Dec 12th, 11:00 AM - 12:40 PM

Adding auxiliary discharge into the entrance pool of a fishway: influence of pool design on fish passage

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German Federal Waterways Engineering and Research Institute (BAW)

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Adding auxiliary discharge into the entrance pool of a fishway: influence of pool design on fish passage

Cornelia Schuetz, German Federal Institute of Hydrology (BfG)
Rebekka Czerny, German Federal Waterways Engineering and Research Institute (BAW)
CHALLENGE
Basic hydraulic principles:

- few turbulences
- only moderate gradients of flow velocity
- ± homogeneous flow directions
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Design
- level ground area
- flow in fishway (v1) and auxiliary discharge (v2) run parallel to each other
Basic hydraulic principles:

- few turbulences
- only moderate gradients of flow velocity
- ± homogeneous flow directions

Design

- level ground area
- flow in fishway (v1) and auxiliary discharge (v2) run parallel to each other
- separate entrance pool (fish) from auxiliary discharge pool by horizontal bar screen
Basic hydraulic principles:

- few turbulences
- only moderate gradients of flow velocity
- ± homogeneous flow directions

Design

- level ground area
- flow in fishway ($v_1$) and auxiliary discharge ($v_2$) run parallel to each other
- separate entrance pool (fish) from auxiliary discharge pool by horizontal bar screen
- **Pool of auxiliary discharge** and **entrance pool** merge along the screen by expanding the entrance pool
Basic hydraulic principles:
• few turbulences
• only moderate gradients of flow velocity
• ± homogeneous flow directions

Design
• level ground area
• flow in fishway (v1) and auxiliary discharge (v2) run parallel to each other
• separate entrance pool (fish) from auxiliary discharge pool by horizontal bar screen
• Pool of auxiliary discharge and entrance pool merge along the screen by expanding the entrance pool
• uniform flow along the total screen surface by uniform flow in cross section A
QUESTIONS
Questions that were left:

**What is the best design velocity of the screen (= screen size)**

A more compact design
- is cheaper
- allows more opportunities in planning (restricted space)

but is it also better for fish passage?

![Diagram showing design velocities](image)

**Test:**

0.2 m/s - low design velocity (based on rheotactic behavior of adult cyprinids)

*versus*

0.4 m/s - high design velocity (based on rheotactic behavior of adult salmonids).
Questions that were left:

**Can we guide fish through the entrance pool?**

A slot from the upper fishway may guide fish through entrance pool and thus speed up the passage.

**Test:**
upper fishway without slot

*versus*

upper fishway with slot
STUDY
Open flume at the BAW, Karlsruhe:

- 2.5 m width
- 1.3 m high
- discharge 1m³/s
- altogether 60 m long
- experimental section ~ 12m long
In our experiment:

- **screen bars**: rectangular profile 12 mm x 60 mm; 15mm spacing

- **good results with fish ≥ 10 cm length (no smaller fish in the test)**
Five species
• relevant in German shipways
• different migration characteristics/demands
• pragmatic and legal considerations

<table>
<thead>
<tr>
<th></th>
<th>size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nase</strong></td>
<td>40 - 50 cm</td>
</tr>
<tr>
<td><em>Chondrostoma nasus</em> (Linnaeus, 1758)</td>
<td></td>
</tr>
<tr>
<td><strong>Gudgeon</strong></td>
<td>10 - 15 cm</td>
</tr>
<tr>
<td><em>Gobio gobio</em> (Linnaeus, 1758)</td>
<td></td>
</tr>
<tr>
<td><strong>Schneider</strong></td>
<td>10 - 15 cm</td>
</tr>
<tr>
<td><em>Alburnoides bipunctatus</em> (Bloch, 1782)</td>
<td></td>
</tr>
<tr>
<td><strong>Roach</strong></td>
<td>10 - 20 cm</td>
</tr>
<tr>
<td><em>Rutilus rutilus</em> (Linnaeus, 1758)</td>
<td></td>
</tr>
<tr>
<td><strong>Brown trout</strong></td>
<td>20 - 35 cm</td>
</tr>
<tr>
<td><em>Salmo fario</em> (Linnaeus, 1758)</td>
<td></td>
</tr>
</tbody>
</table>
Data:
times of fish crossing different lines

From staging area to line A:
max. 30 Minutes
otherwise:
non-valid fish

From line A to line D:
max. 1 hour
otherwise:
experiment ends
Results
Long screen (0.2m/s) vs. short screen (0.4 m/s)

Time-to-Event Analysis

Event "reaching line C": fish has passed the screen and found the the fishway

\[ S[t] = \text{probability of not finding the fishway} \] (at a given point in time)

- \( H_1 \): differs between long and short screen
- \( H_0 \): no difference between long and short screen
Long screen (0.2m/s) vs. short screen (0.4 m/s)

Results

Survival function $S[t]$ analyzed event: fish finds fishway (line C)

- Design velocity:
  - 0.2 m/s
  - 0.4 m/s

Observation period [s]

Log rank test p-value 0.76
Survival curves are statistically equivalent

→ We accept the null hypothesis

n = 246
All species, fishway with slot
**RESULTS**

Slot (flow velocity „impuls“) vs. no slot:

Comparison of Means
Kruskall-Wallis Test

Only Finisher at lines C and D

passage times of all Finishers [s]

- \( H_1 \): differs between slot and no slot
- \( H_0 \): no difference between slot and no slot
Slot (flow velocity „impuls“) vs. no slot:

Data pooled from both screen lengths, only Brown Trout and Schneider

Kruskal Wallis Test p-value > 0.3

→ We accept the null hypothesis
RESULTS

passage time: line C to D

![Graph showing passage time comparison between slot and no slot designs.](image)

- Design A
- Design D
- Design C

- Slot
- No slot

- Y-axis: sec
- X-axis: design (slot or no slot)
RESULTS

mean flow velocities $v_r$ [m/s] - 40cm above ground

- slot
  - short screen
  - long screen
- no slot
  - short screen
  - long screen

hydraulics from slot influence fish behavior:
passage delayed
→ both screen lengths (long - 0.2m/s and short - 0.4 m/s) are similar regarding the probability of successful passage

Planning recommendation:
Use the geometrical advantages of a smaller screen.

→ a slot makes no significant difference for the passage time of fish along the screen

Planning recommendation:
The slot influences fish behavior - therefore hydraulics from a slot and from the auxiliary discharge should not interfere with each other (keep a minimum distance of first fishway slot to entrance pool)

→ fish react to the hydraulics of a slot (slow down)
How was the performance of the now recommended pool design?
How was the performance of the now recommended pool design (line A to C)?

<table>
<thead>
<tr>
<th>non valid fish</th>
<th>N</th>
<th>Finisher line C</th>
<th>Median time [min:sec]</th>
<th>Passage „speed“ [m/sec]</th>
<th>IQR time [sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.6% all species</td>
<td>171</td>
<td>87%</td>
<td>03:29</td>
<td>0.031</td>
<td>725</td>
</tr>
<tr>
<td>0% Nase</td>
<td>27</td>
<td>93%</td>
<td>00:11</td>
<td>0.590</td>
<td>14</td>
</tr>
<tr>
<td>22.2% Gudgeon</td>
<td>21</td>
<td>67%</td>
<td>12:02</td>
<td>0.009</td>
<td>402</td>
</tr>
<tr>
<td>3.6% Schneider</td>
<td>52</td>
<td>96%</td>
<td>07:55</td>
<td>0.013</td>
<td>797</td>
</tr>
<tr>
<td>62.6% Roach</td>
<td>22</td>
<td>64%</td>
<td>04:40</td>
<td>0.023</td>
<td>148</td>
</tr>
<tr>
<td>13.3% Brown Trout</td>
<td>52</td>
<td>92%</td>
<td>02:28</td>
<td>0.044</td>
<td>683</td>
</tr>
</tbody>
</table>

Finisher rate ≠ passage rate in nature!

Influence on Finisher rates of the different species:

- Artificial situation in the flume: full light, no structures/roughness....
- Artificial holding conditions: holding tanks with tap-water, fish handling....
- definition of valid fish
- Motivation to migrate, to explore....
Other designs may work as well, but we can only recommend designs where we have evidence of good function.

$$v_2 \leq 0.8 \text{m/s}$$

$$v_1 \leq 0.4 \text{m/s}$$

Screen angle $$\alpha \leq 30^\circ$$
Thank you for your attention!

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... and was only possible through the help of Matthias Pitsch, Julia Walbrühl, Steffen Wieland, Wilko Heimann, Marcus Herbst, Patrick Heneka, Jochen Eckhardt, Arne Rüter, Bernd Mockenhaupt, Matthias Scholten, Roman Weichert, Heiko Leuchs, Wolfgang Kampke, Tamara Bös and others ......!

of the German Federal Institute of Hydrology
and the
German Federal Waterways Engineering and Research Institute

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