Jun 27th, 3:10 PM - 3:30 PM

Concurrent Sessions D: Design and Performance of Roughened Channels - Response of a Non-Salmonid Fish to Boulder Density and Flow Discharge in an Experimental Pool-Type Fishway

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Does boulder density and flow discharge influence cyprinid fish performance in pool-type fishways?

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Fishways were mostly designed according to criteria developed in northern European rivers.

Specific fish assemblage composition, primarily dominated by large potamodromous and small resident cyprinid fishes.

- Weaker swimmers
- Migratory patterns less known
- Species afford legislative protection under EWFD
Previous hydraulics studies (e.g. Shamloo et al. 2001) demonstrated that boulder placement increase spatial hydraulic heterogeneity which may facilitate upstream fish movement performance.

**Nature-like fishways**

Boulder placement has been used with success in natural fishways to improve connectivity for fish

- *Resting areas for fish*

- *Creation of microchannels (interconnected low stress pathways) for fish movements*

**Pool-type fishways**?

Increasing interest has been expressed in the placement of boulders at the bottom of these facilities.

So far few studies have considered the effect of boulder placement on fish passage performance

Boulder height

Regime 1 (D/H > 4): the effect of the boulder is not felt at the surface, no mixing of flow occurs

Regime 2 (1.3 < D/H < 4): appearance of surface waves and occurrence of recirculation zones behind the boulder

Lower relative depths reduced fish transit time

Boulder density?

Can boulder density (i.e. spacing) and flow discharge influence cyprinid fish performance in pool-type fishways?
Experimental pool-type fishway

- Full scale (1:1)
- Slope: 8.5%
- Number of pools: 6
- Material: acrylic transparent glass panels
- Flume: 10 m long x 1.0 m wide x 1.2 m height
- Upstream tank (discharge control): 2.4 m³
- Downstream tank (fish acclimation): 36.0 m³

Target fish species: **Iberian barbel** (*Luciobarbus bocagei*)

- Large native cyprinid
- Potamodromous
- Sentinel species
Experimental Fish

1. Collection
- Capture by means of low-voltage (250V) electrofishing
- Only mature individuals
- Individuals showing injuries or parasites removed

2. Transportation
- Fish brought in large tanks featuring portable aerators

3. Maintenance
- Fish kept in holding 800L tanks for acclimation (min. 7 days)
- Water monitored, aerated and filtered (turnover rate: 200 L/day)
- Feeding (Tetra Pond) stopped 24 h before experimentation
Experimental Design

- 4 configurations based on Flow discharge (Q) and Boulder Density (BD)

<table>
<thead>
<tr>
<th>Configuration #</th>
<th>Flow Discharge</th>
<th>Boulder Density</th>
<th>d (cm)</th>
<th>$A_o$ (cm²)</th>
<th>$h_m$ (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High</td>
<td>High</td>
<td>84</td>
<td>529</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>Low</td>
<td>84</td>
<td>529</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>High</td>
<td>88</td>
<td>324</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>Low</td>
<td>Low</td>
<td>88</td>
<td>324</td>
<td>5</td>
</tr>
</tbody>
</table>

- Submerged orifices (offset) (0.23 x 0.23 m)*
- Surface notches closed (Santos et al. 2012*)

$d$- water depth; $A_o$- orifice area; $h_m$- water depth at mid-height of boulders

Characterization of hydraulic conditions

3C velocity measurements (ADV Vectrino)

- Horizontal plane
  - 5 cm
    - “mid-height of boulders”
  
- Water velocity
  
- Turbulence (Reynolds shear stress)*

Characterization of fish passage

Fish movements monitored by visual observations and video recording

- % of successful fish
  
- Time taken to negotiate the fishway

Pronounced velocity gradient under High Flow discharge, compared to Low Flow conditions

Similar velocity pattern between High/Low boulder density
Reynolds shear stress ($\tau_{xy}$)

- High density
  - High Flow
  - Low density
  
- Low Flow

Higher turbulence in the vicinity of the inlet orifice

Differences mainly flow-related
Wilcoxon match-paired tests comparing hydraulic differences among each factor (BD and Q)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Hydraulic parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$V_{xy}$</td>
</tr>
<tr>
<td>Boulder density effect (high vs low) with $Q_{\text{high}}$</td>
<td>ns</td>
</tr>
<tr>
<td>Boulder density effect (high vs low) with $Q_{\text{low}}$</td>
<td>ns</td>
</tr>
<tr>
<td>Flow effect (high vs low) with $BD_{\text{high}}$</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Flow effect (high vs low) with $BD_{\text{low}}^*$</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>
**Source of variation** | $P$
---|---
Boulder density (BD) | ns
Flow discharge (Q)* | $<0.05$
Boulder density (BD) * Flow discharge (Q) | ns

* significant with $\alpha = 0.05$

**Mann-Whitney tests on transit time for successful upstream passage**

- High Q
  - High BD (5.3±4.2 min.)
  - Low BD (12.1±6.5 min.)
- High BD
  - High Q: 50%
  - Low Q: 25%
- Low BD
  - High Q: 50%
  - Low Q: 25%
CONCLUSIONS

- Velocity and turbulence patterns differed according to \( Q \) but not to \( BD \).

- Fish passage varied according to \( Q \), which was the key-parameter influencing water velocity and Reynolds shear stress.

- Increased \( Q \) induced a higher proportion of successful negotiations.

- Although independent of \( BD \), a tighter configuration (higher \( BD \)) combined with higher \( Q \) can be beneficial for fish passage, as it was found to reduce transit time. However, if flow volume is a constraint, a low \( BD \) design should be employed instead.
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