German experience in restoration of longitudinal continuity of large rivers

Regional Conference on River habitat restoration for inland fisheries in the Danube River Basin and adjacent Black Sea areas

Marq Redeker

14.11.2018
Brief history of fishways in Germany

- Fish passes have been installed worldwide at migration obstacles and natural barriers for over 300 years, and
- in German rivers for more than 130 years

Fish passes at Bremen Weir, Weser River
2 pool-type passes, 1 fish lock, and 2 eel passes
Figures: Kölle (1918)
Brief history of fishways in Germany

- Historically, fishway engineering focused on high-value and high-performance species, e.g. Atlantic salmon, brown trout/sea trout and shad.
- Conditions in these “traditional” fishways are unsuitable for many potamodromous species, incl. small or weak-swimming fishes.
- These fishway designs generally do not provide passage for a wide spectrum of species.

Pool-type fish pass Mülheim-Raffelberg, Ruhr River in 1920
Photo: Ruhrfischereigenossenschaft
History of fishways in Germany

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Detergent foam in Rhine River in Duisburg
Photo: Ruhrverband

Catch of Atlantic Salmon in Weser River

Early to mid 20th century river pollution & river works

Figure: Landesfischereiverband Niedersachsen

Detergent foam in Rhine River in Duisburg
Photo: Ruhrverband
River quality improvements from 1960/1970s

1988: Germany’s Environment Minister Klaus Töpfer swims in the Rhine River

Wickede WWTP in the 1960s

Photo: Ruhrverband
Fishways „revival“ from 1980s

Rock ramp fishway at Buisdorf Weir, Sieg River built 1989
Photo: Städtler
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Sandoz chemical spill 1986 & Salmon 2000 program
German fish pass best practice

- German Association for Water (DWA, formerly DVWK) develops technical guidelines and standards (besides DIN)
- 1996: DVWK-M 232 “Fish passes - Design, Dimensions and Monitoring” (translated into English by FAO in 2002, and 7 other languages)
- 2005: Guidelines “Fish Protection Technologies and Downstream Fishways - Dimensioning, Design, Effectiveness Inspection”
- 2014: Standard DWA-M 509 „Upstream Fishways and Hydraulic Structures Passable for Fish“ ⇒ replaces the 1996 guidelines (English translation in progress)
(Upstream) Fish Pass best practice

Project

Passage
• Migration corridor
• Geometry: water depth, channel/ pool size, slots/ orifices
• Hydraulics: flow velocity, turbulence

Operation time
• ≥ 300 days/yr (between Q_{30}/W_{30} and Q_{330}/W_{330})
• 24/7

and site-specific

Attraction
• Large-scale location
• Entrance position
• Attraction flow: volume/ flow impulse, angle, flow velocity

conditions

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Photo: FWT
Fish Pass best practice – passage

Fish pass geometry to accommodate adult fish of the largest prevailing or target species

Typical pool dimensions of Vertical Slot Fishways (DWA-M 509)

<table>
<thead>
<tr>
<th>Fish species</th>
<th>Pool dimensions (m)</th>
<th>Slot (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length</td>
<td>Width</td>
</tr>
<tr>
<td>Brown Trout</td>
<td>1,95$^{(1)}$</td>
<td>1,50</td>
</tr>
<tr>
<td>Grayling, Chub, Roach</td>
<td>2,45$^{(3)}$</td>
<td>1,85</td>
</tr>
<tr>
<td>Barbel, Pike-Perch, Sea Trout</td>
<td>2,45$^{(3)}$</td>
<td>1,85</td>
</tr>
<tr>
<td>Salmon, Hucho, Pike</td>
<td>3,00$^{(2)}$</td>
<td>2,25</td>
</tr>
<tr>
<td>Bream, Carp</td>
<td>3,25$^{(3)}$</td>
<td>2,45</td>
</tr>
<tr>
<td>Sturgeon</td>
<td>9,00$^{(3)}$</td>
<td>6,75</td>
</tr>
</tbody>
</table>
Fish Pass best practice – passage

- Ethohydraulic tests in Karlsruhe University Lab (1)
  (Videos: Prof. Lehmann)

Swimming performance in a Vertical Slot fishway $\Delta h = 10$ cm ($v_{\text{max}} = 1.4$ m/s)

*River trout (Salmo trutta)*  
*Bester (Sturgeon hybrid)*
Fish Pass best practice – passage

- Ethohydraulic tests in Karlsruhe University Lab (2)
  (Videos: Prof. Lehmann)

Swimming performance in a Vertical Slot fishway $\Delta h = 10$ cm ($v_{\text{max}} = 1.4 \text{ m/s}$)

*Ide (Leuciscus idus)*
Fish Pass best practice – passage

Fish pass hydraulics to suit the weakest swimming prevailing or target species

Threshold values for max. flow velocity in pool-type fishways (DWA-M 509)
State-of-the-art pool-type pass (for coarse fish)

Head = 7.80 m
Q = 700 l/s (+ 500 l/s bypass if river flow > 120 m³/s)
375 m with 57 pools
P < 125 W/m³
Δh per baffle < 13 cm
Costs: 950,000 €
State-of-the-art pool-type pass (for Sturgeon)

**Geesthacht Fish Pass**
Elbe River
Photo: Vattenfall

**Information on fish pass**
- Fish passes: Paired vertical slot fishway
- Length: 550 m
- Pools & dimensions: 49 pools, LxW = 9x16 m, water depth >1.7 m
- Drop per pool: max. 9 cm
- Slots: 2 x 1.2 m wide
- Discharge: 4.5 m³/s plus max. 3.65 m³/s additional bypass flow
- Remarks: Fishway is being monitored 24/7 for a minimum of 5 years. Quantitatively monitoring results can be obtained from Vattenfall and Germany.

Photo: Redeker

Photo: IfÖ

Photo: IfÖ

Photo: Redeker

Photo: IfÖ

Photo: Vattenfall
Fish passage restoration in German rivers

- Estimated **200,000 barriers in German rivers** (average distance of 1.8 and 4.7 km between barriers)
- **7,300 hydropower plants** (401 large HPP >1 MW)
- Only ~**10% of the upstream passage restoration measures have been completed** in first cycle of the EU WFD implementation, whereas ~**40% have not yet started** (Source: German Environment Agency - UBA)
Fish passage restoration in large German rivers

- All large (navigable) rivers in Germany are owned and managed by the Federal Waterways and Shipping Administration (WSV)
- WSV network of inland waterways:
  - 7,290 km
  - includes 253 sizeable barriers
- WSV responsible for fish passage restoration since 2010
- Nationwide Implementation Strategy in 2010 categorized fish passage restoration measures according to the WFD cycles
  - ~1 billion € investment program
Fish passage restoration in large German rivers

- **Plan was** ... **45 fish pass** projects should start construction or be completed before 2015
- Until now of these 45 fish pass projects ... (Messing, 2018)
  - 8 fishways have been constructed (1 by WSV, 7 by third parties)
  - 1 fishway is currently being built
  - 6 large pilot facilities are being designed
  - 21 other fish passes are still being designed by WSV (5 projects are undergoing planning approval)
  - 7 projects undergoing design are managed by State Authorities
  - 4 projects have been halted & 7 others are at risk of being stopped

**Reasons for delay** incl. lack of staff, projects complexity, difficult negotiations with stakeholders, extra services (e.g. modelling) ...
Fish passage restoration in large German rivers

Fish Pass Koblenz
Moselle River
Head = 6 m
Flow = 0.9 + 4.5 m³/s
Photos: Redeker
Fish passage restoration in large German rivers

Rheinfelden HPP
Rhine River (Border Germany - Switzerland)
Photo: Energiedienst

3 Fishways

Photo: FWT
Fish passage restoration in large (German) rivers

Fish Pass Gamsheim
Rhine River (Border France - Germany)
Head = 11 m
Length = 290 m
39 pools (13 m³ each)
Q = 1.2 m³/s + 13.8 m³/s by SHPP

Photo: www.aufildurhin.com

Photo: ZT-Tiefbau

Photo: Redeker
Fish passage restoration in large German rivers

- 6 WSV pilot fish pass facilities (all in design stage)
  - highest priority projects
  - will serve to scientifically study specific aspects of fish pass attraction and passage for 5+ yrs, e.g.
    - positioning of entrances
    - attraction flow volume and velocity
    - assess fish swimming behaviour in fish pass

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Fish passage restoration in large German rivers

- Hydraulic and ethohydraulic research
  - at German Universities
  - at WSV’s own scientific institutions BAW & BfG

Physical modelling and ethohydraulic investigations of new fish pass entrance concept with auxiliary attraction flow at BAW hydraulic laboratory

Photos: Heimerl

Photo: Redeker

Photo: BfG

German experience in restoration of longitudinal continuity of large rivers
Status quo on fish protection & downstream passage

- **Fish protection regulations in all 16 States fisheries acts**
  - 9 States prescribe fine screen spacing 10-20 mm
  - Regulations mostly applied to SHPP (<5 MW)
  - Not enforced at HPPs with existing licences, only with renewals

- **Mostly physical screens**
  - Screens (12-20 mm spacing) at SHPP (< ~30 m³/s) mainly for Salmon smolts and Silver eels
  - Vertical (inclined to bottom) or horizontal (inclined to flow) bars, depending on bypass placement

- **Management systems in operation**
  - Trap & transport, e.g. on Moselle River for eels
  - Adapted turbine management combined with early warning systems, e.g. Migromat (e.g. Main and Fulda Rivers)
Status quo on fish protection & downstream passage

- Downstream passage & fish protection has been a very contentious subject for last 20+ yrs.
- German Environment Agency initiated the Forum Fish Protection and Downstream Passage (https://forum-fischschutz.de/) for stakeholders to
  - develop a common & nationwide consistent understanding of the issue
  - draw together requirements and solutions to establish and preserve fish populations based on the current state-of-the-art and knowledge
- Topics of forum:
  - Environmental policy framework
  - Strategic and river basin related aspects
  - Technical measures and facilities for fish protection and downstream fishways
  - Applied population and behavioral biology
  - Efficiency and monitoring of measures and facilities for fish protection and downstream passage
- 1st cycle from 2012 - 2014 (⇒ Status quo report & outlook)
  2nd cycle from 2015 - 2018 (⇒ Exchange and R&D coordination)
Challenges of upstream passage restoration in large rivers

Double Vertical Slot Fishway designed acc. to DWA-M 509
- 112 pools
- length = 1.03 km
- pools: 9 x 13.50 m (LxW)
- 2 slots 1.20 m wide
- drop: 9 cm per baffle
- $v_{\text{max}}$: 1.35 m/s
- design flow: 7.50 m³/s
- 3 entrances in tailwater
  (at turbine outflow/ turbulent zone, below turbulent zone, in calm river bank zone)

Auxiliary attraction flow
- $Q_{\text{max}}$ ~45 m³/s provided by SHPP
  ($P_{\text{el}}$ ~3 MW, Output ~ 25,500 MWh)
- attraction flow: 30 - 53 m³/s
  (= 3x 10 - 17.5 m³/s per entrance depending on downstream water level)
- attraction flow velocity:
  0.8 - 1.0 m/s at entrance
Challenges of upstream passage restoration in large rivers

Fish lift
- footprint: 43 x 20 m (LxW)
- lift height: 30+ m
- hopper dimensions: 7 x 9 m, V ~100 m³
- collection channel with crowding device and auxiliary flow supply system

Iron Gates Dams Prefeasibility Study
Iron Gates I, Option (Romanian side)
de Bruijne & Redeker et al. (2014)

HPP design flow = 10,080 m³/s
Head = 20 - 28 m

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Challenges – summary of experiences in fish passage restoration in large rivers

- River-/catchment-wide implementation strategy recommended
  - prioritize sequence of measures, e.g. with regards to suitable upstream habitat
  - realistic, i.e. incl. staffing, funding, stakeholder commitment ...
  - program management with PMO: coordination, administration, controlling and consultation

- Fish pass guidelines are available for multi-species fish passes (potamodromous & diadromous fishes). Design philosophy can be adopted to species requirements in Danube River Basin & Black Sea areas.

- Limited design criteria available for fishways for Acipenseridae (mostly for pool-type fishways; little criteria exists for fish locks & lifts). Every barrier needs an adapted solution. Fishways need special components to function.

- Fish passage restoration in large rivers is extremely complex and design must be carried out by multi-disciplinary experts.

- Downstream protection & passage represents major challenge at large HPP! If at all, only possible for certain target species/sizes and very costly.

- **We have no time to lose!** Acipenseridae are decreasing/critically endangered – some already extinct in DRB.

- Large fishways for Acipenseridae demand special project management, likely a staged strategy & flexible design, and may need trial & error approach.
Good luck and I’m happy to assist

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