

A New, Non-invasive Fish Backpack Biologger to Measure the Physical Conditions Experienced by Swimming Fish during Downstream Passage

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5



7



1



3



6



2



4



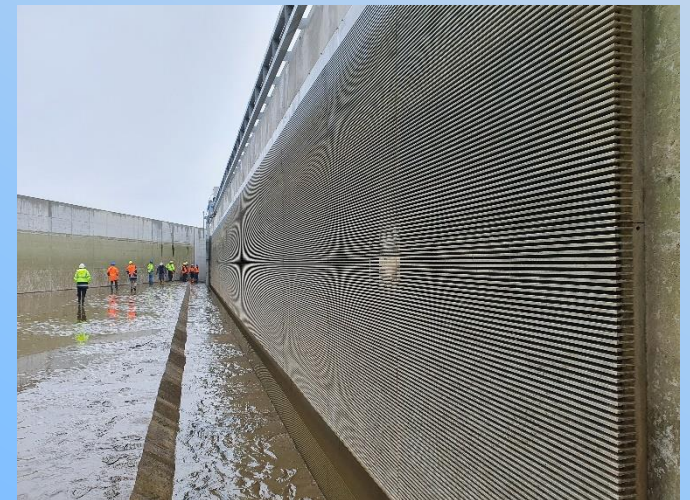
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- Increasing Efforts to Develop “Fish Friendly” Technologies in HPP
Main Strategies
 - Turbine Management
 - Improved and New Turbine Types
 - Fish Protection Devices in Combination with Bypasses
- Increasing Number of Studies on HPP Sites to Proof “Fish Friendliness”
- Life Fish (Injection) Experiments with Potentially High Risk of Severe Injuries and Stress
- Increasing Number of Fish for Field Studies in the European Union
 - 2017: 720,000 Fish for Experiments
 - 2018: 1.7 Mio. Fish for Experiments



VLH Turbine HPP Baierbrunn
Source: Landeskraftwerke Bayern



Fishprotection Screen Mulde River

Goal: Methods to Reduce the Number of Fish Necessary for Fish Mortality Studies at HPP

In Accordance with the „3-Rs Principle“ (RUSSELL & BURCH 1960)

Refinement/Reduction

Tool 3

ACTIVE

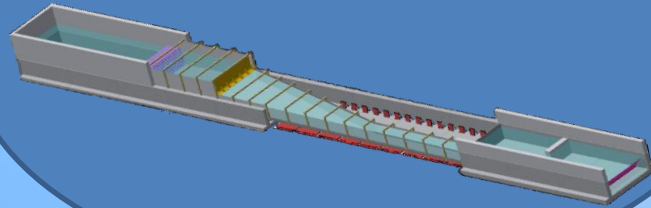
BACKPACK SENSORS

Fish Driven



Sensor Optimization

Ethohydraulic Studies (Turbine Inlet Model)



Physical Data
Behavior Data
Health Data

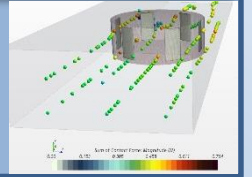
Behavior Rules

Tool 1

ACTIVE

NUMERICAL MODELS

CFD –Active Particles



Tool 2

ACTIVE

ROBOFISH

Fish Model: Rheotaxis, Swimming



Application in Real HPP

Physical Data/Behavior Data

Application in Real HPP



Why Active Fish?

- Fish Behavior Influences Blade Strike Probability and Thus Mortality Rates (COUTANT & WHITNEY 2000; VOWLES et al. 2014; GEIGER et al. 2020)
- Fish React on Hydraulic Stimuli, e.g. Accelerating Flow (PAVLOV & TJURJUKOV 1995; Haro et al. 1998; ENDERS et al. 2009, 2012; VOWLES & KEMP 2012; VOWLES et al. 2014)

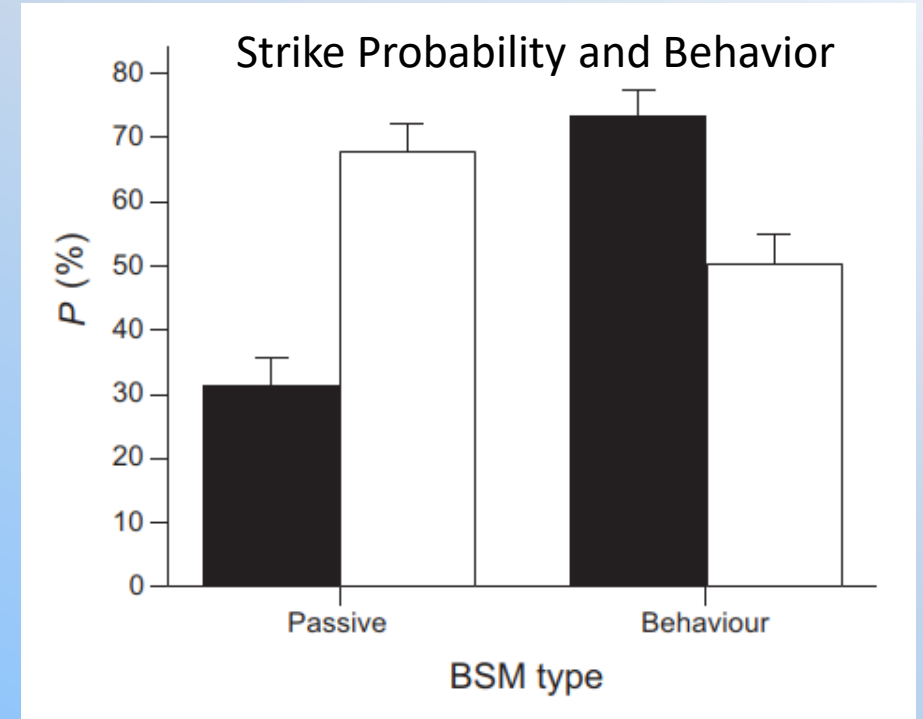


Fig. 5. Probability of strike (P) for trout (black bars) and eel (clear bars) when passively drifting through a HPW while perpendicular to the flow (Passive BSM), and when OL_{fish} and OV_{fish} values were incorporated into the model (Behaviour BSM). Errors bars are +1 SD. Source: VOWLES et al. 2014

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- Passive Sensors Provide Valuable Data from Inside Turbine Conditions and Alternative Passageways (CARLSON et al. 2003; Deng et al. 2007; DENG et al. 2014; Boys et al. 2013; Boys et al. 2018; PAUWELS et al. 2020)

BUT

- Passive Sensors Pass Turbine Randomly - Fish Probably Prefer or Avoid Paths and Accelerate or Decelerate

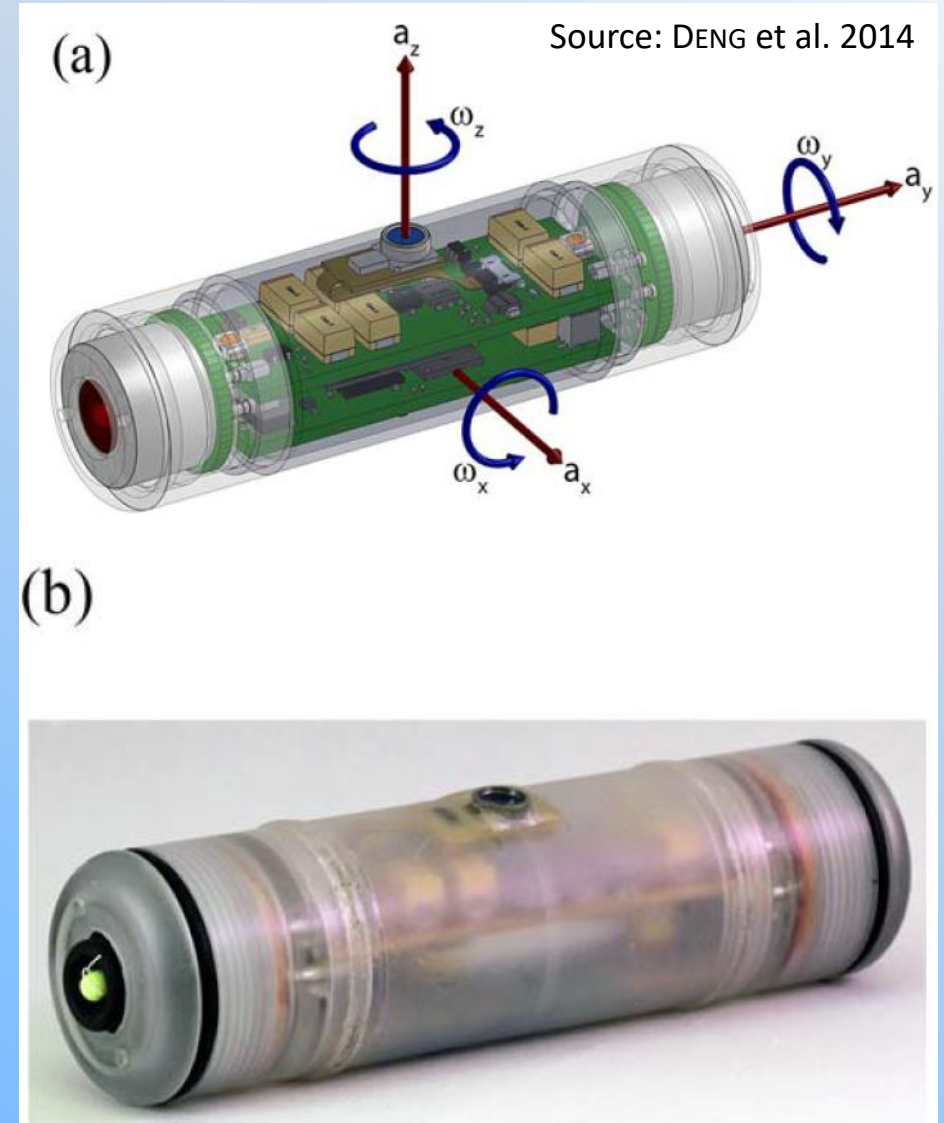
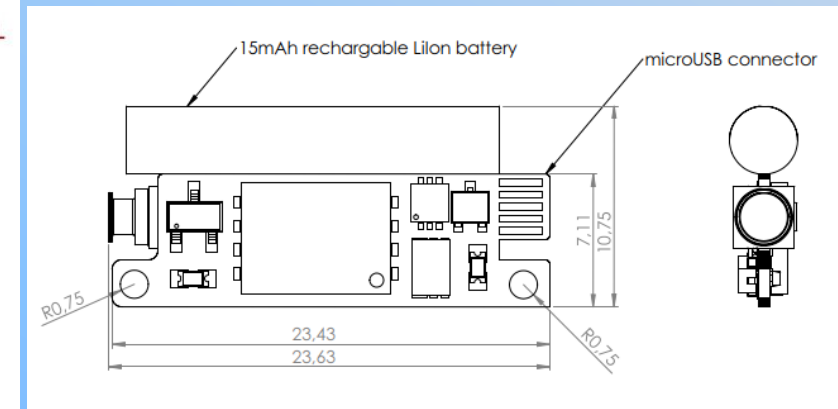
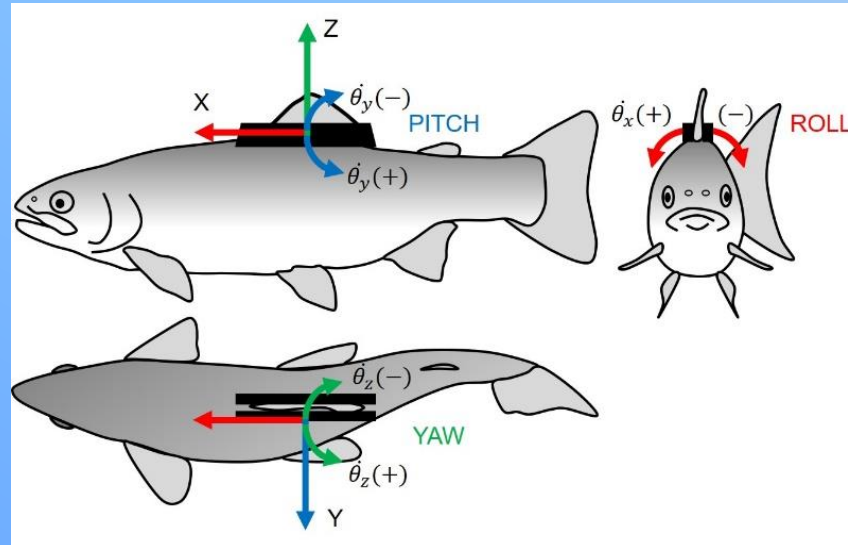


FIG. 1. The Gen 2 Sensor Fish device: (a) CAD model and (b) photo.

▶ Backpack Sensor Design

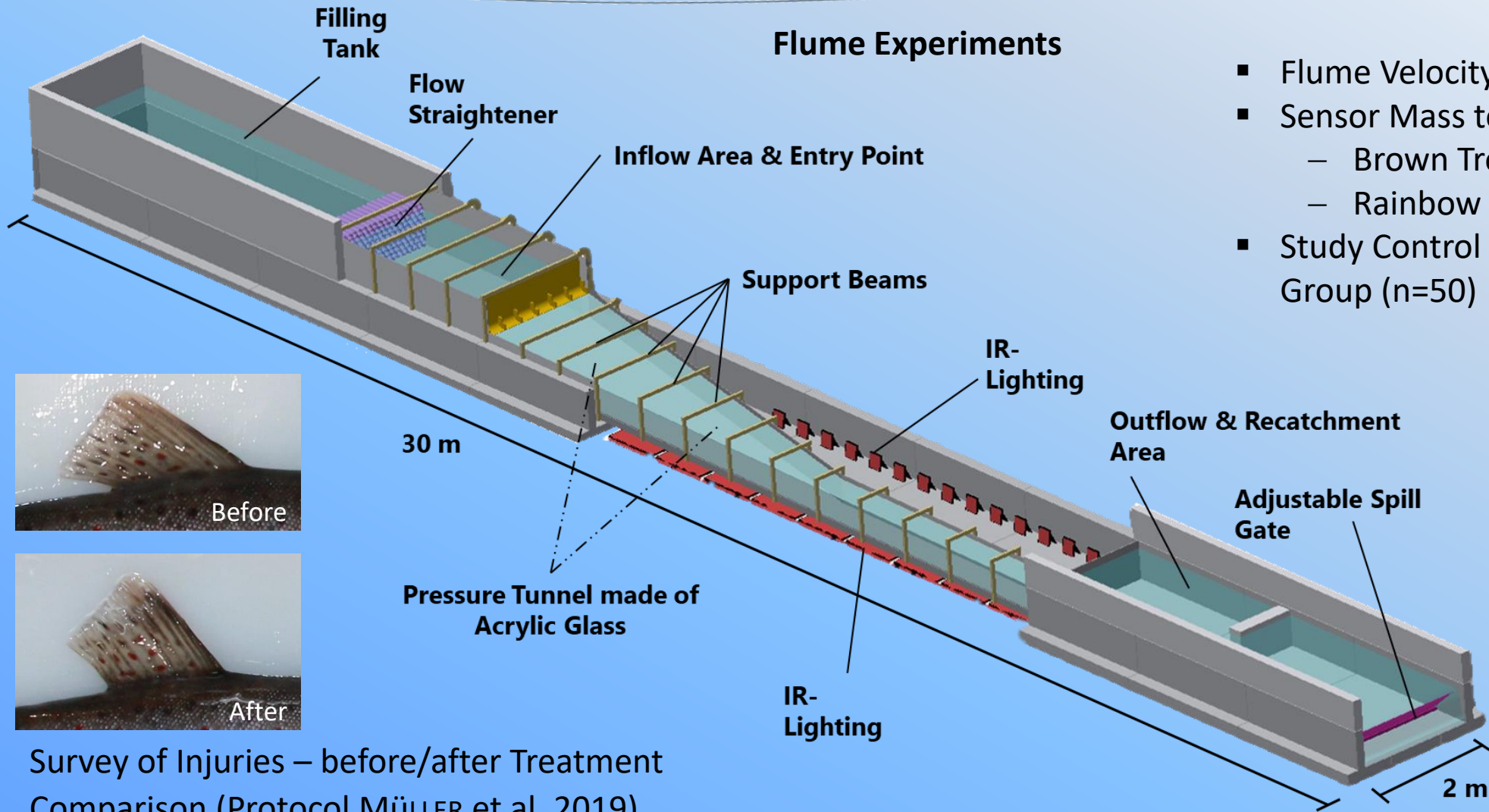
- Attachment: Non-invasive Dorsal Fin Clip
- Total Mass: 3-5 g, Depending on Clip Used (Species Specific)
- Rechargeable LiPo Battery
- Size: 23 x 10 x 4 mm (2. Generation)
- Multisensor Measuring (100, 200 or 2048 Hz):
 - Acceleration +/-16 g or +/- 400 g
 - Rotational Velocity
 - Absolute Orientation
 - Magnetic Field
 - Pressure
 - Temperature

Prototype Test

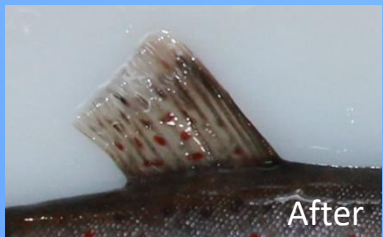


▶ Laboratory Tests - Method

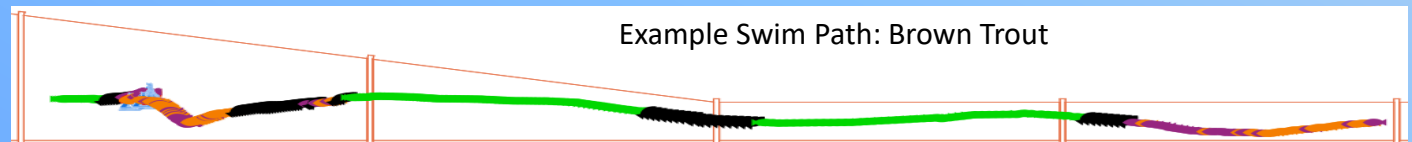
Flume Experiments



- Flume Velocity: 0.1 to 3 m/s
- Sensor Mass to Fish Mass
 - Brown Trout: 8 %
 - Rainbow Trout: 4 %
- Study Control Group versus Sensor Group (n=50)



- Survey of Injuries – before/after Treatment Comparison (Protocol MÜLLER et al. 2019)
- 3D IR-Video Tracking - Swim Path and Behavior



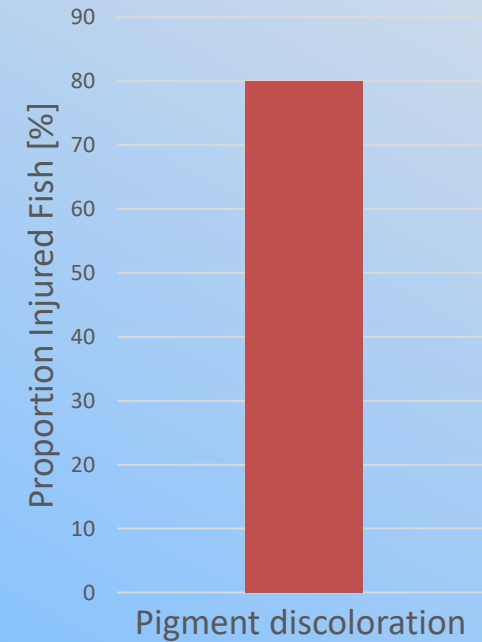
▶ Laboratory Tests - Results

Sensor Effects on Health Condition

- No Serious Injuries Based on Injurie Categories by MÜLLER et al. (2019)
- Minor Pigment Discoloration at Fin Basis Only



Injuries Brown Trout



▶ Laboratory Tests - Results



Sensor Effects on Behavior

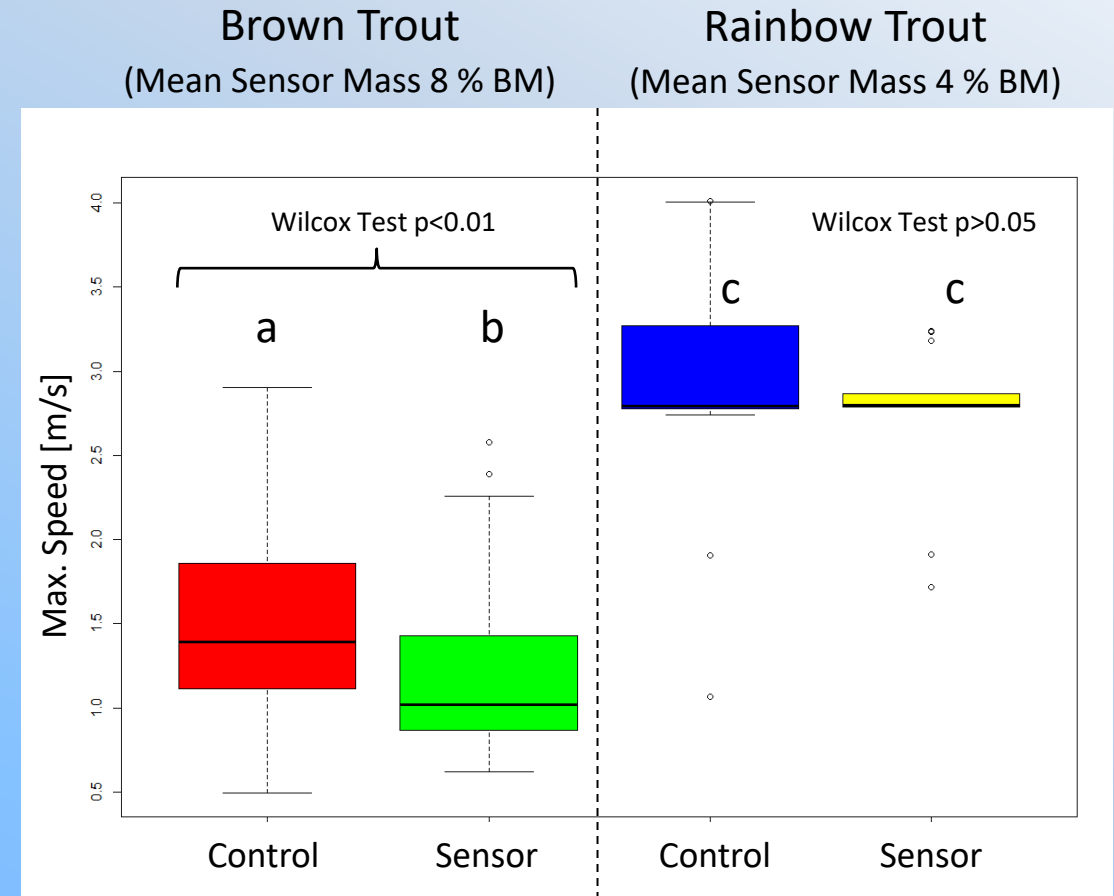
- No Obvious Change in Behavior (Change in Activity, Flight Reactions, Apathy, Scrubbing...)

▶ Laboratory Tests - Results

Sensor Effects on Behavior

- No Obvious Change in Behavior (Change in Activity, Flight Reactions, Apathy, Scrubbing...)
- Maximum Swim Speed: No Effect on Rainbow Trout; Minor Reduction in Sensor Group of Brown Trout

Maximum Swim Speed

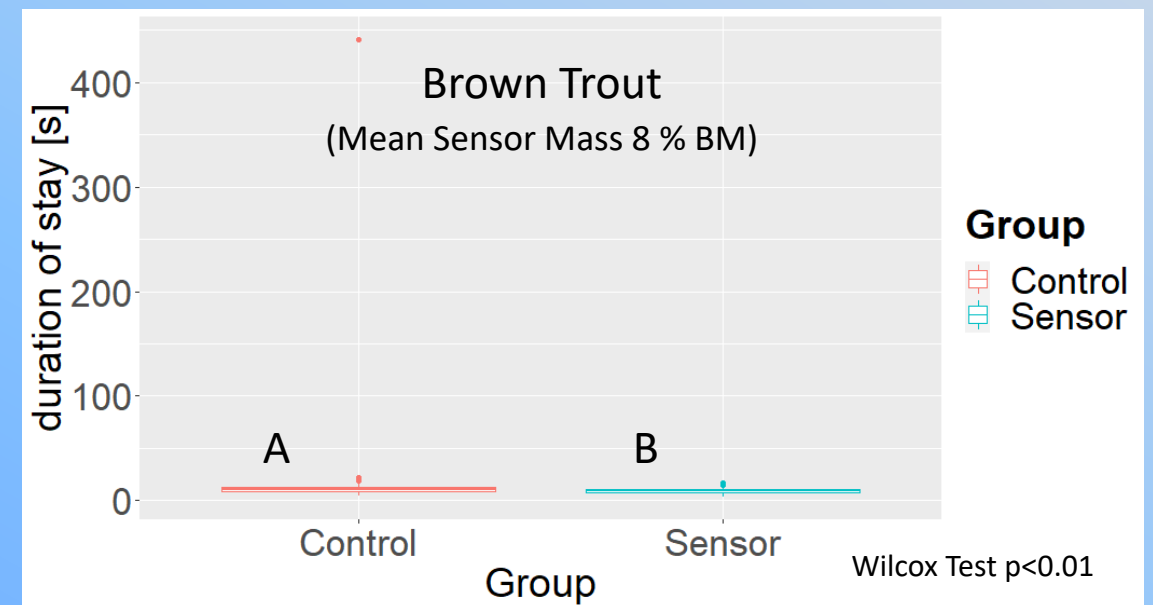
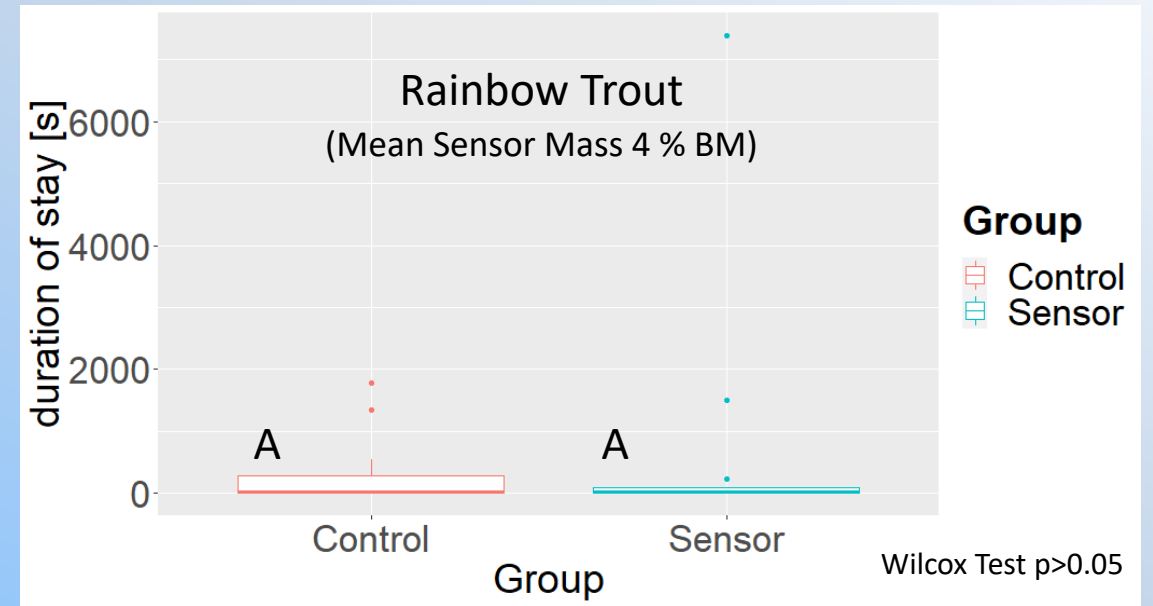


▶ Laboratory Tests - Results

Sensor Effects on Behavior

- No Obvious Change in Behavior (Change in Activity, Flight Reactions, Apathy, Scrubbing...)
- Maximum Swim Speed: No Effect on Rainbow Trout; Minor Reduction in Sensor Group of Brown Trout
- Timespan until Downstream Passage: No Effect in Rainbow Trout but Faster Passage in Brown Trout

Time until Complete Passage

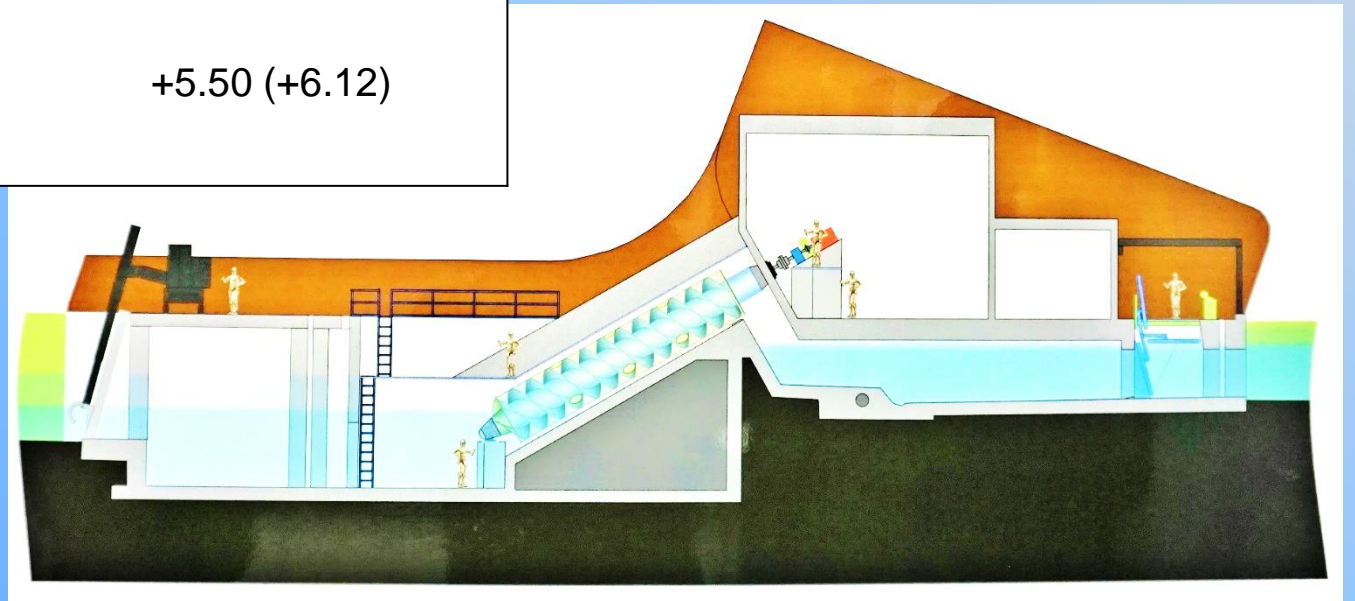


► Case Studies Field - Archimedean Screw: Site Characteristics



	Large Open Screw	Smaller Closed Screw
Discharge (m ³ /s)	3.5 / 2.28	1 / 0.65
Diameter (m)	Inner 1.820 Outer 3.200	Inner 1.025 Outer 2.050
Hydraulic Head (m)	4.76	4.22
Length (m)	11.94	9.87
Angle (Deg)	30	30
Power (kW)	250	75
Tailwater Level (mASL) (Canal Bed Elevation)	+1.60 (+0.57)	+1.90 (+0.57)
Headwater Level (mASL) (Screw Centre Elevation)	+5.40 (+6.360)	+5.50 (+6.12)

- **Archimedean Screws**
- Site Channel Antwerp (Belgium)
- Two Screw Types



► Case Studies Field - Archimedean Screw: Method



A) Injection

Sensors

BDS (Barotrauma Detection System)



Backpack Sensor - European Eel



Backpack Sensor - Roach



B) Catch

Norwegian Nets

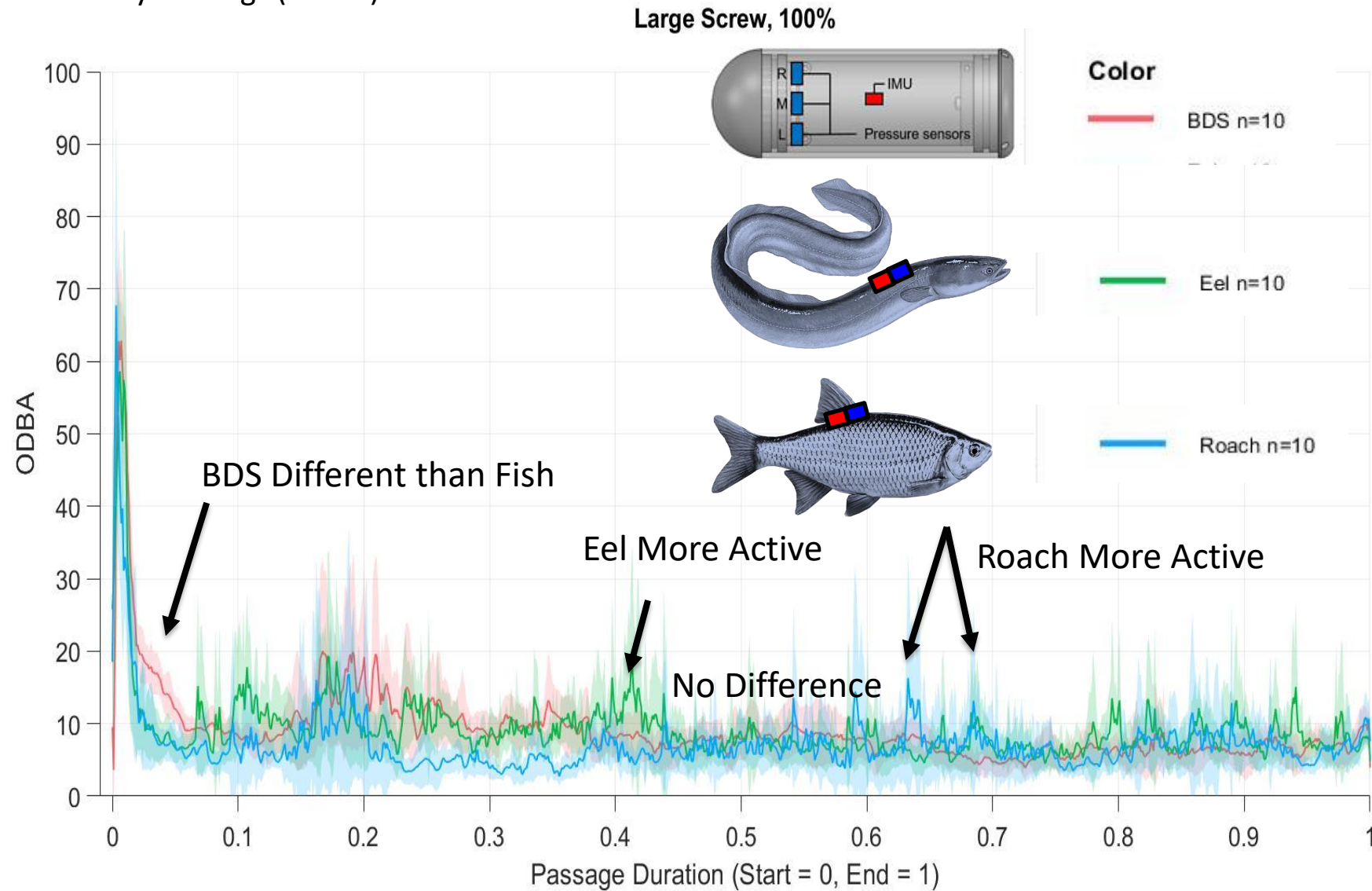


▶ Case Studies Field - Archimedean Screw: Method



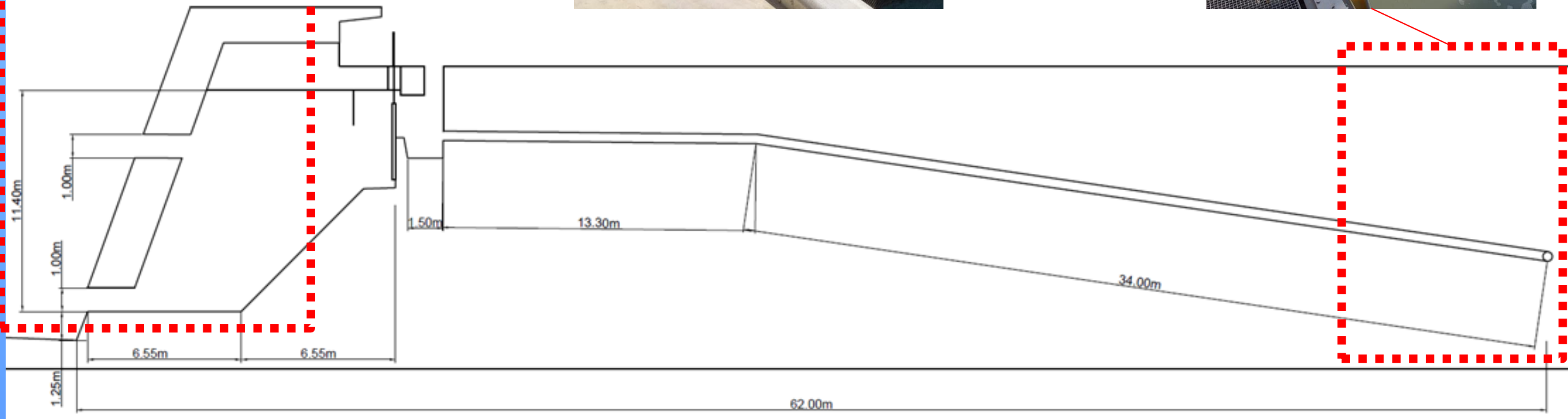
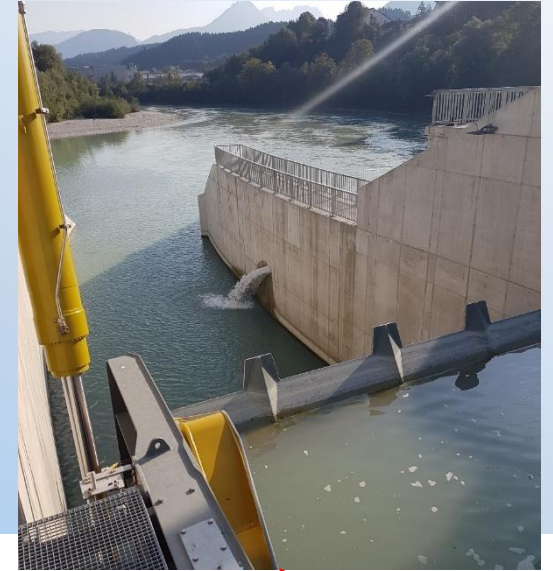
- Group Specific ODBA-Pattern (Overall Dynamic Body Acceleration)
- Behavior Indicator
- Flume Video Data Analysis for ODBA Interpretation Necessary

Preliminary Findings ($n = 10$)



► Case Studies Field – Bypass: Site Characteristics

- **Bypass HPP Kirchbichel, Inn**
(Austria)
- Two Entrances
- Total Length app. 45 m



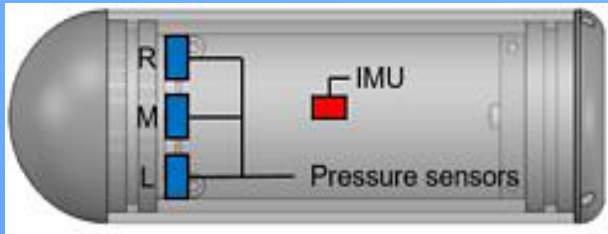


A) Injection

Backpack Sensors



BDS



B) Catch



► Case Studies Field – Bypass: Results



		travel time [s]	impact maximum acceleration [m/s ²]	impact duration [s]
50 l/s Backpack	mean	28.410	63.475	0.088
	std. deviation	13.652	3.612	0.066
50 l/s BDS	mean	26.682	212.904	0.052
	std. deviation	16.635	31.830	0.025

▶ Summary and Outlook

- Backpack Sensors Provide Data of the Fish Environment and Fish Activity
- No Effects on the Fish Behavior in Salmonids when Sensor Mass $\leq 4\%$ of Fish Mass
- No Severe Injuries of Fins during Short Terme Use (1-3 h)
- The Backpack Sensors Passed Field Use Tests and Data Are Different from BDS

- Tests with Cyprinids and Percids Are Planned during the Next 12 Months
- Further Size Reduction of Sensors Is Planned for the Next Project Phase
- Analysis of Impact on Test Fish Using Blood Stress Markers
- Analysis of Video Tracking and Sensor Data to Enable Behavior Categorization Based on Sensor Data



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