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

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French water system : ≈ 70 000 obstacles

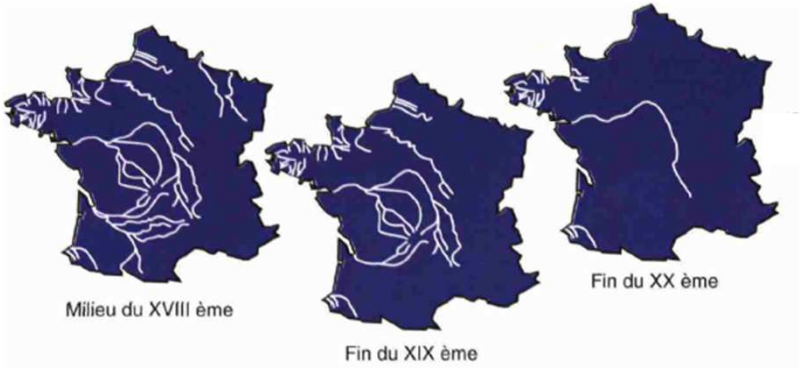
A dam and a weir located on the Vienne river and the Creuse river near Poitiers (France)

Why ?

- Irrigation
- Electricity production
- Navigation

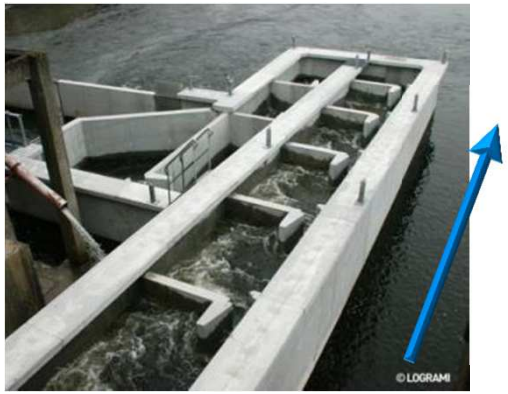
It could alter fish migrations

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



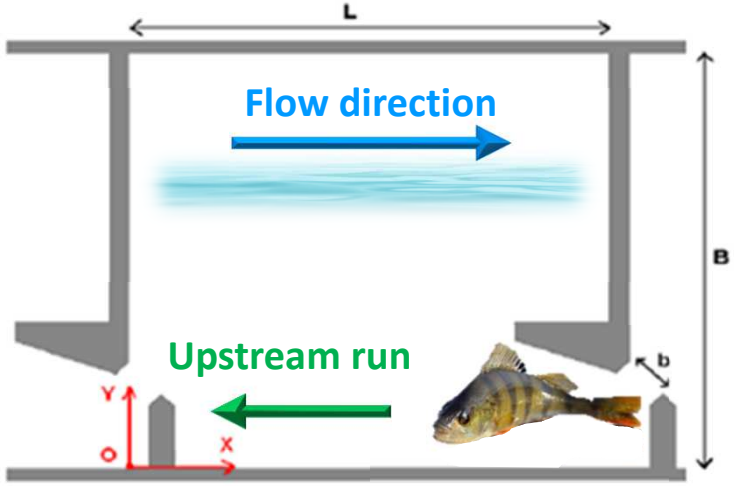
From Larinier (1998)

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



Flow direction

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



Geometrical characteristics of a VSF pool

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

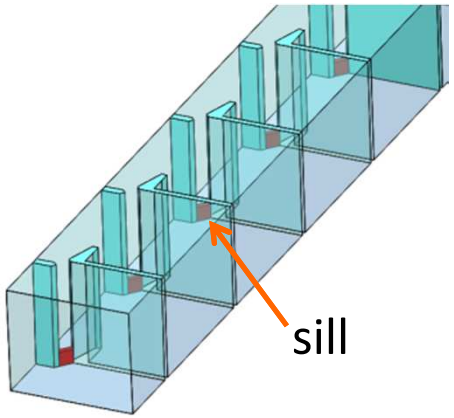
→ **Flow :**

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

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

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

Sills



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

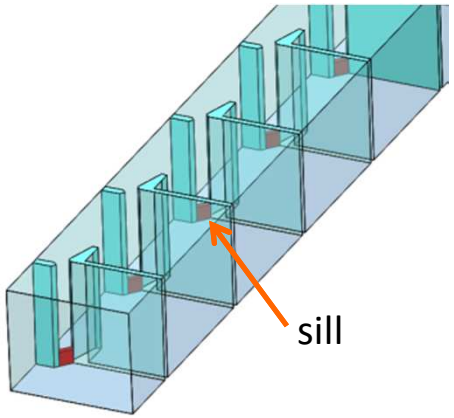
Laboratory VSF

- Slot width : **b** = 0.075m
- Pool width : **B** = 0.5m
- Pool length: **L** = 0.75m
- Discharge **Q** = 23 L/s
- Slope **s** = 7.5% (maximum velocity V_{th}=1,05m/s)
- Sills height : $\mathbf{h_s}$=0.075m

(h_s/b=1)

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

Sills



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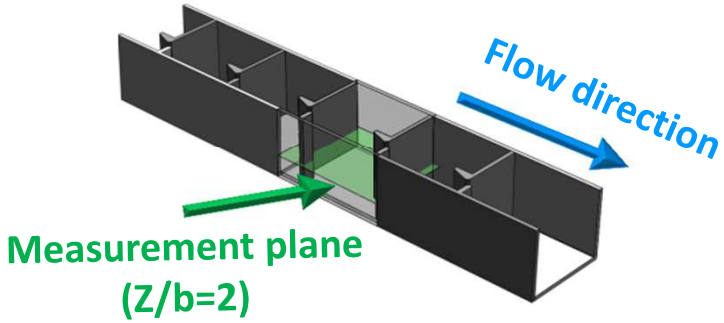
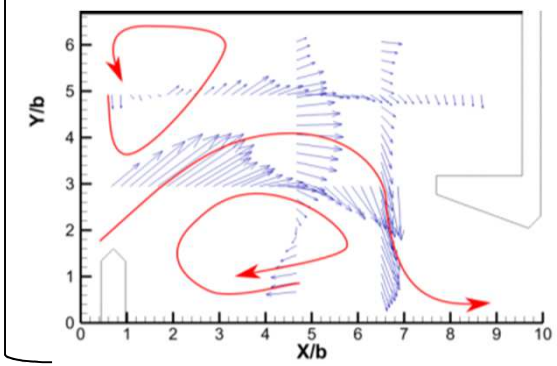
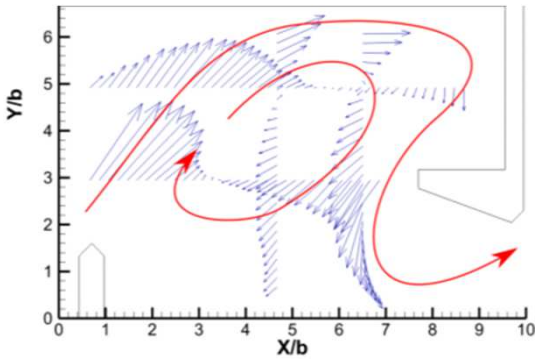
Experimental measurements (ADV)



Without sill



With sill ($h_s/b=1$)



Ballu (2017), phd thesis

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

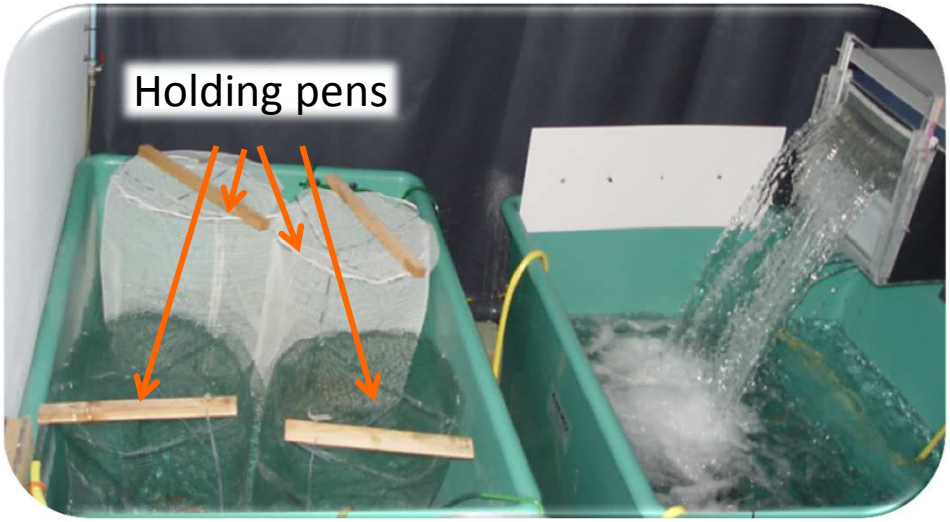
I. Experimental setup

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

II. Results

- Index
- Resting time
- Trajectory

Conclusion



Temperature control valve

Cooling coil

Miror for bottom view

HD camera

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

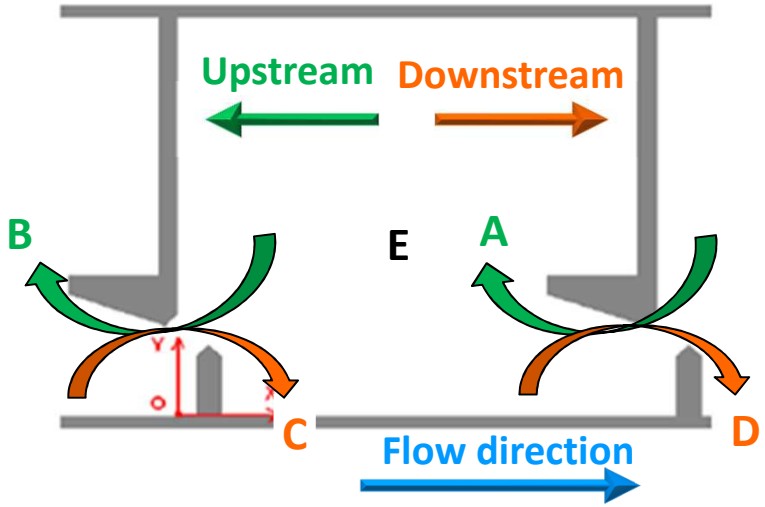
2- Keep the group of fishes in the last pool during 15min for acclimatization

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

Exemple of a video from fish experimentation

Fish motion and scenarii



AB : pass through the pool

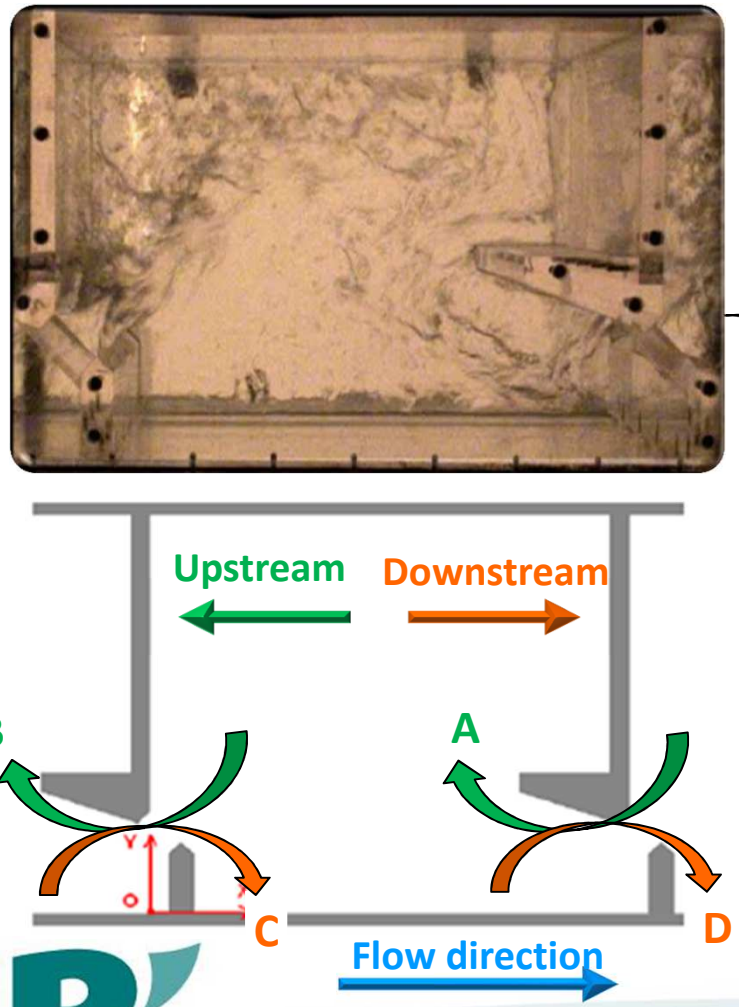
AD : enter the pool but wash back later

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

Exemple of a video from fish experimentation



3 main indices to describe fish behaviours

- Efficiency Index:

$$EI(\%) = \frac{AB - CD - CE}{N_{tot}}$$

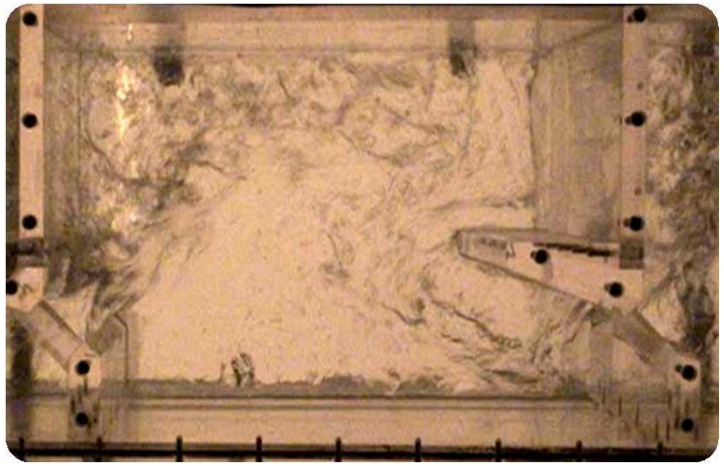
- Activity Index :

$$AI(mov/ind) = \frac{A + B + C + D}{N_{tot}}$$

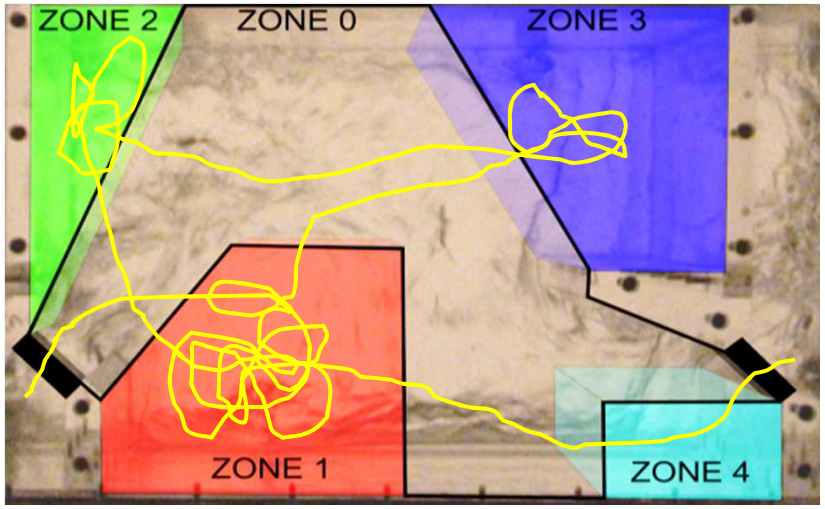
- Downstream Index :

$$DI(\%) = \frac{C + D}{A + B}$$

Exemple of a video from fish experimentation



Resting areas and fish trajectories

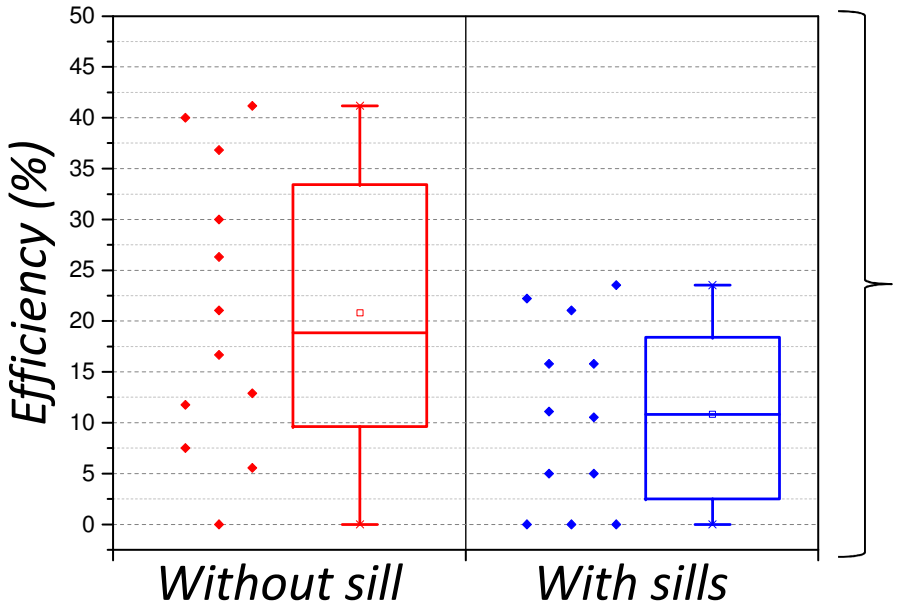


- 4 recirculation zones corresponding to resting areas
- The time spent by each fish in each resting area was measured
- The passage of fishes from zone to zone was analysed and allows the definition of fish trajectories

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

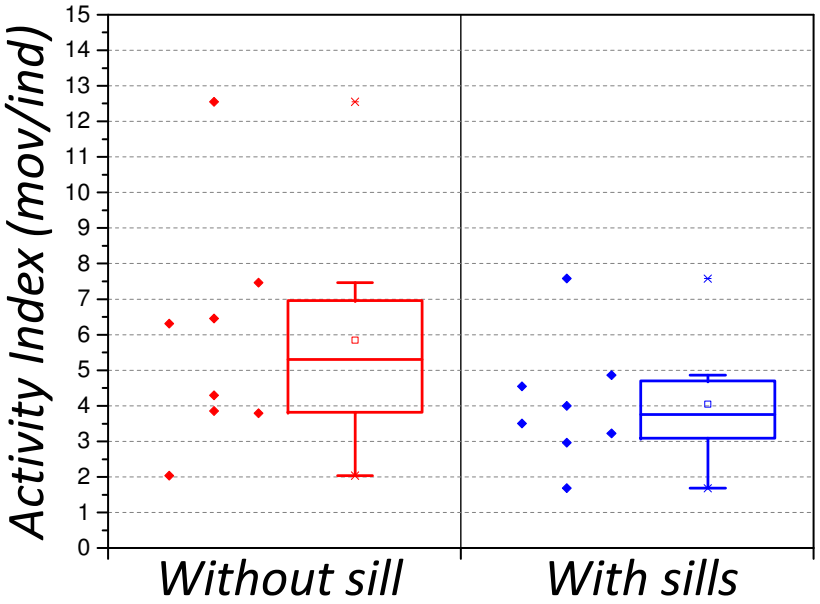


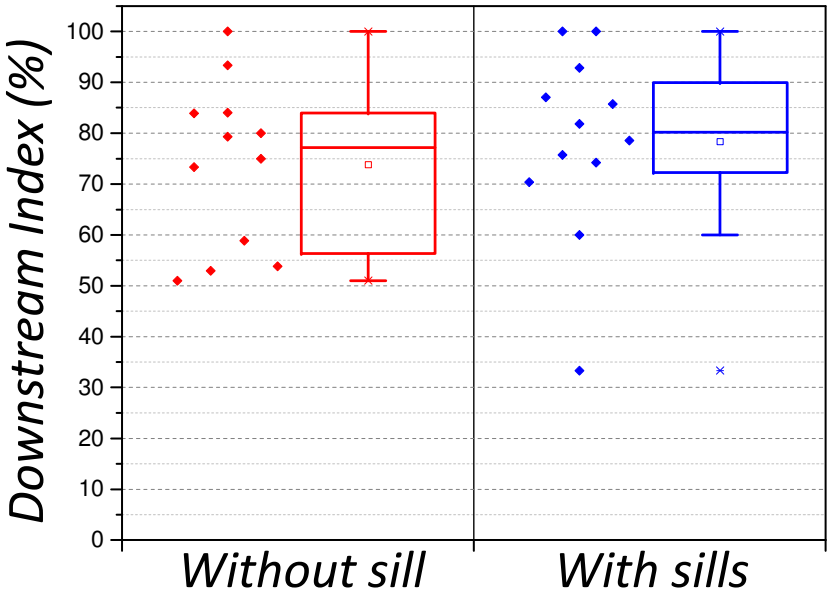
→ Significant **reduction of efficiency** (**-10%**, two sample t test, t=2,1, p=0,049)

Exemple of upstream failure

→ creation of a trapping area behind the sill

Influence of sills on the activity and downstream index



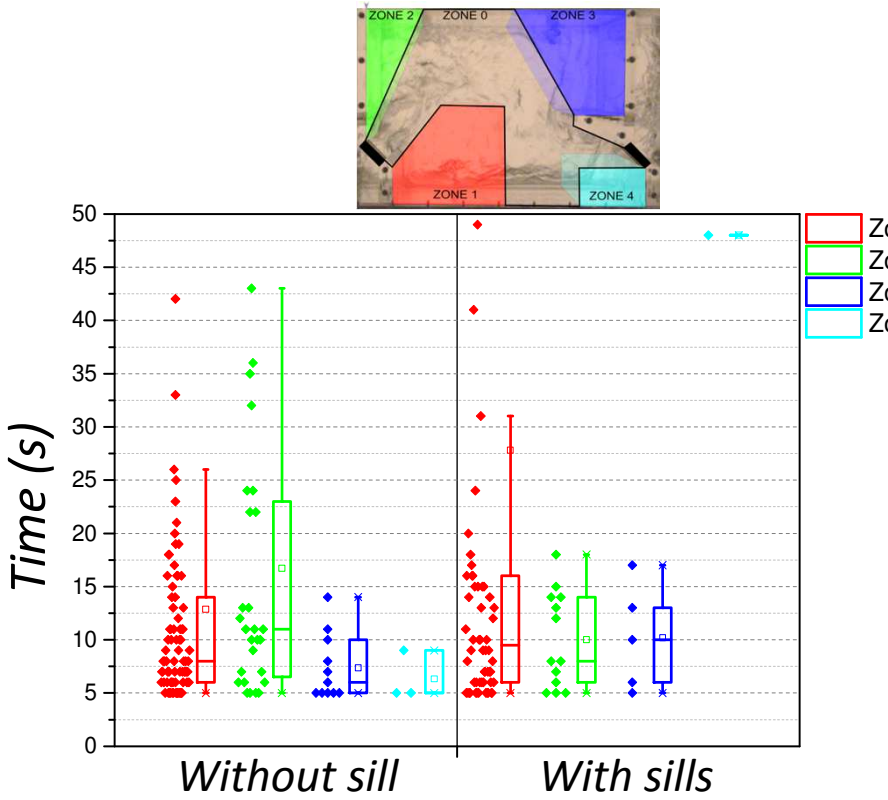


→ Sills tend to reduce the Activity Index

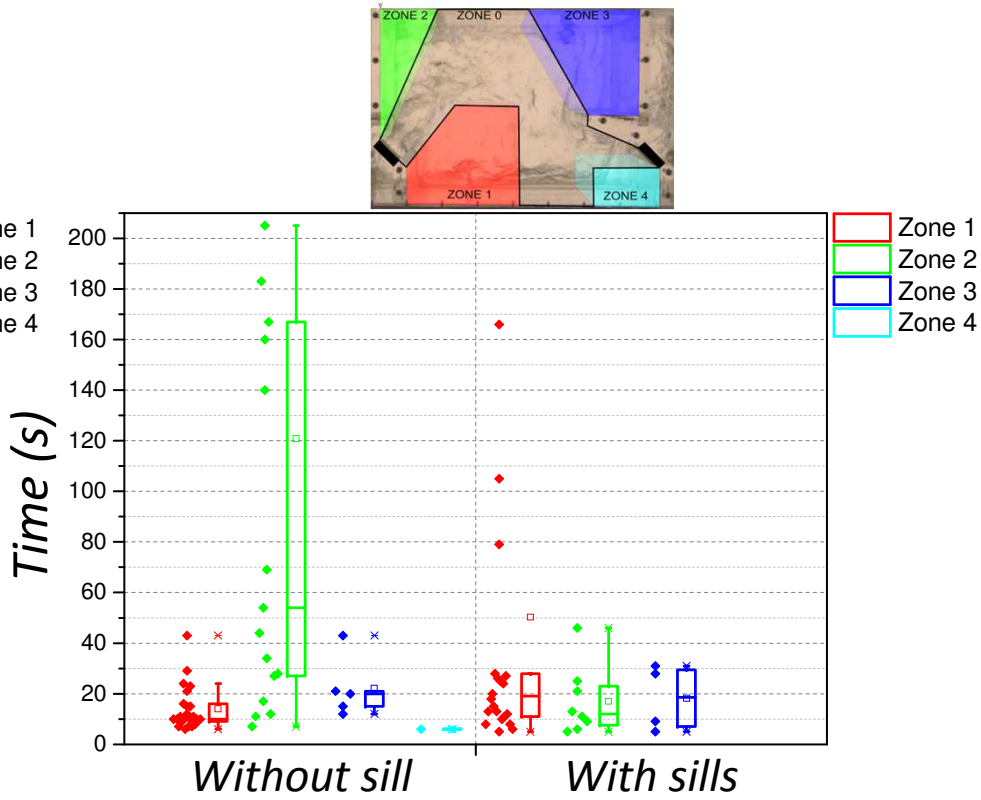
→ Sills do not affect significantly the downstream index

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

Results for bigger fishes (length ≈ 17cm)

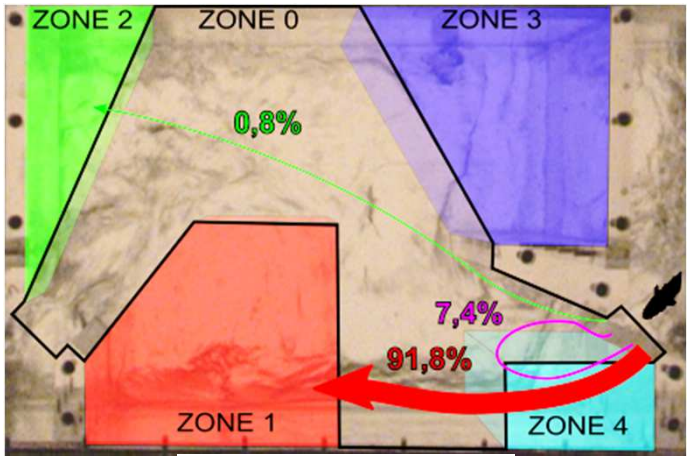


Results for smaller fishes (length ≈ 9cm)

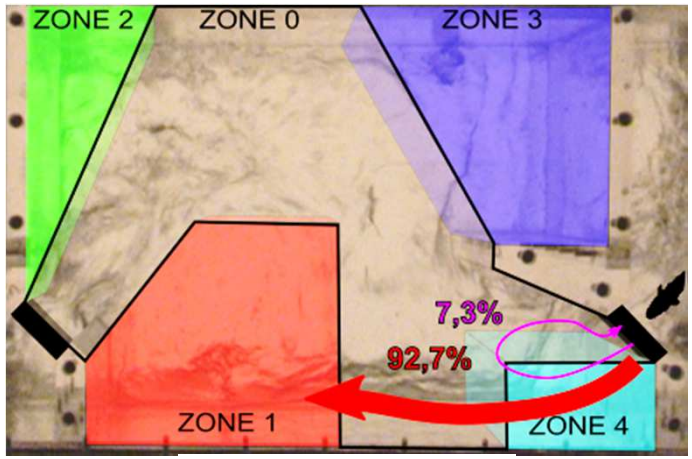


→ The presence of sills changes the fish resting time in zone 2, due to the modification of the mean flow pattern.

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



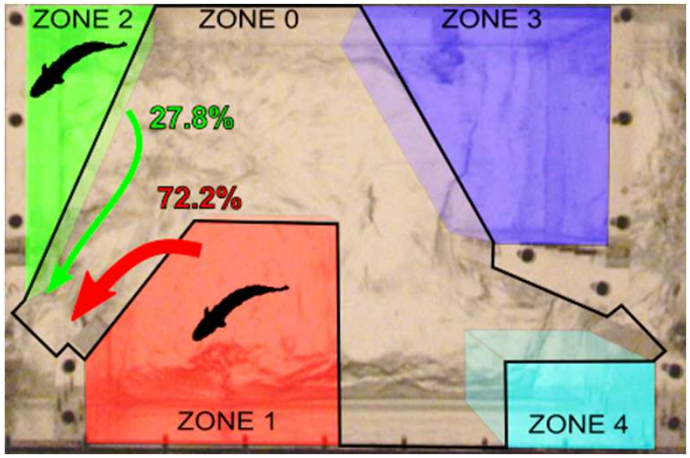
Without sill



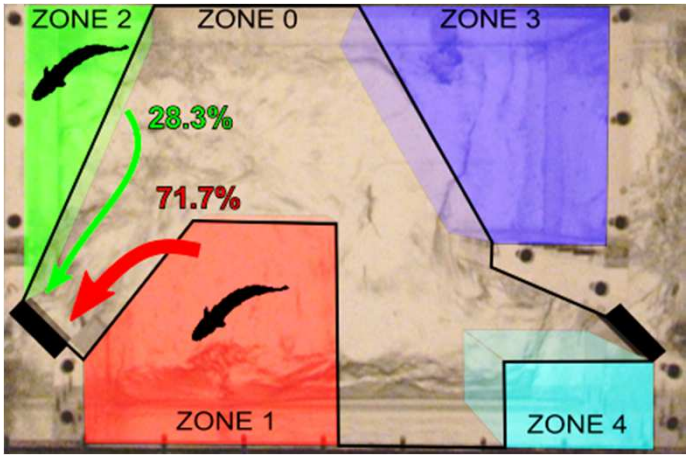
With sills

- The behaviour of the fishes when entering in the pool is **independant 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

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



Without sill



With sills

- 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

Thanks for the financial support :

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MINISTÈRE DE L'ENVIRONNEMENT

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