Constructions used to enable fish migration in the Czech Republic and abroad

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Abstract. This publication deals with the migration permeability of watercourses in the Czech Republic and in the world from the point of view of the constructions enabling this migration. The goal of this article is to compare the situation of fish ladders in the individual continents with the situation in the Czech Republic. It is clear that the area of migration permeability of watercourses was only a marginal topic worldwide, but this sphere of water management has recently gained increasing importance.

1. Introduction
Historically, the building of housing estates was situated along or near watercourses, since a river was seen as a source of food, a transport way, and later as a source of energy. With the development of human culture, there has been an effort to regulate watercourses, whether it was by means of the construction of the first dams or irrigation canals, weirs, hydropower plants or boat floodgates. In any case, it has lead to the creation of barriers on the watercourse and, as a result of these changes, the roughness and ruggedness of riverbeds have been drastically reduced along with the interruption of fish migration. Fish migration should be in the centre of attention of water management as it significantly contributes to maintaining the biodiversity of the aquatic environment. The constructions of fish ladders represent an integral part of damming constructions in the watercourses, but there are approximately 5 basic types of constructions, and not every type is suitable for the species composition of fish in a given stream. Recently, a great emphasis when building these constructions has also been placed on the sustainable management of raw materials and thus the environmental impact of the whole building. In order to meet the requirements of an efficient use of natural raw materials, materials based on waste can be used in the construction of fish ladders. These materials can be incorporated, for example, in concrete structures [1, 2, 3, 4]. Along with the migration permeability of fish, it is also necessary to address the water quality in rivers [5, 6], as well as its protection in today's industrial landscape [7].

2. Situation in the CR
Waters in the Czech Republic are divided into 5 main drainage basins: the Elbe, the Vltava, the Ohře, the Odra and the Morava basins. These drainage basins are managed by drainage basin state enterprises. They take more or less efforts to make the watercourses, on which damming or weirs or small hydropower plants have been built, passable. State drainage basin enterprises are already taking a pro-active approach to this issue and the building of fish ladders is becoming a common part of investment planning of constructions. Migration ramps, channel type fishways, vertical-slot or brush fish ladders were built on various rivers in the past, according to morphology. At the same time, bypass canals are being built around small hydropower plants, or boulder chutes, which function not only as technical structures overcoming the vertical gradient, but they do not represent a migration
barrier for fish either. Recently, the buildings have been providing a high-quality imitation of the natural structure of the stream. The need to monitor the fish ladders of original species gains attention with regard to the stress levels, energy losses and possible injuries. All these activities are related to the strengthening and restoration of the Atlantic salmon population, the restoration of the population of river salmon and the eventual return of other fish species that used to live in such regulated streams.

3. Situation in Europe

3.1. Portugal
The cellular type of fish ladders in small hydropower plants is preferred in Portugal. About half is unsatisfactory for the most frequent group of fish. The fish preferably use openings at the bottom where the current is generated. This helps them to find a way in the fish ladder easier and to pass faster [8].

3.2. France
France, as a country with a large number of small hydropower plants on watercourses has a law stating that any hydropower plant with migrating fish in its watercourses must have a functional fish ladder and they must also ensure a minimum flow rate in the dammed watercourse. Denil type of fish ladders or bypass in combination with trash racks are most commonly used [9, 10].

3.3. Austria
Austria prefers the construction of pool fish ladders, together with cellular and vertical-slot types. For example a 200 m long system with 30 pools has been built on the Mur River, where vertical-slot fish ladder forms the upper part and a bypass channel is situated in the lower part. Austria has several small hydropower plants that allow fish to migrate upstream and downstream.

3.4. Germany
In Germany, the main types of fish ladders include cellular, vertical-slot, Denil, special eel troughs, crossing passage chambers, and fish elevators. However, on the river Kinzig, for example, a rock-ramp fish fishway is built at the dam reservoir [13].

3.5. Sweden and Finland
A fish ladder was built in the north of Finland on the river Kemijoki. It consists of vertical-slot and Denil sections. The Kemijoki River was a river with one of the largest populations of salmon in Europe until the dam with a hydropower plant was built [14].

3.6. England
Many English rivers have enough Atlantic salmon and brown trout. Both species are capable of migrating upstream. There are approximately 380 fish ladders in England and Wales. The most commonly used type of fish ladder is the pool type, but we can also find quite a large number of Denil fishways here [15].

3.7. Scotland
A very intensive movement of adult Atlantic salmon across four pool-type fish ladders has been reported in Northern Scotland. Scottish watercourses have a relatively high gradient due to the terrain morphology, for example on the Tummel River, where a very long cascading fish ladder has been built [16].

3.8. Belgium
Belgium prefers the construction of pool fishways together with the Denil fishways in various modifications. A Denil fishway was built on the Ampsin-Neuville Dam on the Meuse River, where common barbel was observed in 1989–1993. There has been a significant interference in the natural environment with a significant decrease in the presence of common barbell [17].
3.9. Russia
In Russia, fish elevators have been used on large rivers with sturgeon fish. An elevator was built in the 1960s at the Don near the Cimljan Valley Reservoir, which was mainly used by sturgeon, bream, river carp, pelecus and catfish. Two elevators have also been built on the Volga.

3.10. Sweden
A simple bypass was designed for migrating salmonids in southern Sweden at the Herting Dam. The fish went through the dam with very little delay. In any case, Denil fishway with various modifications is widely used type of fish ladders [18].

3.11. Romania
In Romania, the use of a rock-ramp seems appropriate due to the nature of small water places and the migrating species. The construction of this type of fish ladder is particularly suitable for low obstacles. In this context, they study the possibility of a channel cross-section shape (rectangular, semicircular) and they are looking for an optimal solution both in terms of the hydraulic and biological character [19].

3.12. Italy
In Italy, they prefer the pool types of fish ladders. For example, a 5.6 m high weir is built on the Basento River, and it is equipped with a pool fish ladder with openings on the right side. The entrance to the fish ladder goes into a stilling basin. In the stilling basin, there is a bed fitted with a gabion. Fish should use the channel for upstream migration because of the lack of bank vegetation and attractive stream.

4. Situation in Asia

4.1. Japan
About 10,000 fish ladders have been installed on the Japanese rivers Nakamura and Yotskura. They are intended primarily for anadromous salmonids, whose juveniles migrate upstream. Most fish ladders are of pool type, others are of vertical-slot and Denil types. The situation is improving rapidly, we can talk about a revolution in fish ladders [20].

4.2. China
China has a huge system of about 86,000 reservoirs, but they began to build fish ladders only about 40 years ago. About 60 to 80 of them have been built. Most fish ladders are of the pool type. In China, fish ladder constructions began later. We can find three stages of initiation: 1958-1980, stagnation in 1980-2000, and secondary development period since 2000 [21].

5. Situation in America

5.1. USA and Canada
There are about 76,000 dams in the USA. The states of North America such as Canada and the USA use Denil fishways in various modifications and versions along with vertical-slot passes, namely on the rivers of Connecticut, Merrimack and Susquehanna. Denil fishways for salmon are in Maine and Alewife. The most important ones are the two fish elevators on the Conowingo Dam [22].

5.2. South America
South America has a big problem with the passability of their dams. Fish can migrate from 200 to 1000 km. The dams on the upper reaches of the rivers seem to lead to the disappearance of migratory populations in reservoirs and in rivers upstream. There are only about 46 fish ladders in the whole South America [23].
6. Situation in Africa and Australia

Africa has more than 2000 known freshwater fish species. The populations of shads disappeared after the construction of the Sidi - Said Dam which was equipped with a Denil - type fishway. In recent years, there has been an emphasis on the implementation of fish ladders, as the country now has a low diversity of freshwater fish [24]. There are about 50 fish ladders in Australia, mostly of the pool type. They are mostly ineffective, unkempt, they have inappropriate design characteristics and are not adapted to the original species.

7. Conclusion

In general, the issue of fish ladders has received little attention in the past, which has been improving in recent years, and we can find evidence of this effort in the state enterprises of Povodí Vltavy, Labe and Odra. They deal with the issue of fish ladders very intensively. The most common types of fish passes in the Czech Republic are cellular, vertical-slot and nature-friendly bypasses. On the other hand, Denil fishways and fish elevators are not built in the Czech Republic at all. In Germany, they build mainly cellular, vertical-slot or Denil fishways, special eel channels, crossing passage chambers, and fish elevators. Denil fishways and their modifications are used in European countries, mainly in France, Sweden, Ireland, Belgium, Scotland and England. The states of North America such as Canada and the USA use mainly Denil fishways in various modifications and versions along with vertical-slot ladders. In South America, the issue of migration permeability of watercourses is a very marginal topic.

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