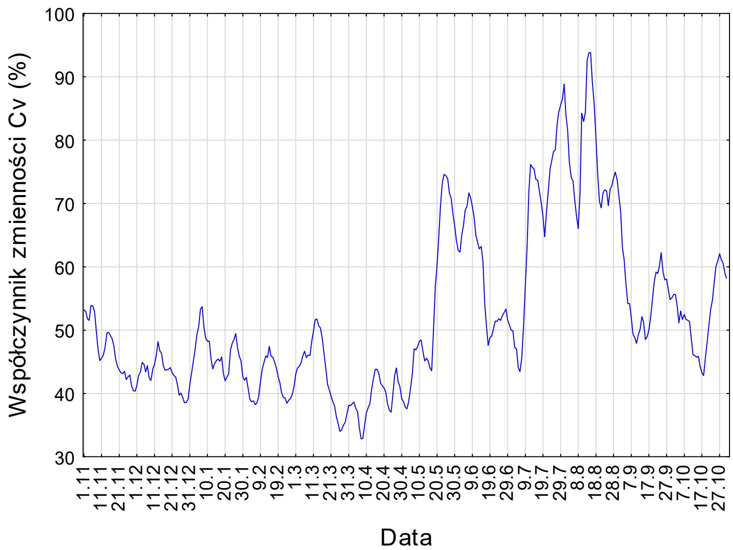


Fig. 2. Characteristic water levels (a) and variability of water levels (b) of the Prosna River in the Bogusław profile in the years 1973-2017

As it results from the annual average water levels, they are characterized by a tendency to decline at a rate of 7,9 cm·dec^{-1} and are statistically significant at p = 0.01 (Fig. 3a). In all months, the water level dropped, although statistically it was significant in nine cases. The fastest decrease in average monthly water levels occurred in August and December at 13.2 and 12,3 cm·dec^{-1} (changes were statistically significant at 0.05 and 0.001 respectively) - tab.1.

Tab. 1. Directions of changes in monthly and annual water levels of the Prosna River in the Bogusław profile as well as temperatures and precipitation at the Kalisz station in the years 1973-2017

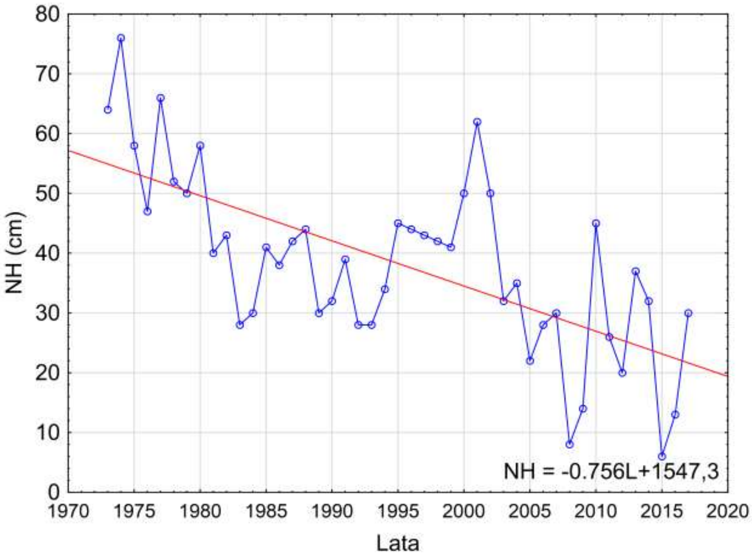
Period	NH (cm)	SH (cm)	WH (cm)	-DH (cm)	+DH (cm)	P (mm)	T (°C)
XI	**	*	+				*
XII	*	*	*		+	+	
I	**	*	*	*			
II	+			+			
III							
IV	*						***
V	***	*					*
VI	***	**	+				**

VII	***	*	*				**
VIII	***	***	**				***
IX	***	**	*				+
X	***	**	+		*		
XI-X	***	**		*	*		**

*significant changes at the level of + - 0.1; * - 0.05; ** - 0.01; *** - 0.001*

The analysis of low water levels has shown that their changes occur almost every month except March. The highest changes in the low levels occurred in September and November - on average 10,4 cm·dec^{-1}. As results from the course of low annual water levels, they are characterized by a downward trend of 7,6 cm·dec^{-1} (Fig. 3b). These changes are statistically significant at 0.001 (tab.1). A slightly different situation was observed in the case of high states, although the tendency to lower them was observed in eight months. These changes were significant at a slightly weaker level than in the medium and low levels. The largest drop in high levels occurred in January and August - 18.6 and 20.2 cm·dec^{-1} respectively (significant at 0.1 and 0.05). With respect to the high annual water levels, although there is a tendency to reduce the level of 17,4 cm·dec^{-1}, these changes are not significant (Fig. 3c).

a)



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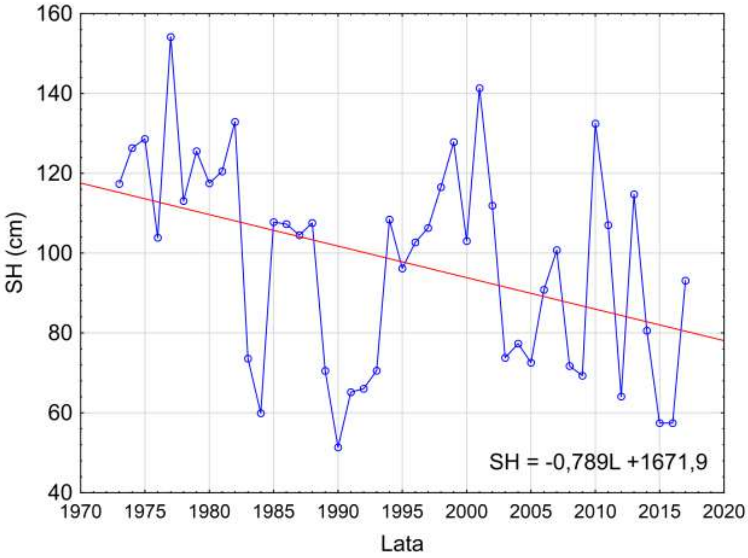


c)

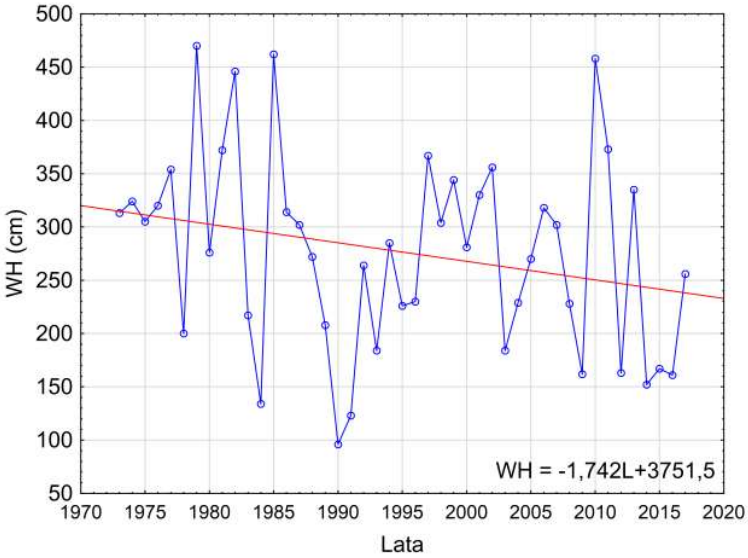
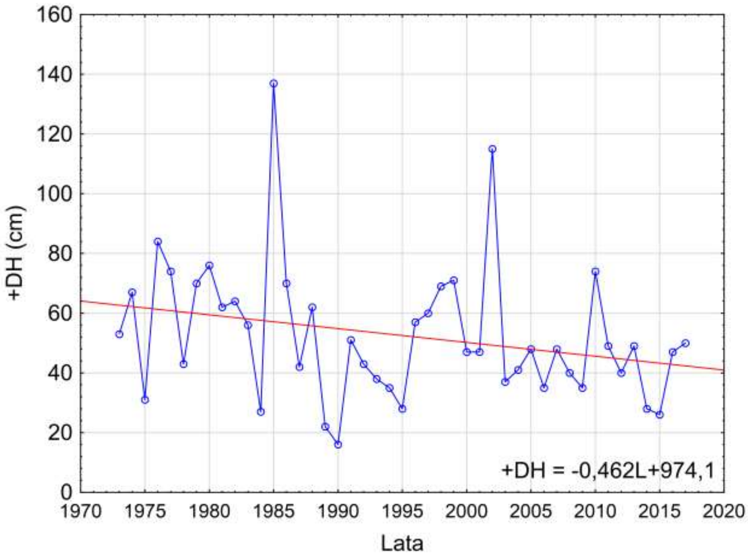


Fig. 3. Trends of changes in medium (a), minimum (b) and maximum (c) water levels of the Prosna River in the Bogusław profile

Over the analysed period, a declining trend was observed in the area of inter-diurnal increments and decreases in water levels (+ DH and -DH) (Fig. 4a and Fig. 4b).

a)



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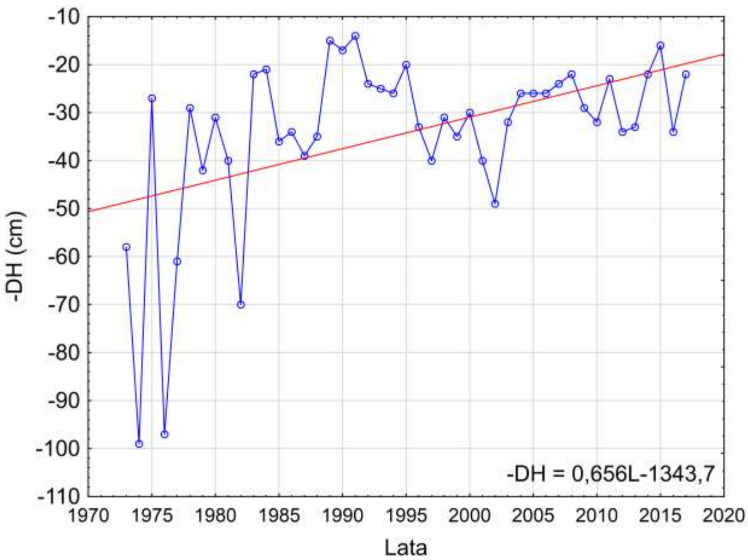
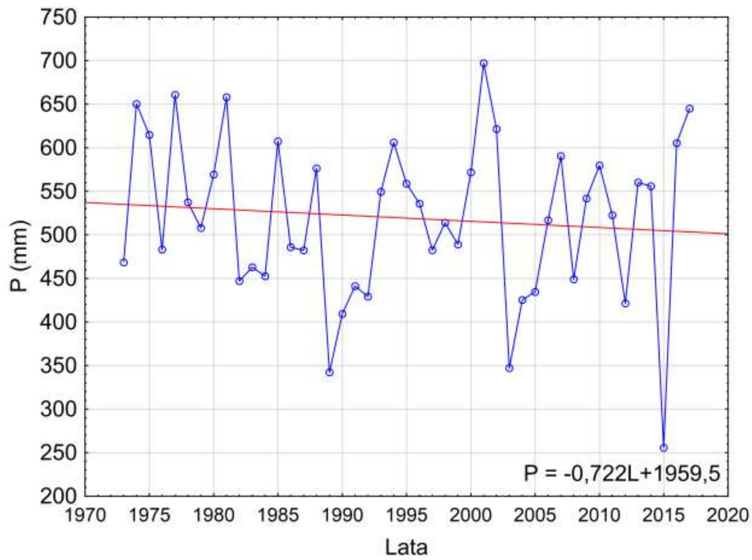


Fig. 4. Tendencies of interdiurnal changes of increases (a) and decreases (b) of water levels of the Prosna River in the Bogusław profile in the years 1973-2017

Interesting information is provided by the analysis of the course of annual precipitation sums and medium annual air temperatures against the background fluctuations of the average annual water levels of the analysed river. The main factor shaping the water cycle is its entry into the system (catchment) in the form of precipitation. The analysis carried out showed that the size of the precipitation, similarly to the water levels, was in a downward trend. However, these changes were not statistically significant both for individual months (except December) and years (Fig. 5a, Tab.1). Statistically significant changes were noted in the case of the average annual air temperature, which increased by 0.36°C in the analysed period by 0,36 $°C \cdot dec^{-1}$ (Fig. 5b). Air temperature changes also occurred in individual months. In seven cases the temperature rise was observed, and the largest occurred in April at 0,71 $°C \cdot dec^{-1}$. This fact could have contributed to changes in water balance components and increased losses on evaporation [Kędziora, 2008, Przybyłek and Nowak 2011]. As a result, this led to a reduction in the amount of water stored in the catchment and reaching the river [Przybyłek and Nowak, 2011].

a)



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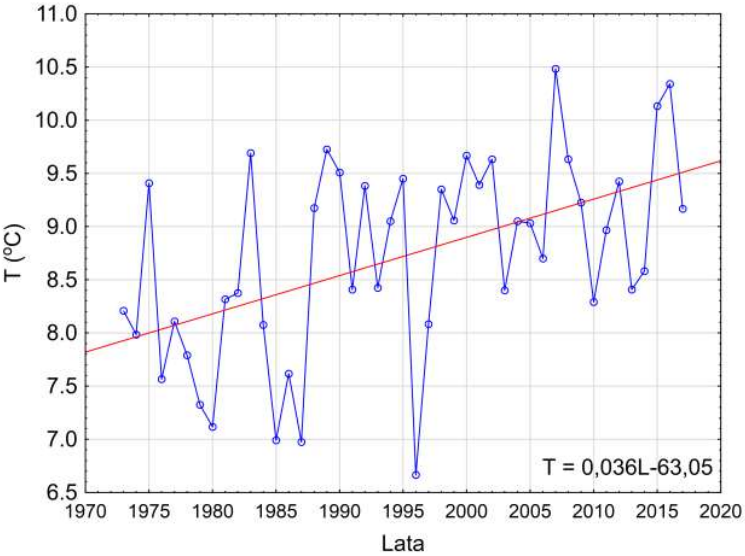

Fig. 5. Changes in annual precipitation sums (a) and average annual air temperatures (b) at the synoptic station in Kalisz

The issue of changes in the water level in the river is willingly addressed by many researchers in various regions of the world [Hudon, 1997, Murat-Błażejewska et al.2005, Jonkeren et al., 2007, Zhang et al., 2009, Biswas et al., 2014, Cochrane et al., 2014]. In particular, climate conditions (precipitation, temperature), which are modified by man, determine changes in the course of water levels. In the case of the discussed river, in relation to the former, a statistically significant course of changes was demonstrated in the case of air temperature, which translated into an increase in losses associated with evaporation. In the case of elements related to human activity in the Prosna catchment, Małecki and Ptak made a certain synthesis in this respect [2015]. The authors inventoried, among others:5 dams, 23 weirs and 112 valves, while stressing that the impact of hydrotechnical structures on individual elements of the hydrological cycle in the discussed area would be an interesting and worth of undertaking detailed research.

The observed situation, in which a permanent drop in the water level has been observed for several decades, is extremely unfavourable for the functioning of the entire ecosystem and closely related elements of the natural environment. It can be stated that the observed situation in the course of water levels is the resultant of processes taking place in the catchment, the nature of which leads to the depletion of water resources (resources that are currently considered one of the lowest in the country). Therefore, it is necessary to take measures to reduce this situation. The most rational would be to increase the natural retention of the catchment. In the case of Prosna, Małecki and Wira [2010] consider it necessary to increase forest, soil and valley retention as well as build drainage chambers.

Another issue is the possibility of deterioration of water quality, which determines the use of water resources of Prosna for the needs of supplying the population (a smaller amount will cause a difficult possibility of dissolving pollutants). This situation coincides with another subsequent phenomenon observed in Prosna, which is the increase in its temperature. Ptak and Nowak [2017] noted that the average increase in water temperature for the Bogusław station in 1965-2014 amounted to 0,27 °C · dec^{-1}. Higher water temperature means, among others, worse conditions for dissolving oxygen and, consequently, limiting the possibility of self-cleaning water and deterioration of living conditions of ichthyofauna. Already a few years ago (Raport ... 2006) Prosna, in terms of hydrobiology, was assessed as a river unsuitable for the existence of cyprinidae. Factors that degrade the usefulness of waters were, among others, nitrates, total phosphorus, dissolved oxygen and many others. The falling water level with the simultaneous increase in its temperature will affect the further deterioration of the current level.

CONCLUSIONS

The analysis of the water levels of Prosna in the profile of Bogusław in the years 1973-2017 showed that:

- significant changes have occurred within the annual low and medium levels,
- changes in low states were 7.6 cm·dec^{-1}, which is about 20% in relation to SNH,
- changes in high levels were 17.4 cm·dec^{-1}, which is about 6% in relation to SWH,
- changes in high levels were 7.9 cm·dec^{-1}, which is about 8% in relation to SSH,
- the largest changes in monthly terms occurred in August in medium and high levels, while in relation to low levels - in September,
- in January, June, July, August, September, October, November and December changes in water levels within high, medium and low levels were observed,
- interdiurnal changes in water levels (increases and decreases) decreased on average by 4.5 cm·dec^{-1},
- changes in water levels are caused by both climate factors (statistically significant increase of air temperatures) and anthropogenic activities, including buildings and transformations of use and management of the catchment.

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