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Impact of Small Hydropower Plant on the Biodiversity of the Selected Area

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Abstract. Renewable energy – wind, solar, geothermal, hydroelectric, and biomass – provides substantial benefits for our climate, our health, and our economy. Each source of renewable energy has unique benefits. Generated electricity from renewable energy rather than fossil fuels offers significant public health benefits. Wind, solar, and hydroelectric systems generate electricity with no associated air pollution emissions and water. This statement is true when it comes to new construction. It should also take into account those buildings that are already built (often with many shortcomings). This paper deals with the assessment of the negative impacts of Small Hydropower Plant (SHPP) in eastern Slovakia, in the boundaries of the village Lukov. This is a SHPP built in the end 60's as one of the first three -once (built in the former Czechoslovakia). The disadvantage of its construction is bypass channel, which causes significant or total reduction of water level on biologically important areas. In terms of biodiversity, it's a serious concern mainly in the fish reproduction period. Dry river course is insurmountable obstacle for them. This results in their death caused by exhaustion and gradual extinction of natural reproduction in the area of interest. Paper contains a case study with variant solution of current situation.

Keywords: Small hydropower plant, bypass channel, Lukov, fish pass.

Conference topic: Water engineering.

Introduction

SHPP systems the energy in flowing water and convert it to usable energy. Although the potential for small hydroelectric systems depends on the availablity of suitable water flow, where the resource exists it can provide cheap clean reliable electricity. A well designed small hydropower system can blend with its sur-roundings and have minimal negative environmental impacts. Moreover, SHPP has a huge, as yet un-tapped potential in most areas of the world and can make a significant contribution to future energy needs. It depends largely on already proven and developed technology, yet there is considerable scope for development and optimization of this technology (Edenhofer *et al.* 2012)

In the world there is no international consensus on the definition of small scale hydropower. In Canada "small scale" can refer to upper limit capacities of between 20 and 25 MW, in the United States "small scale" can mean 30 MW, however, a value of up to 10 MW total capacity is becoming generally accepted. SHPP can be further subdivided into mini hydro (usually defined as <500 kW) and micro hydro (<100 kW). No matter how you define it one thing remains the same, SHPP is one of the most environmentally benign forms of energy generation available to us today (Field *et al*. 2012). In Slovakia can refer to upper limit for SHPP systems into 10 MW (see Table 1) (MŽP SR 2011).

Table 1. SHPP in service on Slovak stream (Source: MŽP SR 2011)

Installed power output	SUM / Σ 203
1–10 MW	19
0.1–1 MW	64
< 0.1 MW / SHPP Lukov 0.007 MW	120

SHPP systems use the energy in flowing water to produce elect ricity or mechanical energy. The water flows via channel or penstock to a waterwheel or turbine where it strikes the bucket of the wheel, causing the shaft of the waterwheel or turbine to rotate (Paish 2002).

When generating electricity, the rotating shaft, which is connected to an alternator or generator, converts the motion of the shaft into electrical energy. This electrical energy may be used directly, stored in batteries, or inverted to produce utility-quality electricity (Paish 1997). A SHPP (see Fig. 1) facility requires that a sizable flow of water and a proper height of fall of water, called head, is obtained without building elaborate and expensive facilities. Small hydroelectric plants can be developed at existing dams and have been constructed in connection with river and lake water-level control and irrigation schemes. By using existing structures, only minor new civil engineering works are required, which reduces the cost of this component of a development (IAE 2016).

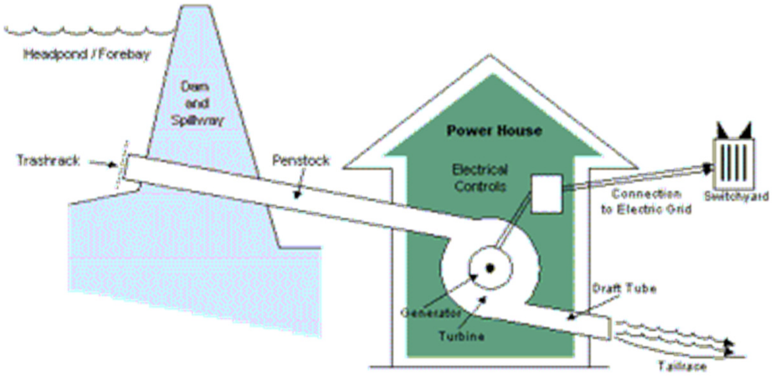

Fig. 1. Part of small hydropower plant (Source: IAE 2016)

Study area

Topľa River springs at altitude 1015 meters above sea level in Čergov mountain chain in north eastern Slovakia. The stream acts there as a mountain stream. Its total length is 136.9 km and total catchment area is 1 506 km^2 (Nemčok 1990). SHPP is located in this area. The average inclination of the upper part of Topľa stream (from spring to Lukov village) is in interval of 18 to 21%. The average inclination of the stream located at Ondavská highlands is in interval of 12 to 16% (Frandofer 2013). There is placed several water-gauge stations on the stream. The water-gauging stations in Bardejov indicate for the period flow to Topla (from 1967) an average value 2.97 m^3.s^{-1} with a maximum 351.2 m^3.s^{-1} in June 2010. The Gerlachov station is measured short, only since 1992 and indicates the average flow rate 1.51 m^3.s^{-1} maximum is measured in July 2008 with a value 90.09 m^3.s^{-1} (Blaškovičová *et al*. 2011). Topľa has several tributaries. Not in the place where the stream channel discontinuous, of between floodgates and tributary Fešáka (see Fig. 2). On the river are built three SHPP: (Sečovská Polianka in km 0.000 = rkm 5.200; Bardejovská Nová Ves in km 0.000 = rkm 101.400 and Lukov in km 0.000 = rkm 124.1 (see Fig. 2b). This is a SHPP built in the end 60's as one of the first three – once (built in the former Czechoslovakia). The entire building is owned by a private person.

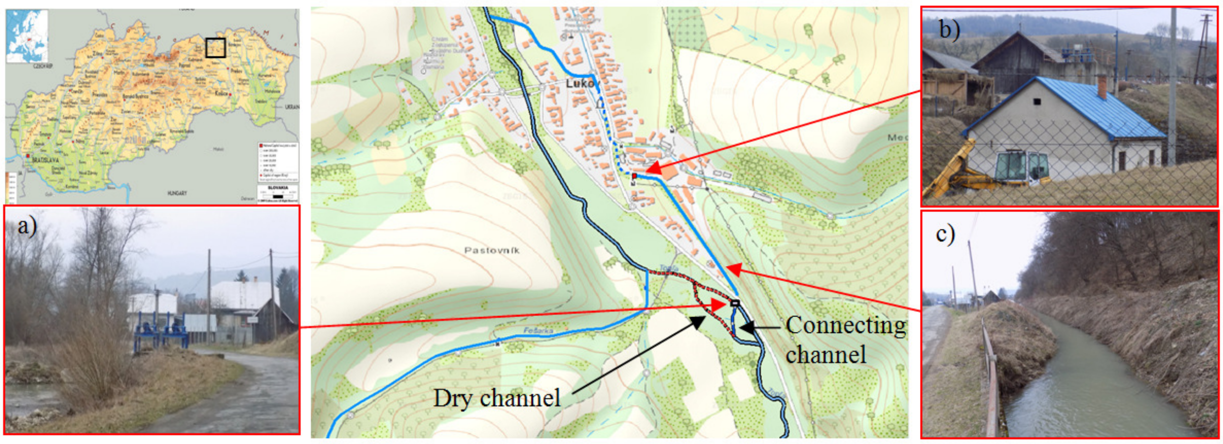

Fig. 2. Georaphical location of study area: a) floodgates. b) SHPP, c) bypass channel (Source: Fijko 2016)

The study area (see Fig. 2) is a part of the intravilan village of Lukov and bypass channel (see Fig. 2c) is located on the southeast border. The bypass channel total length is 1,130 km. In the area of SHPP the heights of bypass channel changes and drops to 14 meters depth where it continues underground. In terms of biodiversity, it's a serious concern mainly in the fish reproduction period. The height changes prevent the natural return of fishes to place where they are able to reproduce. Along with the turbines, the height change is the insuperable problem. The second problem is the lack of water during dry period. The shortage of water cannot supply the SHPP enough. The built connecting channel (see Fig. 3) completely diverted water stream from its natural course. Water flow increased after channel was of built. There was a gradual drying of the former riverbed. The water stream is filled only during rainstorm events. Seasonal changes in the relative abundances of the fish comunity primarily occur during reproductive periods and (for some species) the spring and fall migratory periods. These seasons are the most affected impact of decrease of water flow. The result is an abandoned channel and inefficient management of natural resources

Fig. 3. Connecting channel and floodgates for SHPP (Source: Fijko 2016)

The study area consists of primary forest and shrub cover. Primary forest is distributed evenly in every part of watershed while shrub is only found on downstream. The majority of forest cover in the watershed has positive impact to the MHPP operation as it maintains the base flow of the river, resulting in constant water supply. After milder winter in the spring months and during dry summer months is a problem when of stream channel is not enough stocked with water or completely dry. In the figure (see Fig. 4) we can see a case from March 2016 when after was milder winter the stream channel was absolutely dry.

Fig. 4. Example of a scar (dry) stream channel in the spring of 2016 (Source: Fijko 2016)

Data and methods

The fish are very important part of water environment. Mainly for their size and visibility were usefull to rate health of the water ecosystem in the distant past. Their diversity indicate healthy of enviroment. The fish as bio indicators connect many advantages to sucesfully rate health of water resources (Barbour *et al.* 1999):

Advantages of using fish as water quality control tool:

- Fish are good indicators of long-term (several years) effects and broad habitat conditions because they are relatively long-lived and mobile (Karr *et al.* 1986).
- Fish assemblages generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores). They tend to integrate effects of lower trophic levels; thus, fish assemblage structure is reflective of integrated environmental health.
- Fish are at the top of the aquatic food web and are consumed by humans, making them important for assessing contamination.
- Fish are relatively easy to collect and identify to the species level. Most specimens can be sorted and identified in the field by experienced fisheries professionals, and subsequently released unharmed.
- Migrating fish can pose a problem for bioindication, as well as overfishing.

Migration of aquatic organisms

Fish rely on migrations to satisfy their requirements with regard to the structure of the biotope during their different life stages. Migrations may be either longitudinal in the main channel, or lateral between the main channel and side waters. Is a need the interlinking of different ecosystems to allow the organisms to migrate so as to satisfy their migration and habitat requirements. Important is keep of longitudinal connectivity of rivers having an extremely important role to play with regard to reproductive exchange as well as to the spreading of populations and the recolonization of depopulated stretches of river (DVWK 2002).

One solution to restore fish migration, is the creation fish passes and flow control so that sufficiently supplied SHPP with water.

General requirements for fish passes

When restoring longitudinal and lateral connectivity to a river system it is ecologically sound practice to link the main channel with backwaters and secondary biotopes such as waterbodies that were created after the extraction of solids (e.g. flooded quarries, gravel pits, peat workings etc.). Longitudinal connectivity must be conserved or restored regardless of the size of river, the extent of structural modification of the channel, the present water quality or the interests of current users (Armstrong *et al*. 2010)

Before planning a fish pass, the first step must be to question the need to maintain the existing cross-river obstruction, since the construction of a fish pass is always only the "second best solution" for restoring unhindered passage through a river. In smaller rivers, particularly, there are numerous weirs and dams, such as mill and melioration weirs, whose original purpose has been abandoned but which still stop migration of aquatic organisms. The removal of such obstacles should be given preference over the insertion of a fish pass when attempting restoration of longitudinal connectivity. Exceptions to this principle may occur where conflicts arise with other ecological requirements, such as the preservation of a valued wetland by the higher level of the impounded waters, or with re-gional sociocultural needs (Armstrong *et al*. 2010). The general criteria that fish passes should meet include the biological requirements and the behaviour of migrating aquatic organisms and thus constitute important aspects in planning fishways. However, it has to be pointed out that present-day knowledge of the biological mechanisms that trigger or influence migrations of such organisms is still sketchy and there is a great need for further research to serve as a basis for criteria for fish pass construction.

Optimal position for a fish pass

While in rivers, that have not been dammed, the whole width of the channel is available for the migration of aquatic organisms, fish passes at weirs and dams usually confine migrating organisms to a small part of the cross section of the channel. Fish and aquatic invertebrates usually migrate upstream in, or along, the main current. For the entrance of a fishway to be detected by the majority of upstream migrating organisms, it must be positioned at the bank of the river where the current is highest. This has the added advantage that, with a position near the bank, the fish pass can be more easily linked to the bottom or bank substrate.

In the figure (see Fig. 5) is a flow model in a river with undercut banks and point bar banks. Fish swimming in or along the main current will arrive at the weir along the side of the undercut bank. Consequently, a fish pass should be positioned as closely as possible to the point where the fish meet the obstacle (Jens 1982)

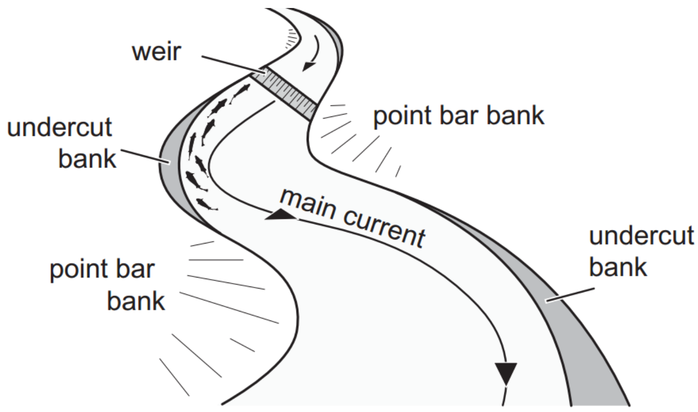

Fig. 5. The flow pattern in a river with undercut banks and point bar banks (Source: Jens 1982)

The most suitable position for a fish pass at hydroelectric power stations is also usually on the same side of the river as the powerhouse. Placing the outflow of the fish pass (and thus its entrance) in the immediate vicinity of the dam or weir minimizes the formation of a dead zone between the obstruction and the fish pass entrance. This is important, as fish swimming upstream can easily miss the entrance and remain trapped in the dead zone.

Natural looking fish passes

The construction material chosen corresponds to what is usually present in rivers under natural conditions. The constructions described below (see Fig. 6) are usually sitespecific and thus cannot be applied generally. Furthermore, the close-to-nature design enables new running-water biotopes to be created in a watercourse, while blending pleasantly into the landscape. For the purpose of these Guidelines the following constructions are defined as “close-to-nature types” of fish passes (Katopodis 1990):

- Bottom ramp and slope: A sill having a rough surface and extending over the entire river width with as shallow a slope as possible, to overcome a level difference of the river bottom. This category also includes stabilizing structures (e.g. stabilizing weirs).
- Bypass channel: A fish pass with features similar to those of a natural stream, bypassing a dam. As the dam is preserved unchanged, its functions are not negatively affected. The whole impounded section of the river can thus be bypassed.
- Fish ramp: A construction that is integrated into the weir and covers only a part of the river width, with as gentle a slope as possible to ensure that fish can ascend. Independently of their slope.

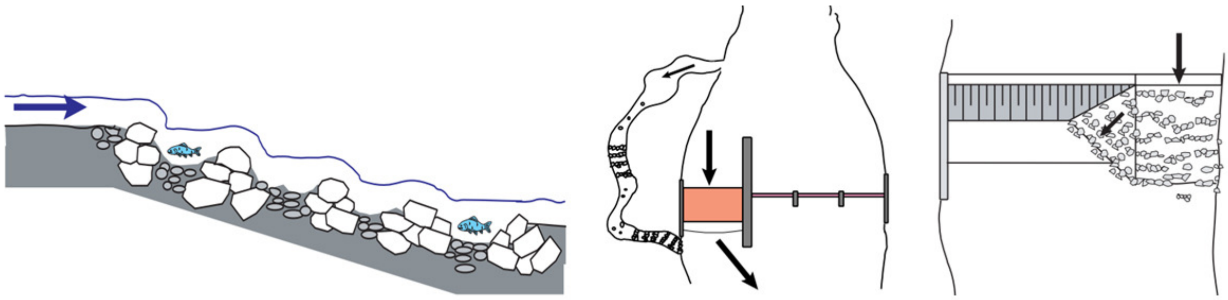

Fig. 6. Overview of the most frequently used construction types of fish passes of natural resource (Source: DVWK 2002)

The figure 7 study shows placement of fish passes and throughput of dry natural stream. With a bad intervention was stream did not enough supplied with water. The fish passes is situated near of the floodgates. On his specific design is possible to use natural resources and incorporated him to the local environment. Near of the floodgates is designed small dam which controle overflow of water during all year. On the left side designed the revival of dry natural stream which with this solution will be fullfill its originally function to secure adequate function a overflow during all year.

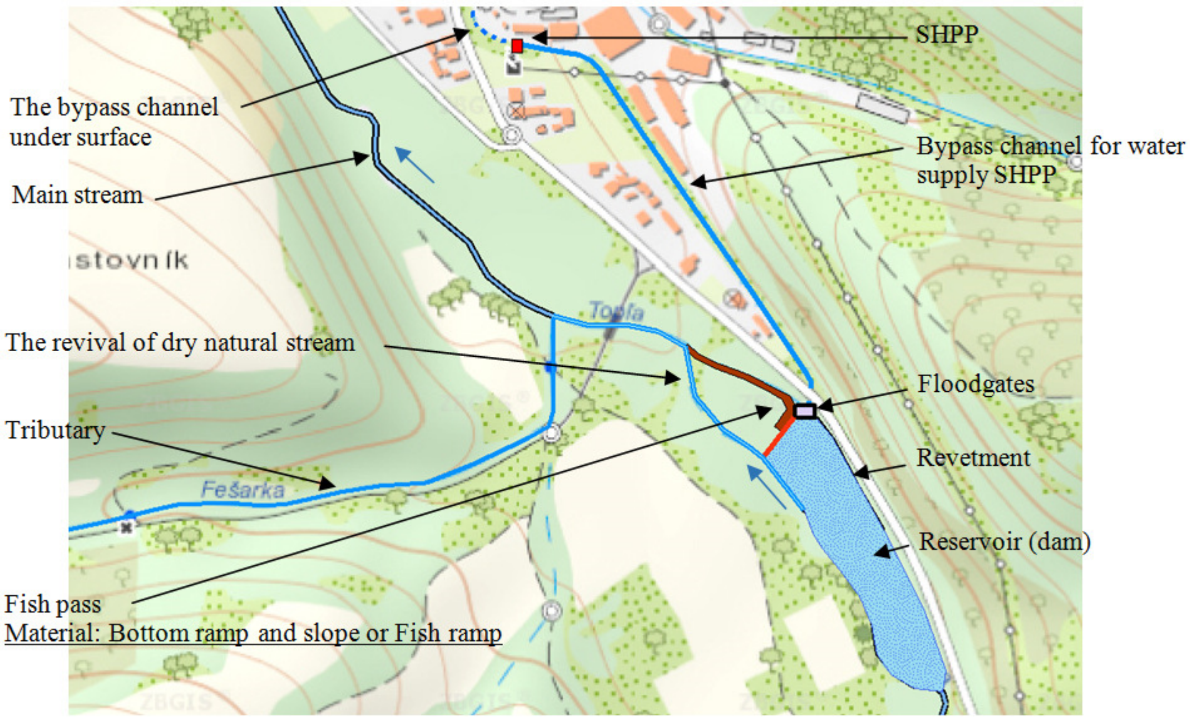

Fig. 7. Solution description revitalization of the Lukov village (Source: Fijko 2017)

Conclusions

Many fish species undertake more or less extended migrations as part of their basic behaviour. Amongst the best known examples in Europe are salmon (Salmo salar) and sturgeon (Acipenser sturio), which often swim several thousands of kilometres when returning from the sea to their spawning grounds in rivers. In addition to these long-distance migratory species other fish and invertebrates undertake more or less short-term or small-scale migrations from one part of the river to another at certain phases of their life cycles (DVWK 2002). This group can also include in our wild brown trout (Salmo trutta fario Morfa), which in the SHPP-Lukov is practical extinct. Fish passes are of increasing importance for the restoration of free passage for fish and other aquatic species in rivers as such devices are often the only way to make it possible for aquatic fauna to pass obstacles that block their up-river journey.

For revival territory on Topľa River we considered a number of options. One resolution appears to restore the dry river channel and construct fish passes. It will be situated in proximity of the floodgates. The fish passes is situated near of the floodgates. For the construction of the system can be used stretch dry channel and revitalize the destroyed section. On his specific design is possible to use natural resources and incorporated him to the local environment (stone, wood). Dams can be scheduled and controlled supply for SHPP a waters. For SHPP is require installed capacity of 0.007 MW.

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Disclosure statement

Authors are required to include a statement at the end of their article to declare whether or not they have any competing financial, professional, or personal interests from other parties.

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