CHAPTER 2

FISHWAYS - GENERAL CONSIDERATIONS

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1. THE PRINCIPLE OF FISH PASSAGE FACILITIES

The aim of a fish passage facility is to **attract** migrants to a specified point in the river, downstream of the obstruction, and then to induce them, or even make them, pass upstream. This is achieved either by opening a waterway (fish pass in the strict sense), or else by trapping them in a tank and lifting them upstream (fish lift or transport systems such as trucking).

For a fish pass to be considered effective, fish should find the entrance and negotiate it **without delay, stress or injury** that might prejudice the success of their upstream migration.

The design of a fishway should take into account certain aspects of the behaviour of migratory species. In particular, its effectiveness is closely linked to water velocities and to patterns of flow in the facility.

The water velocities in the fishway must be compatible with the swimming capacity of the species concerned, and the fishways should permit passage for all individuals and not only the athletes.

Some species are very sensitive to particular flow regimes or conditions. These include water level differences between pools that are too large, excessive aeration or turbulence, existence of large eddies, and water velocities that are too low. All of these can act as a barrier for fish.

In addition to hydraulic factors, fish are sensitive to other environmental parameters (level of dissolved oxygen, temperature, noise, smell, etc.) which can have a deterrent effect. This is particularly true if the quality of the water feeding the fishway is different to that passing across the dam (low oxygen levels, differences in temperature, etc.).

Fish also have requirements or preferences with respect to ambient light intensity. Light conditions at the entrance to and inside the fishway which are very different from those at the obstruction (too steep lighting gradient at the entrance, insufficient illumination in the fish facility or on the contrary illumination during the night for lucifugous species) may have a detrimental effect.

The influence of most of these parameters on the behaviour of migratory species is, however, poorly documented at present, and any information usually comes from local observations. This is why it is not easy to specify design criteria for engineers.

2. THE DIFFERENT TYPES OF FISHWAYS

Incontestably, the type of pass which is most frequently used is the **pool fishway**. This consists of a series of pools in steps leading from the river at the foot of the obstruction to the river above. The walls separating the pools have weirs, notches, vertical slots or submerged orifices which control the water level in each pool and the flow discharge in the fish pass. The pools have a double function : they ensure a proper dissipation of the **energy of water flowing through the fish pass**, and provide **resting areas** for the fish. The difference in level between two successive pools depends on the species being considered. The slope of a pool fish pass varies but is most often between 10% and 15%.

In baffle or “**Denil**” fishways (named after their inventor), baffles of varying degrees of complexity are placed on the bottom, or the bottom and sides, of a steeply inclined flume (up to 20%). The baffles create helical currents that dissipate energy, thereby reducing the velocity of the water through which the fish has to ascend. The flow in baffle fish passes is more intensively aerated and turbulent than in conventional pool fishways.

The **fish lock** (or “Borland” lock) operates on a principle similar to that of a navigation lock: the fish are trapped in a chamber, then lifted upstream in the same way as a boat.

Other devices take the form of traps, where the captured fish are then transported upstream either mechanically by means of a tank and elevator, or else by trucking them.

The **natural bypass channel**, or diversion channel fishway consists of a channel excavated from upstream to downstream in one of the banks of the river. The channel is roughened with artificial or natural obstacles such as weirs, stone-blocks and alluvial material mimicking a natural watercourse. However, the slope of such a facility may not be more than a few per cent, and because of its length the use of this type of installation is therefore often constrained by the limited space available. On the other hand, it usually blends in very well with the landscape.

There are many other less formal and cruder means of facilitating fish passage, generally limited to obstacles of moderate height. One of these is the “**pre-barrage**” formed from one or several weirs constructed downstream of the obstruction, creating a series of large pools which split up the fall. These pre-barrages can be constructed across a substantial part, or even across the full width of the watercourse downstream of the obstruction. Sometimes a simple notch cut in the crest, in the case of a downstream vertical wall, or a diagonal baulk in the case of a weir with an sloped apron, will be sufficient to ensure the passage of fish.

A final solution, as effective as it is radical, consists of **removing the obstruction**. This may be possible, for example in the case of an old mill dam that is no longer in use. This solution offers the opportunity of recreating conditions in the formerly impounded reach, which may once again become favourable for natural spawning and juvenile production.

3. CRITERIA FOR THE CHOICE OF FISHWAY

Except for the solution of removing the obstruction, there is no “miracle” fish passage facility which is more effective than all the others: experience shows that numerous pool fish passes, Denil fishways, fish lifts and natural bypass channels have proved to be equally effective - or ineffective.

It would be tempting to list the different obstructions in various classes, for example by height, and to propose a suitable fish passage facility for each of them depending on the species of migrants. However the multiplicity of constraints and factors to be taken into account (behaviour of target species, hydrology, hydraulic, topography of the site, etc.) means that each situation is unique. Indeed, experience has shown that rigid classification is likely to result either in serious errors, or else in prohibitive costs.

The following points will assist in determining the most appropriate type of fish passage facility in any given situation.

1. When several migratory species are involved (salmon, sea-trout, shad, trout, riverine species, etc.) the **pool fish pass** or the **natural bypass channel** are generally the best solutions, as they are much less selective than baffle fishways. The fish pass will be designed to suit the most demanding species (in terms of the drop between pools, water velocity, turbulence and aeration in pools).

Pool fish passes with notches, whether or not they have orifices at the bottom, are of the greatest interest as they adapt to different situations. Flow discharge can vary from a few tens of litres per second to several cubic metres per second, and they can accommodate significant variations in the upstream level without having to install a regulation system upstream (automatic sluice gates, submerged orifices, etc.), so long as the notches are deep enough.

Vertical slot fish passes are particularly well suited to sites where upstream and/or downstream water level fluctuations are significant. However, for large migratory fish such as salmon, taking into account the minimum width of the specified slot means that a significant flow is required, more than 0.75 m³/s.

Generally pool fish passes with submerged orifices are of little interest except as a regulating section at the upper end of a fish pass when there is a significant variation in the water level upstream. They also have the drawback of trapping floating debris (wood, bottles, polystyrene, etc.) which accumulates at the surface of the pools, unable to escape.

In watercourses likely to transport large amounts of bed material, pools that are too deep may trap coarse sediments, and should therefore not be constructed. It should be ensured that the connection between the pools can extend down to the floor (vertical slots or orifices) to facilitate removal of the material.

Shad present a particular problem with regard to the design of pool fish passes. This species is much more sensitive than salmonids to the flow pattern in the pools, and special precautions must be taken to ensure their passage. Good results have been obtained in the USA with American shad (*Alosa sapidissima*), and in France with Allis shad (*Alosa alosa*), provided that certain conditions are observed. These include low levels of turbulence in the pools, sufficiently wide notches or slots (> 0.45 m) situated adjacent to the sidewalls, surface and not plunging flows, and limitation of recirculation eddies. Fish passes consisting of one or two vertical slots seem to be effective, in spite of a "fall-back" activity in the fish pass which seems to be inherent in the species.

2. **Baffle fishways** are relatively selective and are only suitable for species that have sufficient swimming capacity in terms of both swimming speed and endurance (salmon, sea trout, lamprey, barbell, etc.). They are generally not suitable for small fish measuring less than about 30 cm in length.

Although shad have been monitored in several baffle fishways, it has been observed that this species cannot easily negotiate the helical currents which characterise the flow in

this type of fishway. Furthermore it does so reluctantly, possibly because of the flow aeration and turbulence.

Baffle fishways are particularly suitable for small watercourses in which the available flow for the fish passage facility is only a few hundred litres per second, and on old weirs or mill dams of low height with a sloping downstream apron, into which they can easily be incorporated.

This type of fish passage facility generally becomes less suitable as the height of the obstruction to be bypassed becomes greater. The need to provide resting pools (approximately every two metres of drop) increases the length of the facility and may make a pool fish pass a more suitable alternative.

Certain types of baffle fishways (thick, chevron floor baffle type fish pass) may be used as canoe slides on the condition that their width be sufficient (1.40 m minimum).

Baffle fishways are not installed in watercourses carrying coarse bed material, such as large gravel or pebbles which are likely to be deposited between the baffles, reducing or even negating their efficiency. On the other hand, the helical currents generated in this type of fish passage facility are capable of washing out silt, sand and small gravel.

3. Where there is a high head, a **fish lift** or Borland **lock** is easier and generally less expensive than a traditional fishway. The main disadvantage of the fish lock is that it operates discontinuously. The lift, whose technology has advanced significantly in recent years in France, is to be preferred. However, a lock may be of interest for an obstruction of moderate height when the configuration of the dam precludes installation of a traditional fish pass.

The effectiveness of a lift is closely related to the clear opening of the screens which must be sufficiently small to physically prevent fish from passing through. Its use becomes problematic for small species that need screens with very fine mesh screens that may require excessive maintenance.

The relative complexity of operation of these two types of facility (presence of several automated and moving parts including sluices, tanks, and screens) results in breakdowns or periods of malfunction, which may occur frequently and last a long time. The maintenance costs are also higher than those for standard fish passage facilities. This is the reason why "static" passes (*i.e.* without any moving parts) tend to be preferred in France. Although they are more expensive from a civil engineering point of view, they are easier to maintain and more reliable.

4. MAIN CAUSES OF MALFUNCTION IN FISH PASSAGE FACILITIES

When the causes of poor performance of fish facilities are analysed, certain factors are frequently revealed:

- **Lack of attractivity** of the facility, resulting from a poor position of the fish pass or insufficient flow at the entrance of the facility in relation to the flow discharge in the watercourse.

- **Poor design** of the facility with respect to the variations in the water levels upstream and downstream during the migration period, resulting in under or oversupply of flow to the fish pass, or an excessive drop at the entrance. This may be due to poor appreciation of the range of the upstream and/or downstream water levels during the

project planning phase, or a subsequent change in these levels (due to changes in dam operation, to the erosion of the riverbed downstream of the obstruction, etc.);

- **Poor dimensions:** pools with insufficient volume causing excessive turbulence and aeration, excessive drop between pools, insufficient depth for the fish, or the flow pattern in the pools not being suitable for the target species;

- **Frequent clogging up or obstruction** of the fish passage facility, resulting from inadequate protection against debris, or too exposed a position, or quite simply **inadequate maintenance** on the part of the operator. Obstruction caused by floating debris can result in insufficient water flow in the fish passage facility (blockage of notches or slots, clogging of the screens of the auxiliary water system, etc.) and impede fish passage. In this respect, baffle fishways and pool passes comprising submerged orifices are particularly vulnerable. Even partial obstructions (not causing any obvious disturbance to the flow) may make it impossible for the fish to pass;

- **Malfunctioning** of parts which regulate the flow discharge and the drops between pools (automatic sluice gates, etc.), or which ensure the functioning of the facility in the case of fish lifts and fish locks (automatic sluice gates, hoist for the tank, moving screens, etc.).

External causes not related to the fish passage facility itself may also affect its efficiency. The most common reason is a change in the attractiveness of the facility as a result of the adjustment of sluice gates, or turbines operation, or, more generally, flow conditions at the foot of the obstruction which were not taken into account during the project planning stage. These may cause disturbance to the hydraulic conditions at the entrance to the fish passage facility, or may attract and trap fish in a zone relatively remote from it.

Experience gained in France shows that the most frequent causes of malfunctioning of fishways are poor performance resulting from inadequate maintenance and lack of attractivity of the facilities.

Photo 1: The best fishway...

Photo 2: Pool fish pass on the Steir (Finistere).

Photo 3: Vertical slot fish pass on the Seine river.

Photo 4: Triangular pool fish pass on the Ardeche.

Photo 5: Natural bypass channel on the Gave de Pau.

Photo 6: Plane baffle fish pass on the Evel (Britanny).

Photo 7: Floor baffle fish pass on the Trieux (Britanny).

Photo 8: Pre-barrage pointed with bitumen on the river Nivelle (Atlantic Pyrenees).

Photo 9 : Fish lift on the Loc'h (Britanny).

Photo 10 : Fish lift at Tuileries dam (Dordogne river).