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Ethohydraulic Investigations in a Water Vortex Power Plant (VPP)

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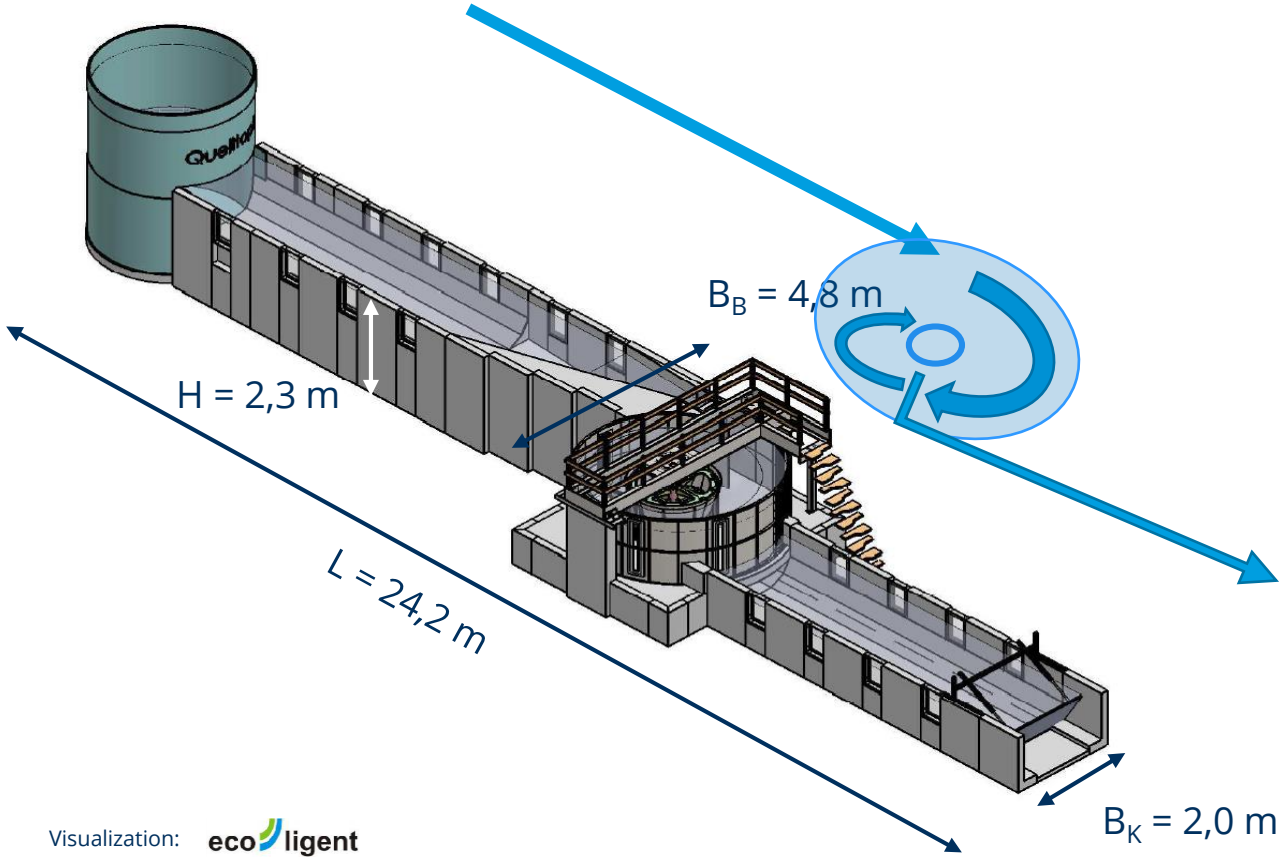
HYDROPOWER SUMMIT 2020
Breakout Session „Environmental Conditions“
February 05 - Trondheim, Norway

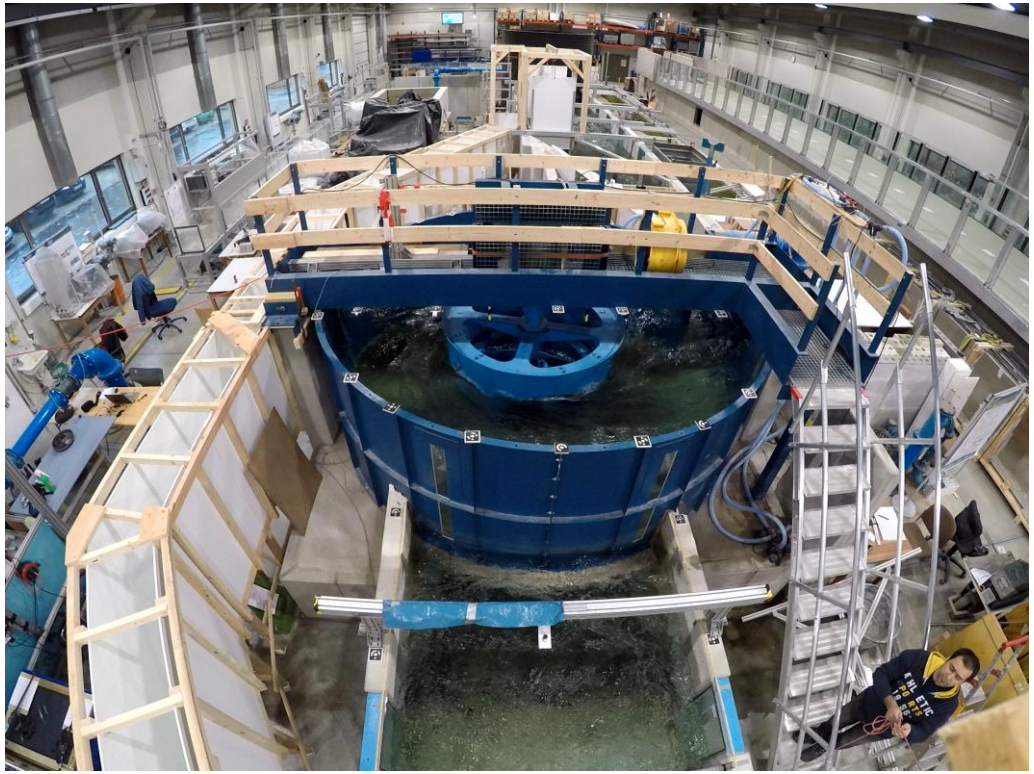
Outline

- Water Vortex Power Plant – Test Site
- Ethohydraulic Investigations
- Conclusions and Outlook

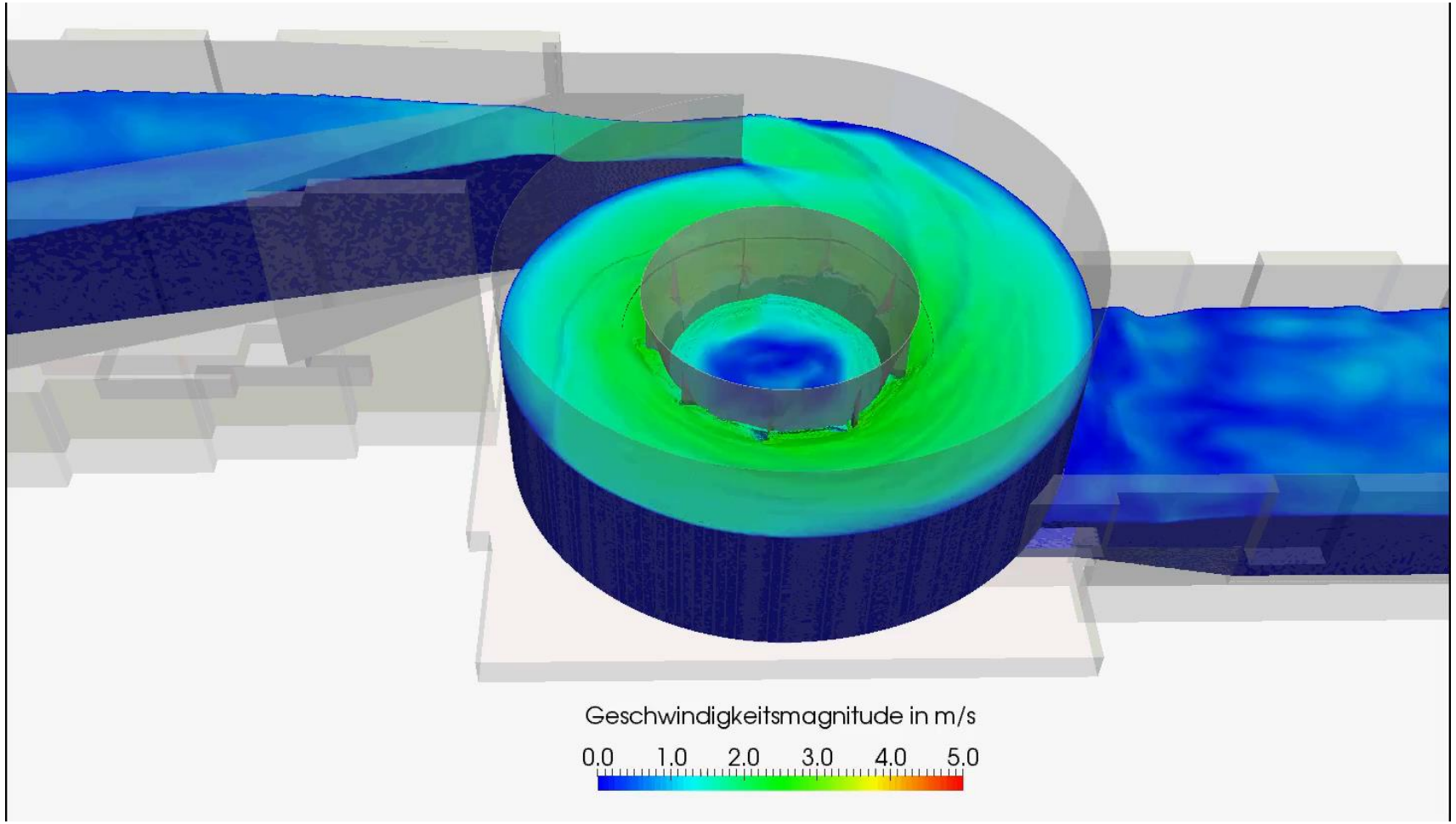
Experimental Setup of Water Vortex Power Plant (VPP)



Visualization: eco ligent



Numerical Simulation
OpenFoam



Ethohydraulic investigations

- Objective: **Analysis of migration behaviour (ascent & descent) of life fish through the turbine**
- **1:1 laboratory model** for ethohydraulic investigations
- **VPP:** 9 blades, **Q_{max} = 710 l/s, n = 24 rpm,** $\Delta h \cong 1$ m

Minnows attempting to ascent to the upper channel at 700 l/s and 27 rpm

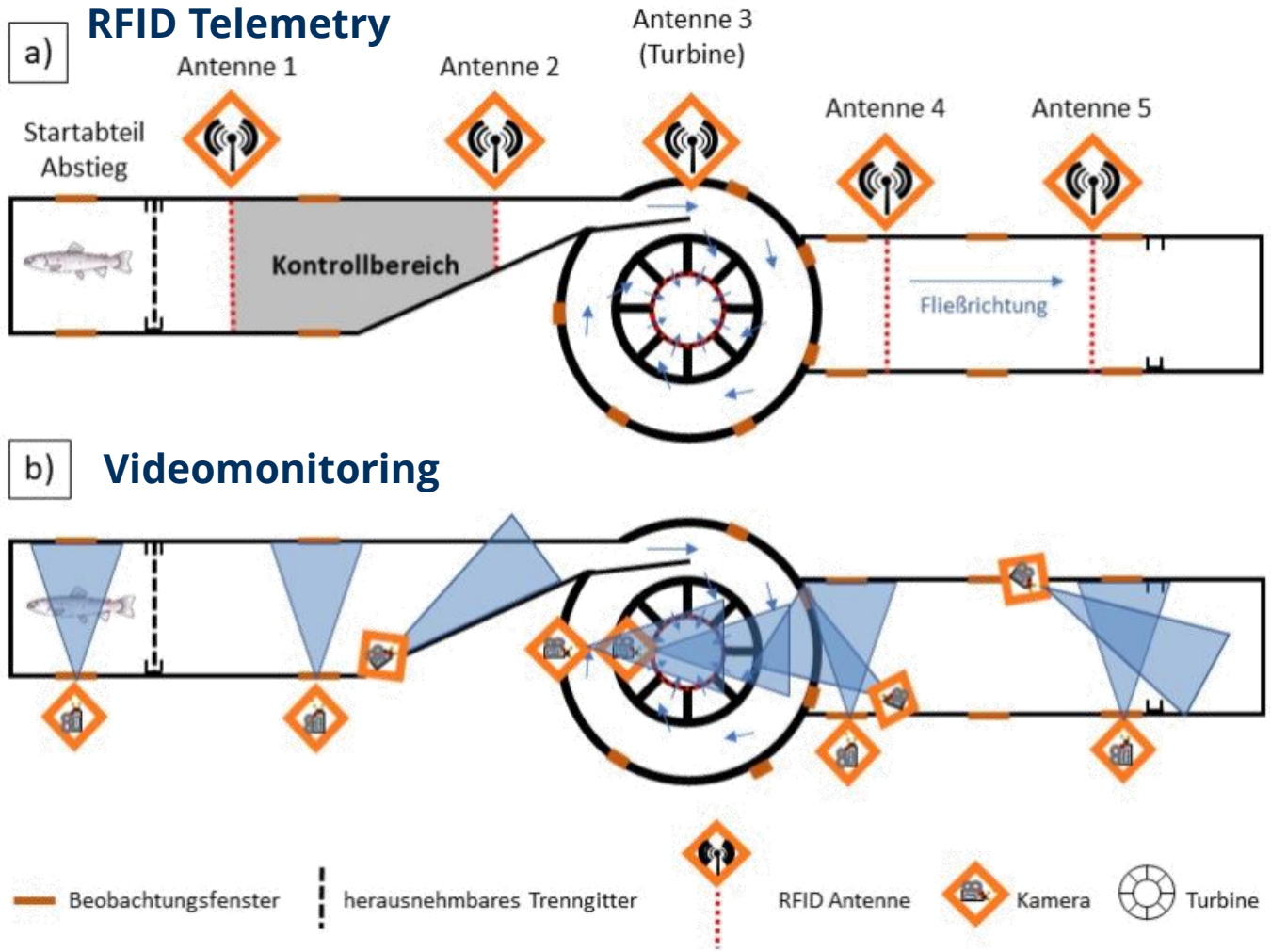
Video: UvGU Magdeburg, ISUT (Cleynen)

Trout attempting to descend through the VPP at 700 l/s and 27 rpm

Ethohydraulic Investigation

Life fish tests require detailed preliminary planning, careful application and controlling during experiments

- Special **fish keeping facility**
- **RFID Telemetry** / RFID antennas
- **Coordination of fish experiments** with other tests/duties in the hydraulic test lab,
  - suspending construction work → avoiding noise and vibrations
  - refilling and cleaning the accumulator before the fish tests
  - constant control and regulation of water temperature (+ 0.5 K/hour)
  - (chemical) water quality
- special fish **protection rakes** needed



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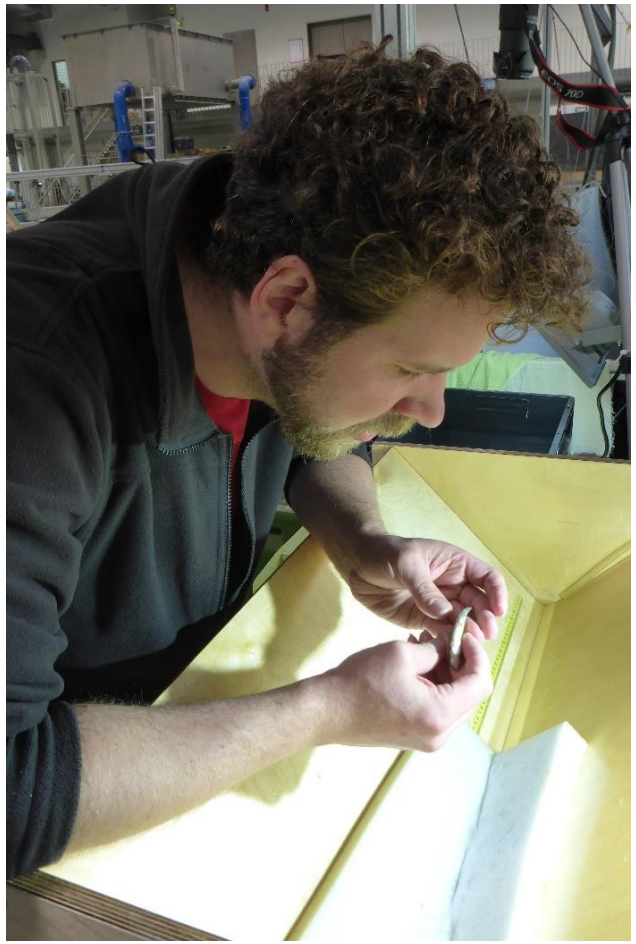
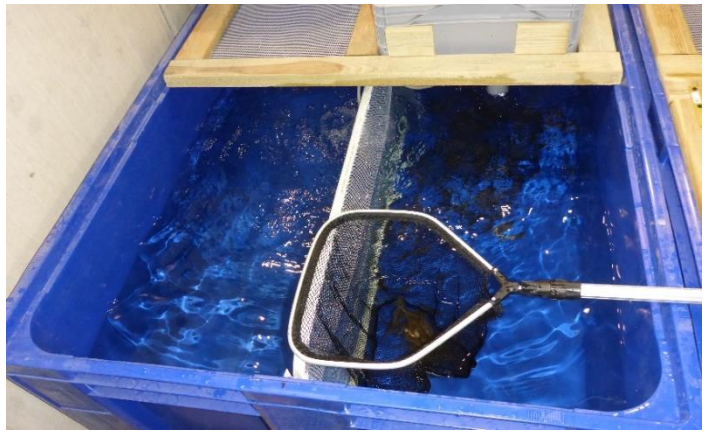
- **Cooperation with ichtyologists indispensable**





Ethohydraulic Investigation

- **Seasonal motivation** of upstream or downstream migration depending on fish species
- Testing of **6 fish species** representing the whole range of ecological guilds **typical for trout and grayling region**

		Jan.	Feb.	März	April	Mai	Juni	Juli	Aug.	Sep.	Oktober	November	Dezember
Eel	**Aal**											Abstieg	Abstieg
Trout	**Bachforelle**			Abstieg	Abstieg						Aufstieg	Aufstieg	
Minnow	**Elritze**				Aufstieg	Aufstieg	Aufstieg						
Gudgeon	**Gründling**					Aufstieg	Auf-/Abstieg	Abstieg					
Roach	**Rotauge**				Aufstieg	Auf-/Abstieg	Abstieg	Abstieg					
Loach	**Schmerle**			Aufstieg	Aufstieg	Aufstieg							

Aufstieg = Ascend

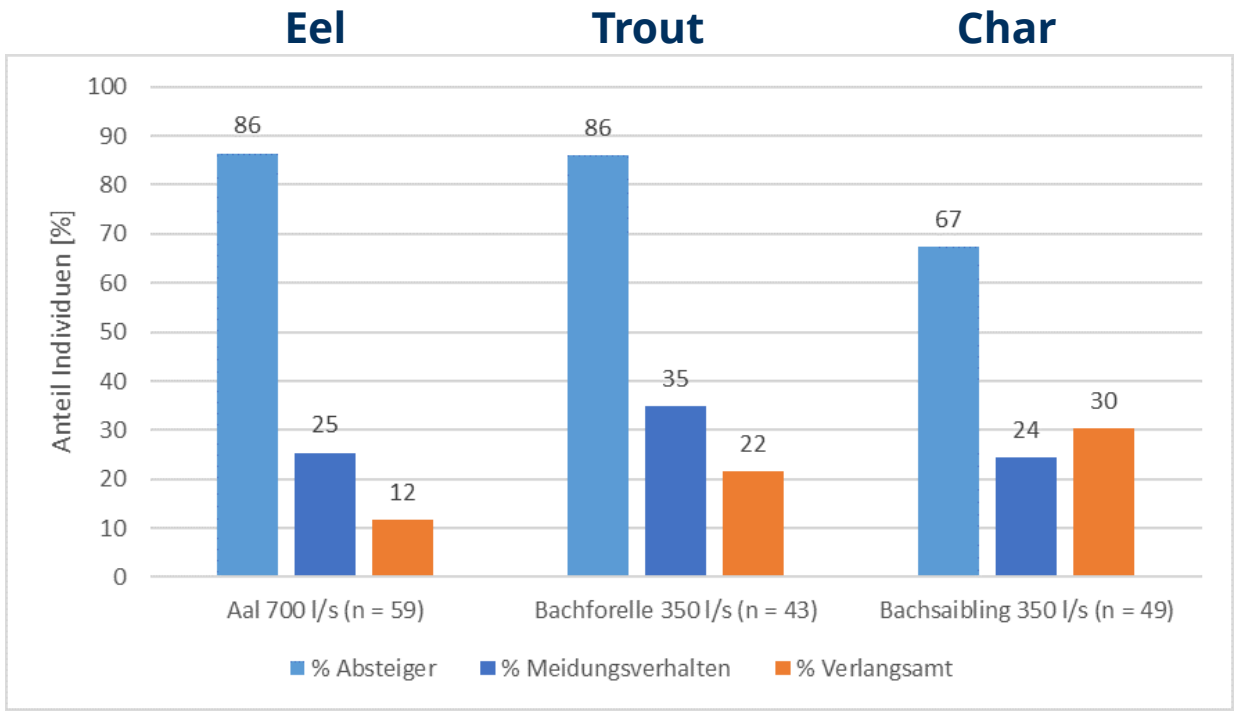
Abstieg = Descend

+ extra tests: Char

Ethohydraulic Investigation

- **Seasonal motivation** of upstream or downstream migration depending on fish species
- Testing of **6 fish species** representing the whole range of ecological guilds **typical for trout and grayling region**

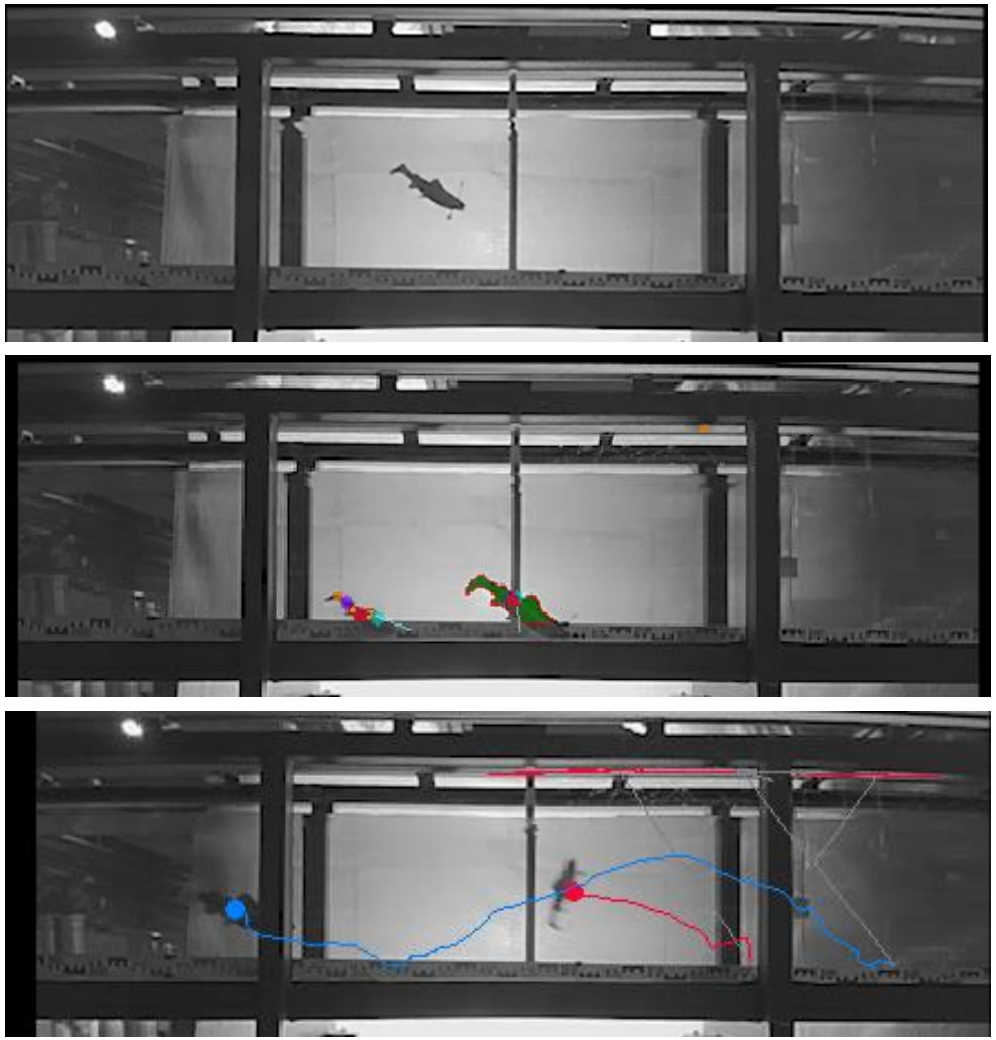
- High motivation for **downstream passage**
- **86 % of Eel and Trout** passed the turbine (extra tests with Char: 67 %)
- Tendency for avoiding passage observed for all species → **reduction of migration speed**
- very few cases (Trout, Roach) for **upstream passage → problematic**
- **no** immediate or retarded (48h) **mortality** (valid for all species) → **rarely (minor) injuries** through downstream passage



Conclusions and Outlook

- **Fish can cope with** velocities and turbulences in **VPP** (**downstream** passage)
- No or minor damage by downstream migration due to beneficial velocity distribution in VPP (**relative tangential & radial velocities** to rotating blades **matter**)
- **Upstream** migration **not as successful**
- **Life fish tests are very challenging** → numerous drawbacks for laboratory operation → **Alternatives???**

- **Project: „RETERO“** (www.retero.org) → **Robo-Fish** („Reduction of live fish testing through science and technology”)
- Start in 2020
- comparison of available **fish tracking technologies** (ETH Zurich, Noldus, …) → **Recommendations?**



Thank you for your attention!

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Choice of fish type:

eel (weak, big, sensitive)

trout (strong, big, robsut)

minnow (strong, small, sens.)

gudgeon

roach

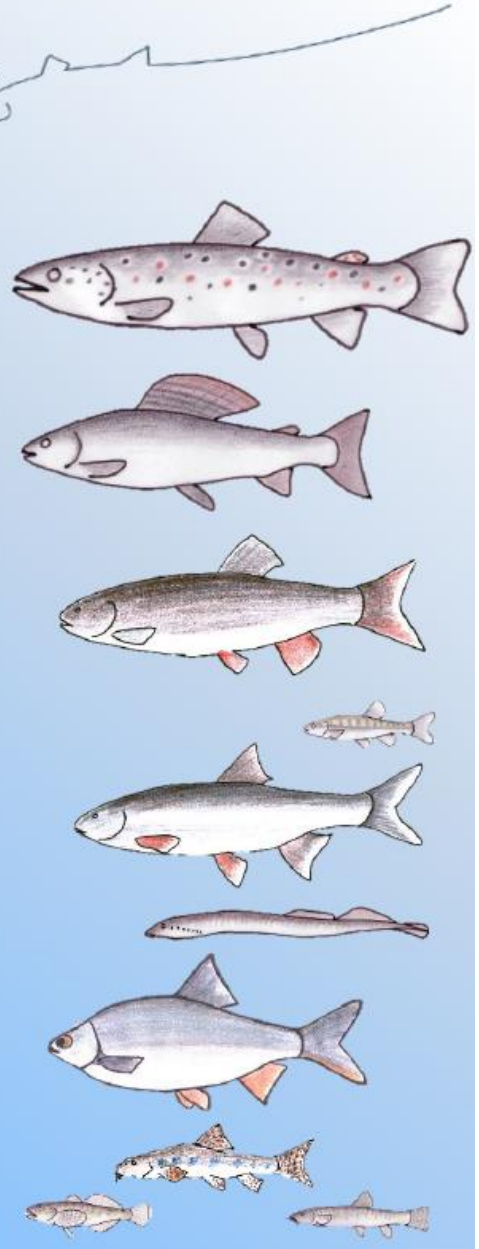
loach (weak, small, robust)

Spectrum of species in a typical grayling area:

Art	Schwimmhorizont	Schwimmleistung	Körpergröße	Kategorie	Empfindlichkeit
Aal	sohlorientiert	schwach	groß	1	sensitiv
Äsche	Freiwasser	stark	groß	2	sensitiv
Bachforelle	Freiwasser	stark	groß	2	robust
Bachneunauge	sohlorientiert	schwach	klein	6	robust
Döbel	Freiwasser	stark	groß	2	robust
Dreistachliger Stichling	sohlorientiert	schwach	klein	6	robust
Elritze	Freiwasser	stark	klein	3	sensitiv
Flussneunauge	sohlorientiert	stark	groß	4	nicht relevant
Groppe	sohlorientiert	schwach	klein	6	robust
Gründling	sohlorientiert	stark	klein	4	sensitiv
Hasel	Freiwasser	stark	groß	2	sensitiv
Huchen	Freiwasser	stark	groß	2	robust
Lachs	Freiwasser	stark	groß	2	robust
Meerforelle	Freiwasser	stark	groß	2	robust
Plötze	Freiwasser	schwach	groß	5	sensitiv
Quappe	sohlorientiert	schwach	groß	1	robust
Schmerle	sohlorientiert	schwach	klein	6	robust
Schneider	Freiwasser	stark	klein	3	sensitiv

Relevant for ascent descent

- 6 relevant species for typical grayling habitat



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Ethohydraulic Investigation

Tracker Attached to Fish

Pictures Taken During Ongoing Fish Tests

Brown Trout During a Test on 08.11.2018

Observing the Fish After Tests

Results

- **Seasonal motivation** of upstream or downstream migration depending on fish species
- Testing of 6 fish species representing the whole range of ecological guilds typical for trout and grayling region

Art	Durchfluss	Probanden	Aktive	Turbinenauslass	Aufsteiger
minnow	360	40	40	11	0
gudgeon	400	49	39	12	0
roach	420	60	57	18	2
loach	400	36	26	11	0
Gesamtergebnis		185	162	52	2




Ethohydraulic Investigation Results

Upstream (ascent) tests in the Autumn

- A minimum of 25% and **max. 50% of trout passed through** the turbine and entered the vortex basin
- About 10 fish swam into the fish trap and then decended into the lower channel again using a slide.
- The **fish were still healthy** after the experiments and were returned to their original waterbodies.

Downstream (descent) tests:

- After passing through the turbine, **no serious injuries** were incurred by the fish

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Conclusion and Next Steps

- 1:1 laboratory model sucecssfully built and instrumented with needed sensors
- Laboratory requirements for conducting the fish requirements were met
- Measurements were extensively collected and evaluations were run
- Implementation of comparative 3D-CFD simulations (OpenFoam) to extend the meaningfulness of the laboratory measurments
- **Fish decent was successful. Fish ascent was only successful for brown trout** and partially successful for roach fish.
- Detailed examination of critical point for fish ascent, e.g. by evaulating the flow fluctuations (turbulence)
- Electricity production has to be increased by further optimization of the turbine and operating system.