TITLE: The impact of the weirs on the migratory pathways of glass eels and juvenile eels at the tidal limits of the Severn and Avon navigation.

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1. Abstract

The weirs at Tewkesbury represents the first significant barrier on the Severn and Avon for glass eels and juveniles. Some practical observations.

This analysis examines the impact of a barrier on the glass eel migration at the upper tidal limit of the Severn at the Tewkesbury navigation weir.

Large numbers of glass eels/juveniles were observed below the weir during the 3–4-day period of maximum spring tide as demonstrated in the videos.

The majority of glasseels were observed on the downstream side of the pass leader. No glass eels/juveniles were observed ascending the pass.

It is possible this barrier is one of the main causes of the Severn RBD failing to meet escapement targets.

2. Upper Lode pass

At summer levels it is 1.8 meters high. Tides greater than 9.0 metres above chart datum sharpness sill will level the weir. Only the largest tides will flow the weir and for no more than 30 mins. This equates to 10 tides in the recruitment period (March and April) and perhaps a further 15 tides up to October are sufficient to level or flow the weir for a short period.

It should also be acknowledged that in addition to the direct role the weirs have in obstructing the upstream migration of juvenile eels there is also the long-standing historical impact due to the elimination of the selective tidal transport mechanism (STTM).

The impact of the elimination of the STTM is twofold. Reduced inland penetration and distribution of glass eel population which results in higher local densities and the consequential increased natural mortality.

2.1 Eel Passage prior to the installation of the pass

Note the smooth flow of water over the crest of the weir and the uninterrupted flow down the side of the weir which established a recognisable migratory pathway with a suitable water/substrate splash zone with a shallow lateral incline.


While there was a suitable and recognisable migratory pathway on the approach to the crest of the weir. The migratory pathway nearer to the crest narrowed, the splash zone was steeper and partially obstructed at one point by a land drain. A combination of the fast flows and no splash zone at the land drain and the crest were significant deterrents to a successful migration.

A large splash zone with migrating eels. Note the importance of the water/substrate interface, to be effective it should have a very shallow lateral incline. The lateral incline will define the width and capacity of the migratory pathway.

Photo 1

Resting positions are important. These small eels do not have resources to support a non-stop migration.

A typical migration at night.

What are the trigger factors that drive this sort of migration What are the factors that create conditions that encourage the eels to leave the water and opt to migrate in the water/ substrate interface?

Temperature

Increased fresh water discharge

Density of Eel Population

Low energy migratory strategy.

2.2 Eel passage post construction of pass

The construction of a new eel pass in the right bank was completed in 2019

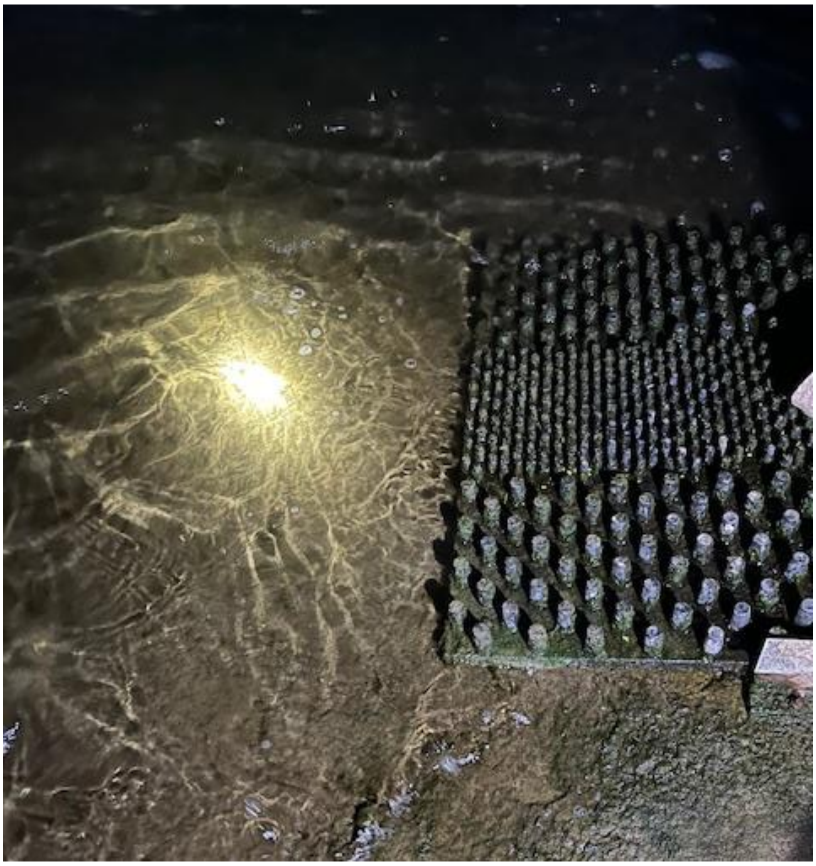
At summer levels the leader to the pass creates a gyre which flows anticlockwise which is counter to the natural route to migratory ascent. There is now a flow upstream towards the weir. The natural expectation is downstream. Similarly in flood conditions there is much larger gyre which extends from the crest of the weir right hand side to mid river. There is a strong natural flow with a standing wave over the end of the pass. The position of the standing wave varies with flow rates.

Mid flow conditions

The downstream flow for the natural migration route is now upstream. Glass eels/juveniles can be observed collecting in the slack water on the downstream side of the pass but not on the upstream side of the pass. A combination of the standing wave, the velocity of the water flowing across the end of the pass and the gyre producing an upstream flow at the pass all conspire to make access to the pass difficult if not impossible.

The pass now obstructs the natural migration route to the weir face.


Note that the pass on the left is flooded with water and has no splash zone. Impassible for small eels.
The same pass on the right for comparison is dry, which is also impassable.
Velocity of water top section 12.5 metres of pass 1.0m/sec, leader 4.5 metres 1.2m/sec.
For Swimming speeds see Appendix.



Dry Pass leader - No connectivity with river. Impassable.

2.3 Observations of Glass eel / Juvenile migration

For glass eels/small juveniles the water / substrate interface important. At Upper Lode minimal water flows and the concrete surface historically provided adequate initial pathway.

Note shadow of glass eels accumulating at bottom of pass leader in slack water. Migration taking place mid-summer in July with no tidal influence. The glass eels /small juveniles migrating in the over-spill at the side of the leader. These juveniles are not ascending the pass.

There will be no positive migration outcome for these small eels on the downstream side of the pass leader.


Bushnell
57F14C
07-17-2020 00:57:24

Juvenile eels migrating up the downstream side of the pass to a blind end.

2.4 Dark to Dawn cycle

Impact of daylight on migration. In this time lapse sequence of photographs, note the disappearance of glass eels on the concrete substrate and the disappearance of the glass eels in right bottom corner with increasing light conditions.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2.5 Observations.

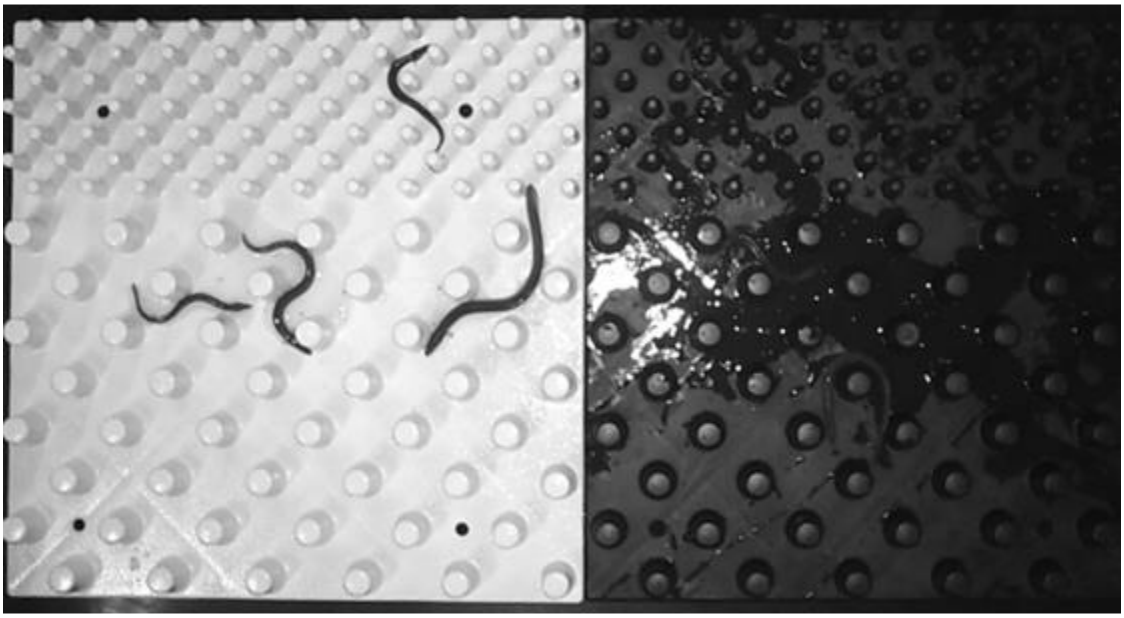
Maintenance

Note the vegetation collecting on the pass resulting partial blockage of flow, increased velocity of water with over spill.

Pass dry blocked by vegetation

White Tiles

For effective photography to prove the passage of the eels over the pass a section of white tiles is a requirement. Black tiles do not offer any contrast making it very difficult observe eels on a black back ground.



White tiles would significantly improve contrast of infra-red photographs as above.

2.6 Installation of tiles

These tiles have been installed to provide a substrate on which glass eels/juveniles ascend the pass. Small eels, glass eels have tendency to move to the margins where water velocities are lowest. The default installation is to place the tiles with the thin protuberances at the margins of pass and thick protuberances in the centre for larger eels. Larger eels need the extra spacing of the centre and are able to cope with stronger flows to undertake an effective migration. The majority of the water is flowing down the centre of the pass This creates some challenging cross flows at the top of the pass leader.

The importance of the interface between water and substrate (Splash zone) as the migratory route cannot be overstated.

The splash zone should have a shallow lateral inclination.

The juvenile eels avoid fast flowing water.

There is a requirement for resting points.

Glasseels have adopted a low energy strategy for migration in the tidal zone using a selective tidal transport mechanism. The migration of glass eels and juvenile eels in the splash zone of the pass is also part of a low energy migration strategy.

Pass with incorrectly installed substrate.

While a lot of consideration has been given to suitable migratory substrates for passes. There has been little consideration given to the adoption of designs to facilitate a low energy migratory strategy.

- The migratory behaviour of glasseels is inhibited by day light.
- Small Juveniles will under some conditions tolerate day light but darkness is preferred.
- The length of the pass is not only limited by the energy requirement but is also defined by the migration distance that can be achieved in the dark period of the day/night cycle.

Migration. A significant population of juvenile eels, size from 0.35 gm to 3gm could be found in close proximity to the base of the pass. Some were attempting to migrate in the over spilled water next to the pass.

In spite of the presence of eels collecting in the eddy in the downstream side of the pass it was not possible by direct physical observation to detect any concurrent migration on the pass or detect any eels resting in the slack water on the pass or any eels at the crest of the weir.

Draining and cleaning the pass revealed the presence of one small eel only. In our extensive time series, we have not been able to demonstrate an equivale migration as shown in Photo 1.

The development of an eel pass that is effective for all life stages and at all locations is challenging and, in some circumstances, passes may not be viable options.

It has not been possible to demonstrate that the upper lode pass offers a viable and functional route over the weir.

2.7 Action required

Manage the water flow to reduce waterflow.

Widen the pass and create a laterally inclined splash zone.

Transpose position of tiles to enable migration of the glass eels / juvenile eels at the lateral edges.

Introduce white tile for photography.

Measure the passage of eels and prove the concept that the pass works.

2.8 Further ideas for enhancing migration upstream at navigation weirs.

The navigation locks also offer an opportunity to assist the passage of a range of species of migratory fish.

At end of day down-Stream lock gates should be set partially open for the night. Closed first thing in the morning and Up-Stream gates opened to release the migratory fish.

2.9 Video streams Upper Lode Pass

2.9.1 Glass eel stranding

Video Link

Note: Glass eels are failing to negotiate the pass and are trapped on the down stream of the pass leader with a significant population of glass eels stranded in the stones below the weir.

2.10 Design challenges

Video Link

Note: There is a strong and conspicuous up stream eddy. Downstream flow is right to left. The leader is creating the eddy and glass eels are collecting downstream of the eddy. There are no glass eels on the pass. There are glass eels on the upstream side of the leader. There is an overspill and the pass is flooded with water. There is no splash zone over which the glass eels/ juveniles can migrate. Just upstream of the leader there is large standing wave with fast flowing water which is will be a challenge to migrating glass eels/ juveniles.

2.10.1 Pass failure

Video Link

Note: The pass is flooded with no splash zone making glass eel/juvenile ascent difficult or impossible. At the top of leader in the corner there was an area of slower flowing water where glass eels might rest. It was not possible to demonstrate the presence of glass eels/juveniles on the pass. This is in sharp contrast to the large population of glass eels of that could be seen on the downstream side of the leader or the population stranded in the stones below the pass.

2.11 Appendix

While glass eels are vigorous and directionally oriented for the primary migration when first entering fresh water it is not long before they start to lose body condition (<0.25Gm) and vigour and have little ability to undertake a sustained migration until the metamorphosis is complete and body condition improved (0.45Gms).

In some conditions the eels have a preference to migrate at the water/substrate interface. Accessibility to the pass is conflicted by the requirement of water flows that are sufficient to attract the eels which are at the same time not great enough to overcome the ability of the smallest eels to climb the pass.

The emphasis up to now has been to try and produce one design with zero maintenance that will cater for all life stages at all locations. Different life stages have a varied ability to migrate that require different substrates and managed water flows. Current pass designs are not be suitable for those applications requiring movement of large populations between significant head differences.

At the upper tidal limits, the principal objective must be to design and install passes that are suitable for glass eels and juvenile eels less than 3 gm in size. It is important to recognise that the life stage of a juvenile eel accurately defined as a glass eel have limited capability of swimming up a pass or the adhesive properties to negotiate vertical surfaces. These properties are acquired in the later stages of glass eel development towards the end of the recruitment period.

The design of passes for eels is very challenging. For the early life stages of the migrating eel passes are high maintenance and unless these specific challenges are recognised there is little value in investing in passes. Trap and transport are likely to be more effective and of better value.

Swimming performance

It is importance to recognise in estimating swimming velocities that there is a balance to be struck between endurance and burst speeds, between 0.25m/sec to 0.36m/sec, in the design of a pass. Elvers could swim at high speeds for 0.1 -0.45 m before exhaustion. Elvers make virtually no progress against water currents 0.5m/sec. For vertical ascent, velocities are measured in mm/sec. There is little data available specifically for glass eel performance.

J. D. McCleave
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https://doi.org/10.1111/j.1095-8649.1980.tb03723.x

Temperature is also an important factor. Maximum velocity at 8.0°C 0.3 M/sec and at 13.8°C 0.45 m/sec. Water velocities over 0.6m/sec are not negotiable

D. Blennerhassett E.J.P. Wood, JUNE 2010
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