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Presenter Information
William Peirson, Isaac Kim, Kieran Pugh, John H. Harris, Stefan Felder, and Richard T. Kingsford
Hydraulic optimisation of a system for transporting fish in water vertically at near-atmospheric pressure

William Peirson, Isaac Kim, Kieran Pugh, John Harris, Stefan Felder and Richard Kingsford
Background

Freshwater fish populations are declining globally (>75% collapse over the past 40 years) due to lost opportunity to spawn, feed and hide.

A major factor is loss of connectivity in rivers due to weirs and large dams

- Weirs: 2 to 10m high and maintain water levels in river reaches (millions internationally)
- Major dams: >100m high and are to store water (>47000 internationally)
Fishways for high structures

A fishway is required to restore connectivity.

For high structures:

- Constructed fishways are large and expensive.
- Direct mechanical pumping cannot be used as fish are damaged.
- Trap and haul techniques are reliable, but require personnel to operate.
- Bucket and winch systems are subject to mechanical failure.

Remote sites require simple designs with low maintenance requirements.
A new pump fishway

Two key study components to date:

1. Attracting fish into a “transfer chamber” for transport upstream. (Harris et al., 2018)
   - Experiments with live juvenile fish demonstrating effective attraction and capture

2. A pump system to lift the transfer chamber contents to the upstream delivery point.
   - Minimal moving parts
   - Minimal footprint
   - Transported fish remain in water at near-atmospheric pressure.
   - Tested at 1 metre vertical scale.
   - Numerical model has been verified against the physical model.
   - Numerical model predicts reliable operation at vertical scales exceeding 100 metres.
Pump System
Fish entry

Operation commences with the flow inlet valve closed.

The fish inlet valve is located in a pool downstream of the dam.

An open fish inlet valve allows fish to enter the transfer chamber.

Fish are attracted to the pool and into the transfer chamber by an attraction flow.
Fish transport

The fish entry valve is closed to allow flow to be applied to the transfer chamber.

Flow inlet valve is opened.

Water enters the transfer chamber from the inlet conduit.

Transfer chamber contents are pushed into the delivery conduit.

The transfer chamber contents remain at approximately atmospheric pressure.
Fish delivery

Transfer chamber contents are forced over the dam crest.

Fish are discharged to the reservoir above.

After discharge, fish are free to migrate upstream.
Numerical Model

- Unsteady flow
- Colebrook friction
- Euler timestepping

\[
Z_1 - K_{\text{entry}} \frac{U_1^2}{2g} - \frac{f_1 Z_1}{D_1 \sin \theta} \frac{U_1^2}{2g} - K_v \frac{U_1^2}{2g} \frac{\partial U_1}{\partial t} \sin \theta - K_{1-c} \frac{U_2^2}{2g} - \frac{f_c L_c}{D_c} \frac{U_2^2}{2g} \frac{\partial U_c L_c}{\partial t} \sin \theta - K_{c-2} \frac{U_2^2}{2g} - \frac{f_2 x U_2^2}{D_2} \frac{\partial U_2 x}{\partial t} \frac{1}{g} = x \sin \theta + K_{\text{exit}} \frac{U_2^2}{2g} + \frac{U_2^2}{2g}
\]

Testing at larger scale

A model with a lift of 4m has now been successfully tested at the Water Research Laboratory.

This larger unit incorporates a delivery conduit diameter of 90mm.
Transfer chamber hydraulic coupling

Transfer chamber geometry must suit the fish, not the engineering!

The hydraulic consequences of three different supply arrangements have been determined.
Transfer chamber hydraulic coupling II

Oblique flow entry induced strong swirl and an air core vortex.

Energy is lost as swirl and it is unlikely to be enjoyed by fish.

An improved design has been recommended.
Conclusions

• Proof-of-concept of an unusual pump system demonstrated to transport water from a transfer chamber at the foot of a high hydraulic structure over its crest.

• Chamber water remains near atmospheric pressure during transport - critical to avoiding fish injury.

• The internal structure of the pump has been designed to be smooth to avoid injury to transported animals. It has only two moving solid components: the two valves.

• Numerical predictions verified using models at metre and 4 metre scale.

• Numerical prediction of successful operation at 100m scale.

• Coupling of inlet water supply to the transfer chamber is critical to biological and hydraulic performance.

• A large scale system combining the two components is now being built for testing at field scale with live fish.