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Influence of the presence of sills on the behavior of brown trouts (Salmo trutta) in an experimental vertical slot fishway

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Influence of the presence of sills on the behavior of brown trouts (Salmo trutta) in an experimental vertical slot fishway.

Aurélien BALLU, Gérard Pineau, Damien Calluaud, Laurent David
Introduction -- Context

French water system: \( \approx 70,000 \) obstacles

A dam and a weir located on the Vienne river and the Creuse river near Poitiers (France)

Why?
- Irrigation
- Electricity production
- Navigation

It could alter fish migrations

Evolution of the number of the water courses used by the Atlantic salmon in France

From Larinier (1998)
**Introduction -- Context**

**Vertical slot fishway (VSF)** is a very common crossing device in France:

- **Not very selective**
- **Wide range of head**
- **Good adaptation to the land constraints**
- **Small sensitivity to the upstream/downstream water level**

**Flow:**

- **Turbulent**
- **Unsteady**
- **Three-dimensional**

Must be related to the swimming capacity of the fish species that have to cross the device (target species)

*Chatellerault (France)*
http://www.logrami.fr

**Geometrical characteristics of a VSF pool**
Introduction -- Purpose

How to adapt the flow characteristics to the target species swimming capacity?

- **Sills**
  - Restore the balance between pools
  - Reduce the discharge in the VSF

- **Laboratory VSF**
  - 5 pools VSF
  - Slot width: \( b = 0.075 \) m
  - Pool width: \( B = 0.5 \) m
  - Pool length: \( L = 0.75 \) m
  - Discharge: \( Q = 23 \) L/s
  - Slope: \( s = 7.5\% \) (maximum velocity \( V_{th} = 1.05 \) m/s)
  - Sills height: \( h_s = 0.075 \) m

(h\(s/b=1\))

*http://www.pprime.fr/recherche-scientifique/d2/hydee*
Introduction -- Purpose

How to adapt the flow characteristics to the target species swimming capacity?

Sills

- Restore the balance between pools
- Reduce the discharge in the VSF

Experimental measurements (ADV)

- Without sill
- With sill (h_s/b=1)

How do the sills affect the passage of fishes through the VSF?

Ballu (2017), phd thesis

http://www.pprime.fr/recherche-scientifique/d2/hydee

21/06/2017 – Fish passage 2017
I. Experimental setup

- Laboratory VSF model for biological experiments
- Experiments
- Video monitoring

II. Results

- Index
- Resting time
- Trajectory

Conclusion
I. Experimental setup -- Laboratory VSF model for biological experiments

Temperature control valve

Cooling coil

Mirror for bottom view

HD camera

Holding pens
I. Experimental setup -- Experiments

Biological model

Fish species: Brown trout

- 9 cm (max velocity ≈ 1.07 m/s) → 2 groups of n=38 fishes
- 17 cm (max velocity ≈ 1.7 m/s) → 2 groups of n=44 fishes

Experimental design

→ 2 configurations:
- fishway without sill
- fishway with sills \( h_s/b = 1 \)

1- Introduce a group of fishes in the last pool
2- Keep the group of fishes in the last pool during 15min for acclimatization
3- Release the fishes and record the passage in the third pool for 90min
4- Reduce the size of the last pool with a grid, for 5 min every 15min to encourage the fishes to move
I. Experimental setup -- Video monitoring

Exemple of a video from fish experimentation

Fish motion and scenarii

AB : pass through the pool
AD : enter the pool but wash back later
CB : wash back from the upstream pool and enter again
CD : wash back through the pool
AE ; CE : enter the pool and stay until the end of the experiment
I. Experimental setup -- Video monitoring

Exemple of a video from fish experimentation

3 main indices to describe fish behaviours

- Efficiency Index:
  \[ EI(\%) = \frac{AB - CD - CE}{N_{tot}} \]

- Activity Index:
  \[ AI(\text{mov/ind}) = \frac{A + B + C + D}{N_{tot}} \]

- Downstream Index:
  \[ DI(\%) = \frac{C + D}{A + B} \]
I. Experimental setup -- Video monitoring

Exemple of a video from fish experimentation

Resting areas and fish trajectories

- 4 recirculation zones corresponding to resting areas
- The time spent by each fish in each resting area was measured
- The passage of fishes from zone to zone was analysed and allows the definition of fish trajectories
II. Results -- Index

Statistical data analyses

Statistical tests were chosen depending on the number of samples, the variance homogeneity and the normal distribution of the samples.

Influence of sills on the efficiency index

![Graph showing efficiency index with and without sills](image)

- Significant reduction of efficiency (-10%, two sample t test, t=2.1, p=0.049)

Exemple of upstream failure

creation of a trapping area behind the sill
II. Results -- Index

Influence of sills on the activity and downstream index

Sills tend to reduce the Activity Index

Sills do not affect significantly the downstream index
II. Results -- Resting time

Influence of sills on the fish resting time in each resting zone

Results for bigger fishes (length ≈ 17cm)  Results for smaller fishes (length ≈ 9cm)

The presence of sills changes the fish resting time in zone 2, due to the modification of the mean flow pattern.
II. Results -- Trajectory

Where are going the fishes when arriving in the pool from downstream?

- The behaviour of the fishes when entering in the pool is **independent from the tested configuration** (with or without sills).

- Due to the curvature of the jet in the pool the fishes are mainly directed in the zone 1 (+90%).

- About 7% of the fishes exit the pool just after entering.
II. Results -- Trajectory

Where do the fishes come from when exiting the pool upstream?

About 70% of the fishes use the zone 1 to exit the pool and 30% use the zone 2, regardless the tested configuration (with or without sills).

The fishes position themselves parallel to the incoming jet to leave the pool.
The insertion of sills in the bottom of the slots of a VSF *creates a mean flow pattern* that is less favourable for fishes.

Biological experiments *(in laboratory conditions)* show that for a specific fish species *(the brown trout)*:

- sills *reduce the efficiency* of VSF by the creation of a *trapping area* downstream the sills

- sills *modify the fish resting time in zone 2* due to the modification of the mean flow pattern

- Sills *do not significantly affect the fish trajectories* in the measurement pool
THANKS FOR YOUR ATTENTION

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voies navigables de France