IMPACT OF ANGIRIAI HYDRO - POWER STATION ON THE ECOSYSTEM OF THE RIVER ŠUŠVĖ

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Abstract

After a 16-m high dam was constructed and a 297-ha pond was arranged in the river Šušvė nearby Angiriai in 1980, the previous natural flow regime of the river has changed: 15500000 m^3 of water accumulated above the dam is not discharged via a natural bed, but through two 1.5x1.5 m bottom orifices, and flood discharges (up to $Q_{1\%}$ = 296 $m^3 s^{-1}$) are directed into the lower reach through a 16-m high shaft spillway of floods. Such arrangement of the Angiriai dam ensured it to become an essential obstacle for migrating fish. In 2000, after the arrangement and operation of Angiriai hydro-electric power station, the water regime downstream the dam has been changed and new hydrological pulses as well as ecosystem biodiversity are to be adapted. Thus, the operation of Angiriai HPS on the river Šušvė generating hydroelectric power can have adverse effect on the river habitats and hydro ecological connectivity. To evaluate the effect, the eco-hydraulic water regime measurements in 2005 in a lower stretch with and without turbines operating were made. The study results showed that artificial water levels fluctuation (≈ 4 m hr^{-1}) induced by Angiriai hydro-electric power station as well as the discharge flowing through the bottom orifices due to high velocities (13–14 m s^{-1}) and temperature differences could create stressful situations for young fish in the lower bank.

According to the data of soil texture of the Šušvė river, the bed armoring process is going on below the Angiriai HPS is quasi-stable and no impact of HPS operation is found.

Key words: river below the dam, artificial hydro pikes, impact on ecosystems.

Introduction

The hydro-electric power station located on the river Šušvė is a typical example of the operation of small and mid-sized HPS in the plains of Middle Lithuania. After a 16-m high dam was constructed and a 297-ha pond was arranged in the river Šušvė nearby Angiriai in 1980, the previous natural flow regime of the river has been changed: a 15500000 m^3 pond has been formed, from which the water is discharged into the lower bank not by a natural bed, but through a 16-m high shaft flood spillway arranged in the pond. During the flood this spillway is able to release a flood discharge of $Q_{1\%}$ = 296 $m^3 s^{-1}$, which means that the highest water levels and flow discharges have not changed. However, the transforming effect of the turbines may be significant for the lowest river discharges and velocities of the dry period of the year when the water may flow into the lower stretch only through two 1.5x1.5 m orifices and the environment protection discharge (0.340 $m^3 s^{-1}$) is taken from the bottom of the pond. According to S.J. Peake (2004), critical swimming speeds of a small mount bass (Micropterus dolomieu) range from 65 to 98 cm s^{-1} and are positively correlated to fish length. The investigations of the habitat density distribution in the Austria river Drau show that about 80% of fish select water flow velocities 0.2 – 0.5 m s^{-1} and the depth till 0.5 m. Spanish researchers (Alonso-Gonzalez et al., 2004) have determined that frequent unnatural floods occurring during the incubation period may significantly reduce the amount of young fish. (Spina, 2001). Frequent artificial floods may also result in a negative effect to aquatic vegetation (phytoplankton). However, a contrary effect is also possible, when the flood water improves the conditions for the fish spawn survival in reed in drought. Other researchers (Bustamante et al., 2004) confirm that low dams (up to 3-m high) make no negative effect on the development of macrophytes and the movement of plankton, although higher N concentrations have been observed in small ponds, and comparatively short residence time of nutrients does not ensure favorable conditions for denitrifying bacteria. Speaking about medium or large dams (h>10 m), their effect is significant – large ponds act as bioreactors transforming nutrients into the plankton mass, and results in more stratified less oxygen saturated and colder water outflow from bottom orifices of such dams (Navarro et al., 2004). Changes in the hydraulic regime also affect the development and spread of mollusca and larvae populations, as well as the distribution of algae mass and growth of macrophytes (Medvedeva, 2004; Breugnot et al., 2004; Franklin et al., 2004). The erection of a dam on a river and an increment of water depth in the pool cause the decrement of water velocity and increased sedimentation of sand and silt there. Dams of hydro-electric power stations (HPS) can change significantly the connection and existence conditions of ecosystems (Alonso-Gonzalez et al., 2004). As the researcher G. Sabas has concluded (2005), rapid water level fluctuation pulse below the dams of Lithuanian HPS significantly effect on the natural regime of rivers and must be regulated in respect of standards of Lithuanian ecosystem (0.2 m h^{-1}). Recent research, however, suggests that fish react to locally environmental factors that operate at a fine-scale (Kemp et al., 2004). The direct observation of their behavior revealed that individuals elicit strong avoidance when they encounter areas where hydraulic conditions change rapidly.

On the basis of the data obtained, a hypothesis has been made that artificial flooding due to the operation of HP station can create a stressful situation for aquatic ecosystems of the Šušvė during the dry period in lower reaches of the river. The objective of the study was to evaluate the impact of the operation of turbines on the existing conditions of ecosystems of the river Šušvė below the Angiriai dam during the dry period of the year.

Materials and Methods

To evaluate the effect of Angiriai dam on the eco-hydraulic water regime of the river Šušvė, water flow velocities were measured and the environment protection discharge was calculated in three profiles of the lower reach during the dry period of the year on 14 July of 2005 (Figure 1).

Figure 1. Location of study places below Angiriai dam in the river Šušvė:
① In the pond; ② 300 m below the dam; ③ 1500 m below the dam; ④ 3000 m below the dam

Measurements of water flow were made with the help of a micro-propeller flow meter with micro-computer calculation system. Moreover, samples of water and bottom bed-armored soil were also taken; their turbidity, the oxygen saturation degree, grain-size composition of river bed, water temperature regime and nutrient ($N\text{-}NO_3$, P, O_2) pollution were determined under the laboratory conditions. Concentrations were determined by the spectrometric method, using an FIA star 5012 analyzer, according to the water quality investigation standards (LST EN ISO 13395:2000; LAND 38:2000). Measurements were replicated having started operating one turbine with the nominal power of 500 kW (discharge 5.5 $m^3 s^{-1}$). The material and data of previous investigations were also analyzed (Vaikasas and Poškus, 2006)

Results and Discussion

During the investigations the stones of the bottom were covered with algae film saturated with nutrients. With minimal discharges, water visually seemed to be clean; a 2.0–2.5-m wide flow was meandering at the depth of 0.3–0.5 m. In some places the flow developed till the whole width of the riverbed. Changing flow velocities depended on barriers of vegetation (rushes) and large stone islets (0.3–0.4 m). Below the dam, banks of the river Šušvė were overgrown with willows and bushes. However, a 100–200 m long strip of the bank situated below the dam is less overgrown with vegetation due to a continuous gradient fluctuation; therefore, there were almost no shadows on the riverbed. As the determined runoff modules of September and October of 2002 show that the river discharge below Angiriai was not lower than the environmental discharge – 340 l s^{-1} (Pauliukevičius, 2004).

During the dry period of the year on 14 July of 2005 in the upper part of the pond extreme measured water temperature was 27.5 °C, i.e. it exceeded the air temperature (t_{air} = 25.5 °C). Slopes of the pond in the upper bank of HPS were also overgrown with bushes and rushes, and smaller than 0.01 mm particles (clay and silt) made up even 97.8% in the soil of the bottom. As one can see, these are typical examples of the bed of the pond and a lower bank. No erosion of slopes was detected in the pond.

Considering the environment protection requirements, the intensity of the water level lowering should not exceed 0.2 m per day in the pond. But below the Angiriai dam the intensity of fluctuation significantly exceeded the 0.2 m value (Figure 2).

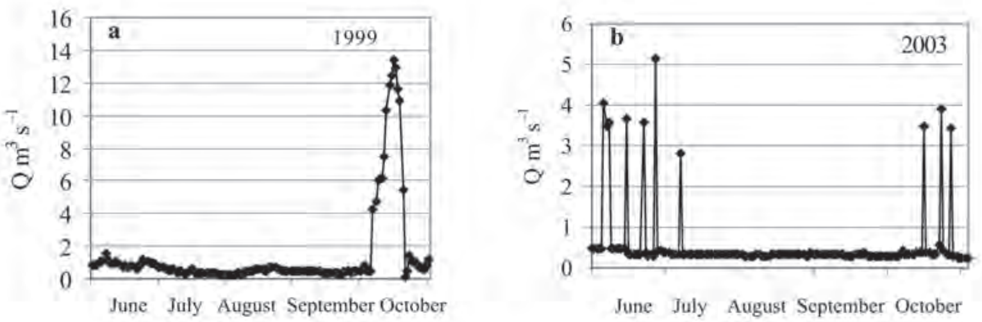

Figure 2. Everyday discharges at Josvainiai water measurement post before (a) and after (b) the construction of hydro-electric power station in 2003.

These sudden and frequent fluctuations of runoff indices may have a negative effect on the ecological conditions of the coast. However, although the fluctuations are more intensive during the cold period of the year, their negative effect on the ecosystems of coasts is less significant. This is because the vitality is less active in winter. Those are the reasons why the stress experienced by the ecosystems in summer is more influential (Kesminas and Virbickis, 1999).

The changes of everyday discharges due to the HP station may also be evaluated having compared the discharges of different years (Fig. 3). As one can see, after the construction of the Angiriai dam in 1980 the spring peak discharges of the Šušvė decrease on 25-30 %.

Having started operating the hydroelectric power station, periods of the smallest discharges from the pond became longer (Figure 4). Longer duration of small discharges ensures more intensive growth of macrophytes.

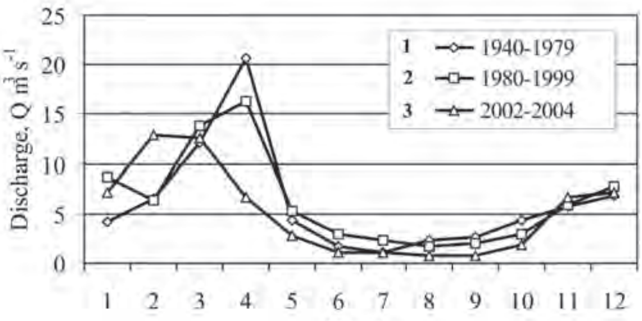

Figure 3. Data of annual hydrograph in Josvainiai post (before the construction of Angiriai dam (1) after the construction of Angiriai dam (2) and during the operation of hydro-electric power station) (3).

However, there is no data available about the overgrowth of the bed before the construction of the electric power station.

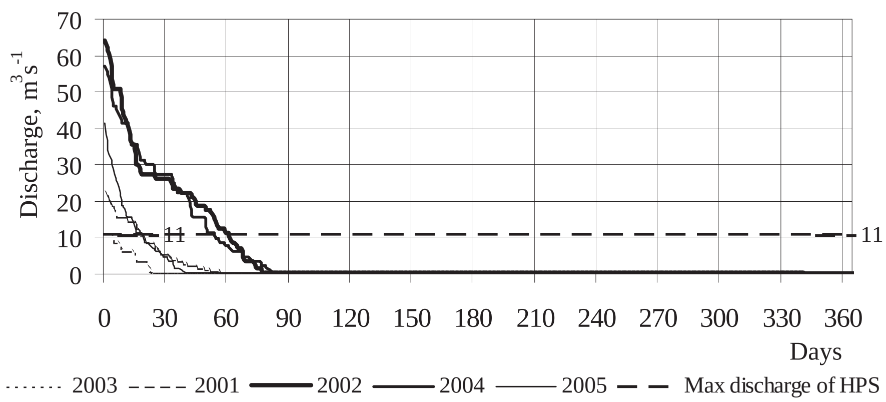

Figure 4. Duration of discharges released through the shaft spillway of the dam in different years.

The smallest discharge and velocities distribution during the dry period was measured in 2005 in 3 bed cross-section profiles at 200 m and 300 m below the dam. In all profiles the water depth did not reach 30 cm during the measurement, and the water flow did not occupy the whole width of the bed. The distribution of flow velocities differs significantly from the shape of the cross-section; actually, it depends on the grass cover of the bed.

After the hydroelectric power station is turned on, the discharge suddenly increases from the measured minimal 372 l s^{-1} to 5800 l s^{-1} (when one aggregate is operated) or even to 10800 l s^{-1}. Water at 200 m below the dam (at profile 1 of minimal discharge measurements) rose by 0.7 m on the average, and maximal flow velocity increased from 0.36 to 0.98 m s^{-1}. During the artificial flood induced by the hydroelectric power station water level rose by 0.45–0.7 m within 5–10 minutes, and the highest flow velocities increased up to 0.6–0.85 m s^{-1} at the coast and 0.93–0.98 m s^{-1} in the middle of the river channel. Therefore, particularly during summer and autumn months when the base flow varies around 0.35 $m^3 s^{-1}$, the riparian areas of river are severely affected by continuous water pressure and flow velocity fluctuations.

The intensity of the water level fluctuation was 4.2 m h^{-1}. It is the largest intensity of the measured fluctuation compared with other Lithuanian HPS (Sabas, 2005). Values of velocities distributed more evenly, water inundated shallow places and lay down the macrophytes. Visually, water became more turbid and similar to the floodwater. Turbulence of water released from the turbine into the retention pond also increased, which resulted in higher concentrations of dissolved oxygen (11.78 mg l^{-1}). It showed that the flow discharges and velocity fluctuations due to the electric power station action are significant and similar to velocities caused by storms and spring floods.

During the measurements, the average N-NO_3 concentration on the surface of Angiriai pond was 3.4 mg l^{-1}. Bottom orifices are arranged in the lowest silt spot; therefore, the released ground water contained larger amounts of nutrients N-NO_3 concentration reached 4.2–4.9 mg l^{-1} below the dam. However, in the reach of the river near Josvainiai, at 4 km from the dam N-NO_3 concentration decreased and was only 3–3.7 mg l^{-1}.

During the investigations the bed of the lower bank and fish community was observed visually. Despite the favorable conditions, no units of fish were observed below the dam in 14 July of 2005. On the contrary, in 2000, i.e. 5 years ago, an ecologists V. Kesminas and T. Virbickis (1999) found a lot individuals and biomass of fish in the lower bay of Angiriai.

It was determined that a rather stable 0.10-0.15 m deep layer of stones (diameter – 1.2–1.4 cm) was formed on the sandy bottom. This was also confirmed by the data of the analysis of the soil mechanical composition – sand particles make up to 28.2–97.1% here. According to the grain-size composition, the bed armoring process below the dam of HPS Angiriai is going on.

Particularly significant differences were observed between the temperatures of flowing water: on the surface of the pond water temperature was 27.5 °C, while the temperature of the water flowing from bed orifices reached only 13.5 °C. Differences in temperatures were also observed in water flowing 0.5–1.0 km below the dam – it was 15.3–15.6 °C, and only at 4 km from Josvainiai the temperature of the surface water reached 24.5 °C. Amounts of oxygen O_2 dissolved in water were: in the pond - 9.2 mg l^{-1}, below the dam - 8.67–10.52 mg l^{-1}

Having suddenly turned on one turbine of the hydroelectric power station, the flow discharge increased from 0.37 to 5.8 m^3 s^{-1}, which resulted in the increased turbulence of water and increased O_2 amounts (up to

11.23–11.78 mg l^{-1}). The temperature of stream water became 25–25.5 °C. This implies that warmer water from the surface layers of the pond was released.

Conclusions

Artificial floods induced by the Angiriai HPS operation during the dry period of the year is the main reason creating stressful situations for younger fish and invertebrates in the lower bay. This is due to the following facts: in summer the environment protection discharge released through the bed orifices is distinct for low temperatures and increased biogenic pollution; when the turbines are activated the flow velocities and water levels increase suddenly. Angiriai HPS hidropiking water levels fluctuation speed is 400 cm h^{-1}, which is about 100 times more than natural water level fluctuation during the natural excessive rain fall or flood. In the lower bank the velocities suddenly increase till 0.98-1.1m s^{-1}, and it is more than the acceptable critical swimming speed for juveniles. However, the highest flow velocities may reach even 13-14 m s^{-1} (in the orifices). Small fish caught by such flow is carried to the lower stretch where it experiences stress. In the present situation the artificial floods induced by the turbines can be mitigated, by prolonging the starting time of turbines and choose the turbines to enable operation through out the year (Zdankus and Sabas, 2005; Rintamaki, 2001). According to the data of the Šušvė river soil texture, the bed armoring process is still going on below the Angiriai HPS. No visible impact of HPS operation on this process is found.

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