New approaches to assess upstream and downstream migration of fish –
integrating field survey and modelling

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1) Modelling Upstream migration behaviour

• Fish lift Runserau, Austria
Modelling Upstream migration behaviour

- Categories of rheoreactive response velocities

<table>
<thead>
<tr>
<th>Flow velocity</th>
<th>[m/s]</th>
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<tbody>
<tr>
<td>3,33 m³/s</td>
<td>0.0 - 0.2</td>
</tr>
<tr>
<td>1,67 m³/s</td>
<td>0.2 - 0.4</td>
</tr>
<tr>
<td>0 m³/s</td>
<td>0.4 - 0.6</td>
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<tr>
<td>0 m³/s</td>
<td>0.6 - 0.8</td>
</tr>
<tr>
<td>3,33 m³/s</td>
<td>0.8 - 1.0</td>
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</table>

Behavior-relevant velocity classes

- 0.00 - 0.15: No clear orientation
- 0.15 - 0.30: Young fish oriented
- 0.30 - 1.00: Adult fish oriented
- 1.00 - 1.75: High swim capacity
- >1.75: Limit of swim capacity
Modelling Upstream migration behaviour

- Fish agents integrated in Fish habitat model of CASiMiR

Migration paths: situation without weir spill

[m/s]
Modelling Upstream migration behaviour

- Fish agents integrated in Fish habitat model of CASiMiR

Migration paths: situation with additional flow of 5 m$^3$/s on right bank from desilting chamber
Modelling Upstream migration behaviour

• Observing fish behavior and relating it to hydraulics

• Setting up hydrodynamic model

• Studying attraction flow for different flow situations

• Optimization of agent-based fish migration model
2) Measuring flow how fish sense it

Fish sensor with a lateral Line

A fish is not a point in **space**

Fish use **two modalities** to sense acceleration and **gradients**

Superficial – senses velocity gradient at point

Canal – senses pressure gradient over body

**Superficial** Neuromasts < 30 Hz

**Canal** Neuromasts 30-200 Hz
How does a fish experience turbulence?

Moving vortex over fish body

A series of peaks shows that a vortex is passing over the body.
Vortices and fish behaviour

Bioinspired sensing fish robot (FP7 project FILOSE)

- Adjusted tail beat timing based on lateral line signal (frequency, amplitude, phase)
- Increased the propulsive efficiency by 100%

Video

https://www.youtube.com/watch?v=3nQYaRtNzKY
Flow signatures (Project FISHVIEW, BONUS programme)

- Measurements in vertical slot pass, laboratory

- Different flow signatures in different zones of a Vertical slot pass

- Goal: Find signature categories that are relevant for fish behaviour
Lateral Line Probe / Flow signature categories

The flow around the body leaves a hydrodynamic signature
Lateral Line Probe / Flow signature categories

The signatures can help to identify **similar regions** in a fishway.

→ Fish sensor as assessment and monitoring device for fish pass hydraulics?
3) Downstream migration and flow signatures

- Fish approaching inlet screen
Downstream Migration / flow signatures

Flow velocity components in front of inlet screens

- Knowledge about behaviour in different geometries, angles, flow components
- Thresholds for flow velocities for different species and life stages
- Current approaches consider mean flow velocities and swim capacities

Modified after Ebel (2016)
Downstream Migration / Flow signatures

Lateral line probe with sensors in tail fin

- Measuring flow signatures in front of screens and bypasses as fish sense it
- Combining knowledge on flow field, fish capacities and fish sensitivity to design functional bypass installations
Final remarks

• Upstream and downstream migration facilities are often not fully functional (differences between planning and implementation, attraction flow, complex hydraulics)

• Demand for deepened knowledge on hydraulics and related fish behaviour (flow fluctuations, flow signatures)

• Biological monitoring is a MUST but there’s also a need for tools and devices to enable hydraulic monitoring (economy!)

• Integration of measurements and modelling can provide an important support to satisfy these needs (better understanding, better design, better functionality)