CHAPTER 10

FISHWAYS FOR EELS

J.P. PORCHER

Conseil Supérieur de la Pêche, DR 2, 84 Rue de Rennes, 35510 CESSON SÉVIGNÉ - France.

1. BIOLOGICAL FACTORS

While eels are one of the most abundant fish species, for example they represent half of the biomass of fish in rivers in Brittany, there have been many indications of a decline in stock in recent years (reduced catches in fisheries and population surveys). The first eel pass in France was installed in 1994 in Poitevin marshes. Eel fishways must take into account their special biology and their poor swimming ability. Eels passes are very different from classic fishways, although the latter can be adapted to the requirements of the different life cycle stages of the species.

1.1 Colonisation of the freshwater environment

Unlike other migratory species for which upstream movement in a watercourse involves migration of adults for breeding purposes, the progression of eels upstream in a watercourse is for colonisation purposes and involves the juveniles of the species (elvers and small yellow eels).

Consequently, the number of migrants at the downstream end of a river catchment is not numbered in thousands or tens of thousands as in the case of salmonids, but is generally numbered in millions.

1.2 Wide variety of migratory stages

Colonisation commences when elvers, measuring around 70 mm in length with an average weight of 0.3 g, enter an estuary. Two successive phases of migration can be distinguished:

- Passive migration using the flow. At the beginning of the migration season elvers do not have an active, orientated swimming ability. They use tidal currents to move upstream with the flood tide, and bury themselves under the sediments during ebb tide.

- Active migration. From around the month of March (in Europe), the elvers acquire the ability to swim and crawl, allowing them to make active progress and to pass some obstacles. This phase continues until the end of the summer. Colonisation of the freshwater environment by the eels continues through older stages, when the fish are known as “small” or “yellow” eels. The size of the migrators can therefore vary from 10 cm to more than 40 cm.

The migratory activity of small eels is seasonal. It coincides with the period of warmer temperatures every year (April-September, maximum activity between May and July) and allows the migrators to progressively colonise the whole catchment.

Article available at http://www.kmae-journal.org or http://dx.doi.org/10.1051/kmae/2002099

Facilities at the obstacles to ensure free passage must take account of the following factors:

- The large number of individuals needing to pass during a limited period.

- The average size of the migrators, which increases from the downstream to the upstream end of the catchment.

1.3 Swimming capacity and the type of obstructions to migration

Although there is not much data available on the swimming ability of the eel, what there is shows that their performance is weaker than that of other species. The maximum burst speed quoted for elvers varies from 0.60 m/s to 0.90 m/s. McLEAVE (1980) studied the swimming performance of elvers (lengths between 6.9 cm and 7.5 cm) and showed their ability to pass a laminar flow to be very limited. The maximum distance covered in a flow of 0.30 m/s was around 3 m. It decreased to around 30 cm in a flow of 0.5 m/s, and faster flows were impassable.

The only figure given in the literature for the maximum swimming speed of a sub-adult eel is 1.14 m/s for an eel 0.60 m in length at a temperature of between 10°C and 15°C (BLAXTER and DICKSON, 1959). The eel is therefore likely to be blocked by obstructions that do not stop other migratory species, in particular:

- **Drops**, even low ones (a few centimetres) can be impassable.

- **Culverts** or **weirs** where passage is prevented even by moderate current velocities in the absence of heterogeneity in the flow.

The type of obstruction that prevents migration of the eel is therefore specific. Occasional observations of elvers migrating over vertical obstructions by climbing on moist surfaces, and of the presence of eels in ponds isolated from the river network, have resulted in the impact of obstructions on watercourses being underestimated for a very long time. No matter how spectacular it may appear, the ability of the eel to climb moist surfaces where no facilities have been provided is often illusory. Passage in this way is very selective in terms of the size of the migrators, very dependent on the discharge in the watercourse and, in almost all cases, only permits a negligible number of individuals to continue their migration.

Although the eel can sometimes make use of weak flows on rough surfaces or those covered with vegetation, such as weirs with a sloping downstream face at former mills, its passage is compromised by many situations. These include all obstructions occupying the whole width of the watercourse that have vertical smooth surfaces (concrete or metallic material) forming drops or breaks in gradients, or causing flows with a high velocity.

1.4 Specific problems of downstream migration

Downstream migration affects sub-adults as they become sexually mature. The descent of the watercourse generally begins with the first autumn spate. The eels travel at night and by relatively passive means following the main current. These characteristics, in addition to the large size of the individual fish, make them particularly vulnerable when passing hydraulic equipment. Turbines can cause a high mortality rate, but there is not yet a proven method for deflecting eels from them. However, recent work carried out in the Netherlands on water intakes and fisheries has demonstrated the potential for diverting eels efficiently by using the repulsing effect of light, even in very turbid water (HADDERINGH *et al.*, 1992). While this offers some potential specific experiments are still necessary to determine when and how this method can be used operationally on diverse types of plant.

2. DIFFERENT WAYS OF PASSING OBSTACLES

2.1 Operations at estuary installations

This technique can be applied at some obstructions that are located in estuaries, and which operate to prevent saline incursion or flooding (when high river-discharge occurs at the same time as high tide). At these sites the tide is either wholly (tidal flaps) or partly excluded (barrage). Their mode of operation (closed on floodtide, open on ebb-tide) completely interrupts the passage of elvers, which therefore gather at the foot of the barrier. Since the migration of elvers is passive in the lower areas of the estuary, where they have only recently arrived, the provision of a fish passage facility only partly solves the problem. This is because it cannot work until the elvers develop the ability to swim or crawl.

In order to prevent the situation where migration is totally blocked, arrangements can be made to permit some upstream passage during the flood tide. A limited amount of sea-water is allowed past the barrier, either through or else over a carefully controlled structure. The opening of the barrier must be timed to coincide very accurately with **nocturnal flood tides** (LEGAULT, 1990). It is recommended that the efficiency of the operation be monitored periodically, by measuring the density of elvers present in the volume of water allowed upstream of the barrage.

The regular operation of the facility permitting saline water to pass upstream at every high tide is to be preferred, since it also helps maintain a **salinity gradient** in the estuary. This allows the migrants to gradually adapt to a euryhaline environment, thus preventing mortalities which otherwise might be caused to fish whose physiology is unable to withstand a sudden change in salinity.

2.2 Passage through traditional fishways

Because the eel has a limited swimming ability its passage through fishways designed for other species cannot always be assumed, this is especially the case for smaller individuals. Pool passes with deep notches or vertical slots (to permit passage without leaping), and moderate differences in the level between pools are passable by this species. However, there have been few studies carried out on this subject since the fish traps used in fishways are not generally suitable for catching thin fish such as eels. Visual observations on fishways with glass windows show that the eel can exploit the low velocities associated with the boundary layers, or else areas of turbulence and heterogeneity of flow in the higher velocity zones. A modified design (for example by using a device such as brushes in the deepest part of the notches) can improve the passage of the eel in some types of facilities. In Sweden, the use of brushes in a vertical slot pass improved the passage of lampreys (LAINE *et al.*, 1998). Experiments are required to evaluate the real benefits of such devices for eels.

2.3 Specific fishways for elvers and small eels

Their capacity for climbing and crawling on moist, rough surfaces have been used to create migratory fishways for elvers and small eels. Eel passage over an obstacle can also be facilitated by the provision of a ramp equipped with a suitable climbing medium in the vicinity where the migrants collect. Fishways of various configurations (ramps, conduits, pipes, etc.) have been installed abroad (RIGAUD *et al.*, 1988).

3. DESIGN OF FISH PASSAGE FACILITIES FOR ELVERS AND SMALL EELS

3.1 Design principles

Fishways for elvers and small eels are composed of two sections (Figure 1):

- The ascent ramp, with the lower section submerged in the water downstream. This ramp is covered with an appropriate substrate to facilitate progression. The nature of the substrate varies depending on the region or country. It is kept permanently moist either by using water fed by gravity from the upstream impoundment, or else by sprinkling. The small flow required for moistening the surface (a few litres/minute) is complemented by a more significant flow injected near the base of the ramp for the purpose of attracting migrants to the entrance of the pass.

- The upstream section, designed to allow the migrants easy access to the upstream water level. It is desirable to ensure a transition zone that does not cause any obstruction for the migrants, either through discontinuity of the water feed, or through the presence of excessively high velocity flows which could wash the migrants back downstream.

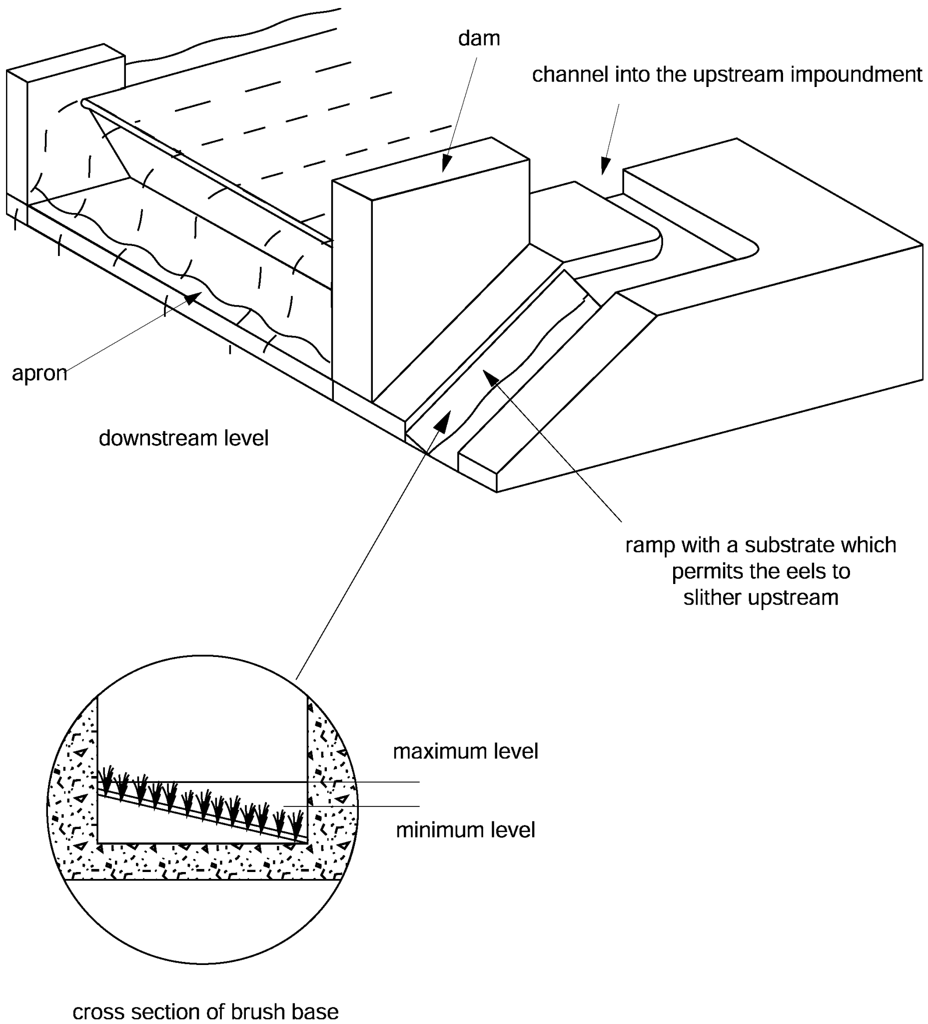

Figure 1: Schematic plan of a fishway for elvers and young eels.

3.2 Ramps

Passage facilities in France or abroad use ramps between 0.20 m and 1 m wide, generally with slopes between 5 and 45%.

The substrates vary greatly, depending on the country.

They may be natural (pebbles, branches, briars or straw) or artificial (mesh or brush, etc...) in origin. Natural substrates require more frequent maintenance and must be replaced periodically.

Experiments carried out with brush surfaces in France (LEGAULT, 1991) showed that the performance of fish passage facilities for eels depended on the dimensions of the substrate, and the gradient of the ramp. These factors should be chosen in relation to the size of the migrants present at the site. There are currently two types of brush substrate used in France (LEGAULT, 1993):

- For elvers the spacing of the tufts of bristles is 7 mm.

- For small eels and yellow eels the spacing is 14 mm

On fishways installed near the sea, where there is a mixture of sizes of eel (elvers and small yellow eels), it is possible to use a ramp with juxtaposed longitudinal strips of brushes, each with a different spacing of brushes.

3.3 Upstream section

The main problem in this section is with fluctuations in the upstream water level. Any decrease in the water level is likely to result in the fish passage facility drying out. On the other hand, a rise may quickly result in an excessive water feed to the climbing ramp and therefore an excessive water velocity on it.

This problem has been dealt with in three different ways:

- The climbing ramp has a lateral gradient (Figure 1) which permits it to absorb moderate variations (about 20 cm) in the level of the headpond, while maintaining a shallow zone with a moderate velocity at one side to enable the migrants to pass. Several ramps of this type may be grouped together at different levels to cover large variations of the upstream water level. The first results of a study in France (VOEGTLE and LARINIER, 2000) suggest that a lateral gradient of 50% (1 vertical by 2 horizontal) is satisfactory to enable the passage of eels, while also accommodating some variation in the upstream water level.

- The whole facility is placed at a level lower than the minimum level of the headpond (Figure 2), and passage to the upstream level is possible by traversing a bed of branches wedged under a sluice, and serving to reduce the velocity locally. This procedure is restricted to modest variations in the upstream level, and its efficiency has never been fully assessed.

- The upstream end of the ramp is situated at a higher level than the maximum level of the headpond (Figure 3). It is sprinkled with water from a pumped supply in order to moisten the ramp. The migrants reaching the top of the climbing ramp are swept down an inclined chute, and fall either into the upstream pond or else into a holding pool. Here they can be are captured for transporting and counting.

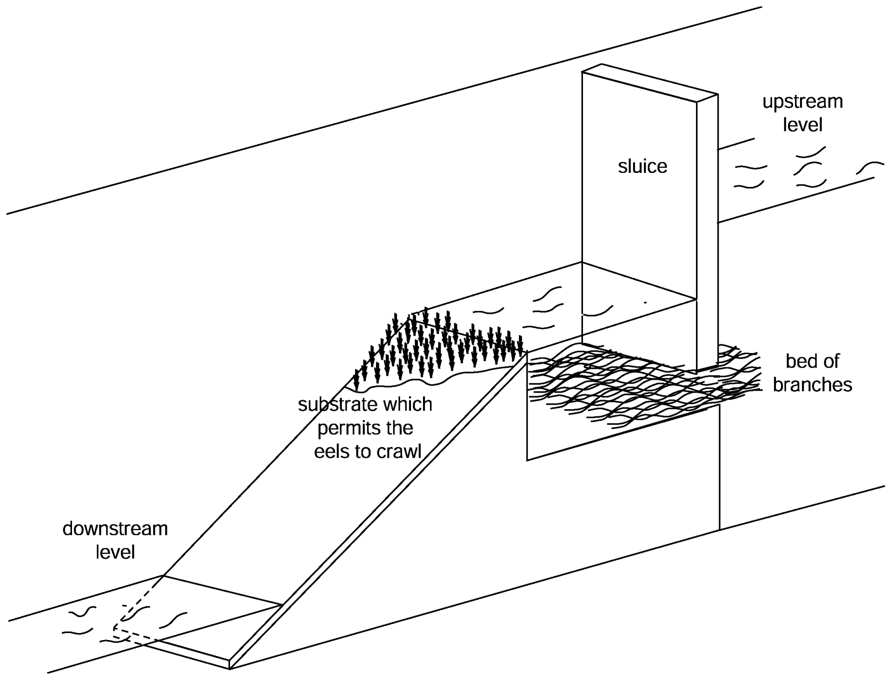

Figure 2: Regulation of the flow discharge and eel passage with a layer of branches under the sluice gate.

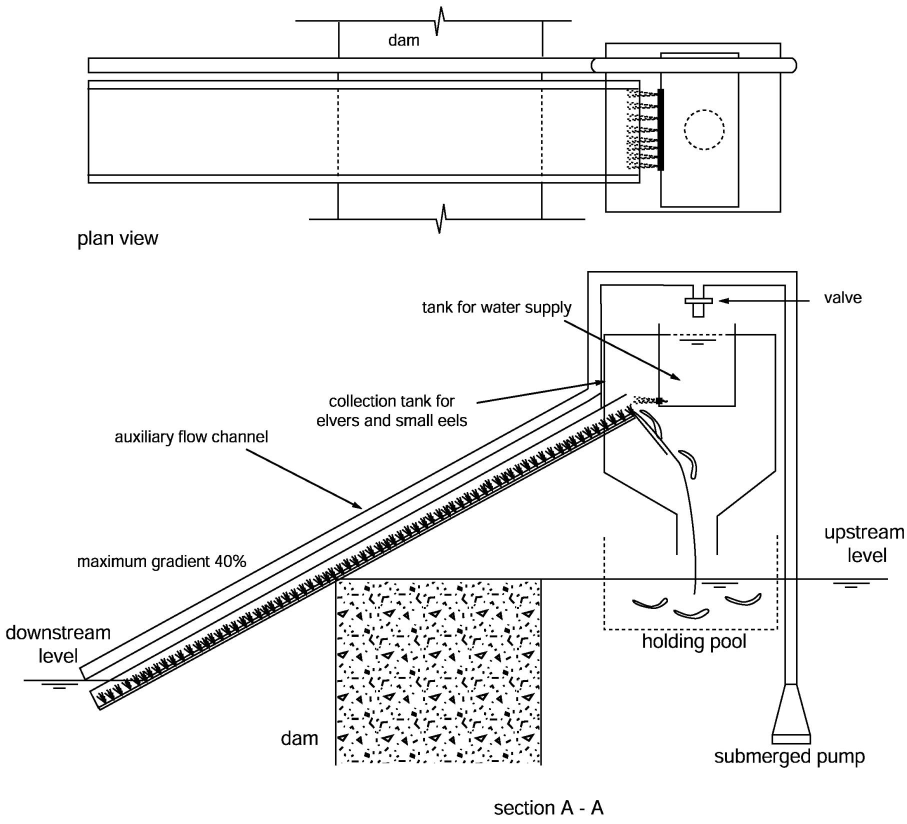

Figure 3: Fishway with upstream trap for elvers and young eels.

3.4 Location at the site

The concept of attractivity of the passes is currently less well defined for the eel than for other species. A recommendation which can be made is to site the entrance for an eel pass as close to the obstruction as possible, and near to the highest upstream point reached by the migrators. It is important that there be a calm zone nearby to provide a holding and resting area for the migrants.

As a guide to determining the correct location of the pass at an existing obstruction, the resting and assembly areas for the approaching migrants should be identified. Before installing the permanent facility tests should be carried out on site using a mobile eel trap, in order to confirm the optimum location of the entrance.

The presence of eels is often observed near fishways designed for the passage of other species. It is possible to take advantage of this attraction, by combining the two facilities. An eel ramp can be installed either at the side of, or even within, another type of fishway (Figure 4).

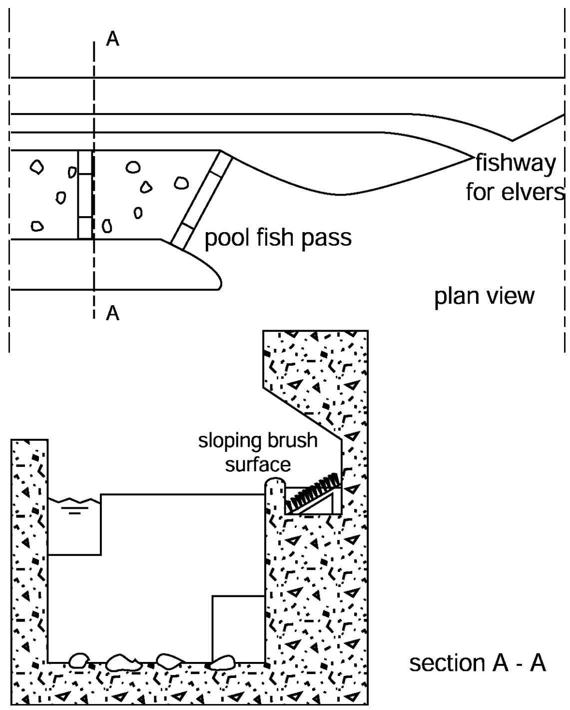

Figure 4: Pool type fishway with an associated pass for of elvers and young eels (from JENS, 1982).

3.5 Observations on current technology

While a number of fishways have been constructed abroad to facilitate eel migration, very little monitoring has been carried out on this type of fish passage facility. Where studies have been made they are often incomplete. Experiments are currently in progress in France (VOEGTLE and LARINIER, 2000) to compare the efficiency of various substrates (brush, concrete blocks, geotextiles, etc) for different sizes of eel. They are being tested at different slopes (from 15° to 45°) and head water levels.

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Photo 1: Eel trap at the Ville-Hatte dam on the Arguenon (Britanny).

Photo 2: Eel fishpass on a radial sluice.

Photo 3: Eel fish pass on the Arzal dam (Vilaine river).

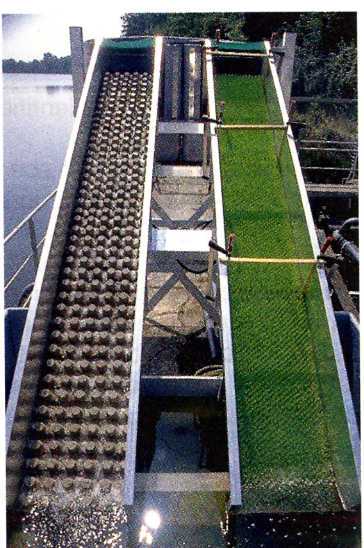

Photo 4: Experimental flumes to test eel substrate on the Tuilieres dam.

Photo 5: Concrete blocks on downstream weir face to make small eel passage easier (Tardoire river).