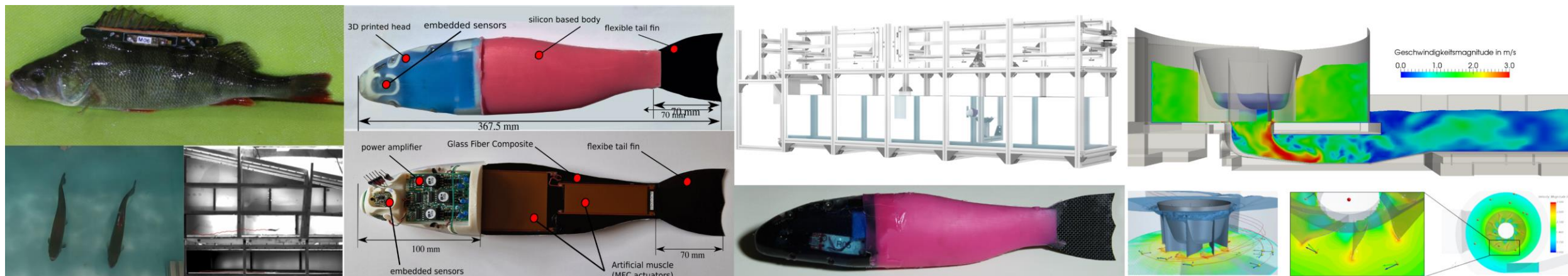


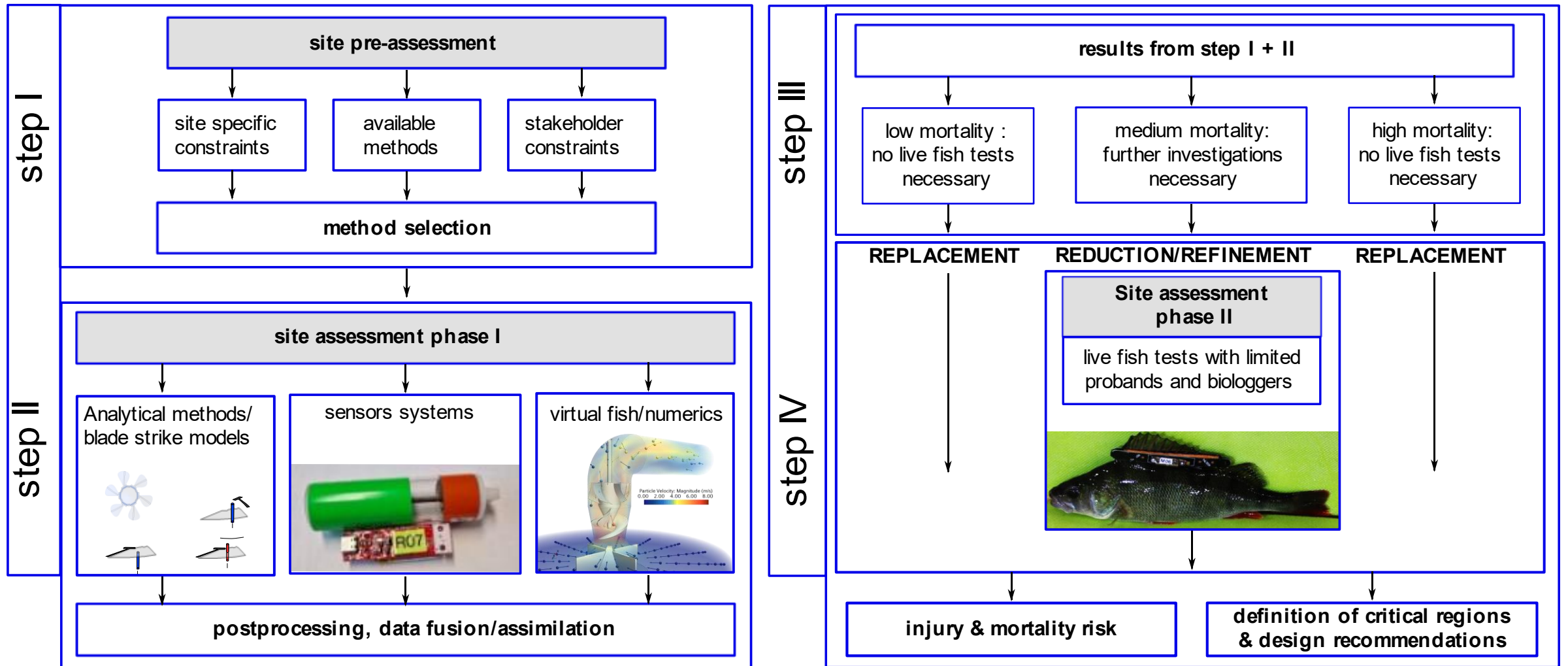
15th International Symposium on Ecohydraulics and Fish Passage 2024

Towards a reliable and validated toolbox to replace live fish tests for the assessment of injury and mortality during downstream passage

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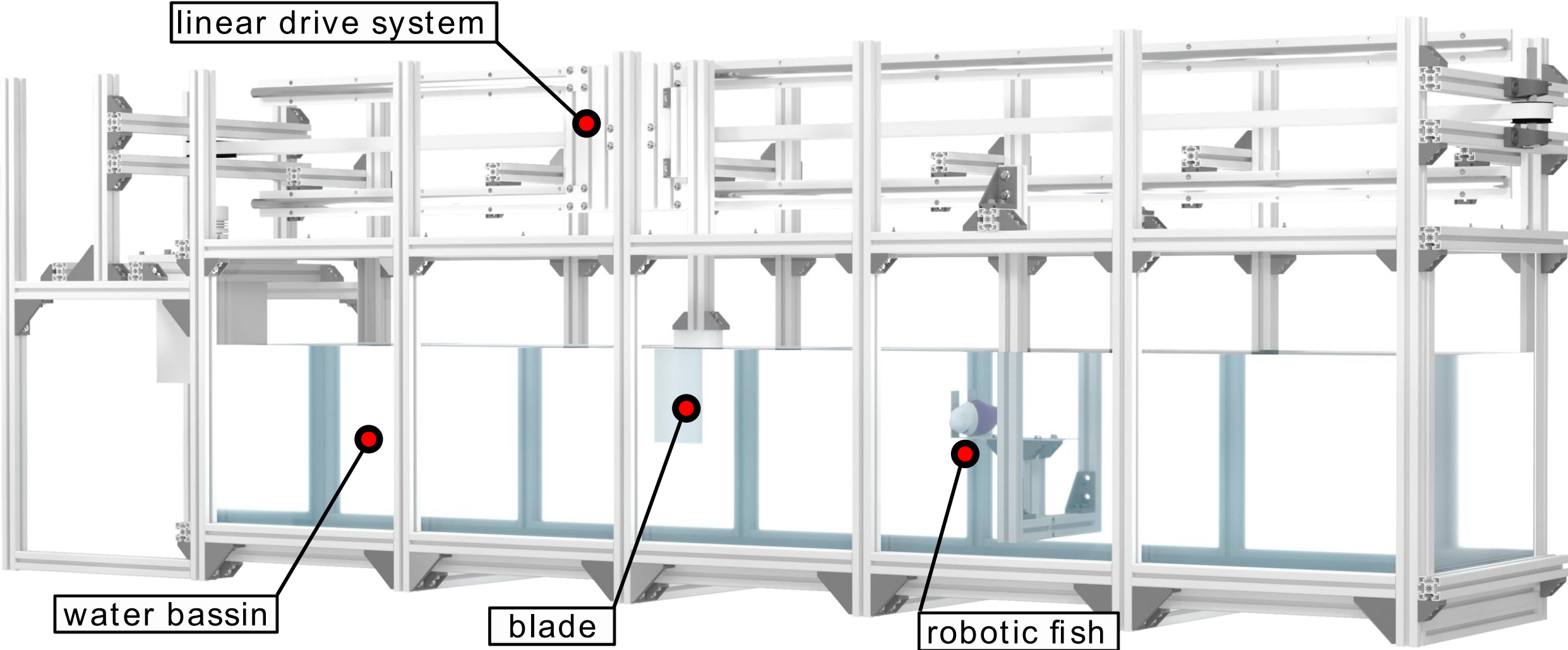
Replacement of live animal tests & integration of new methods in the standards requires faith by evidence

- what are the criteria for injury, e.g. thresholds, parameters, etc. ?
 - biological well studied for some species, what about others ?
 - good knowledge and transferability from fish to surrogate system for barotrauma but challenging for blade strike and collision
- how can we link sensor data to injury and provide evidence ?
- what about different sensor types/vendors or modeling methods ? Are results comparable and reliable ?
- for experimental methods : reference data from test sites with
 - mortality rates from live fish (*limited but feasible*)
 - known & reproduceable boundary conditions (*difficult*)
 - continuous access for repetition with new/novel devices (*very difficult*)

or : lab tests with standardised protocols (*easier ?*)

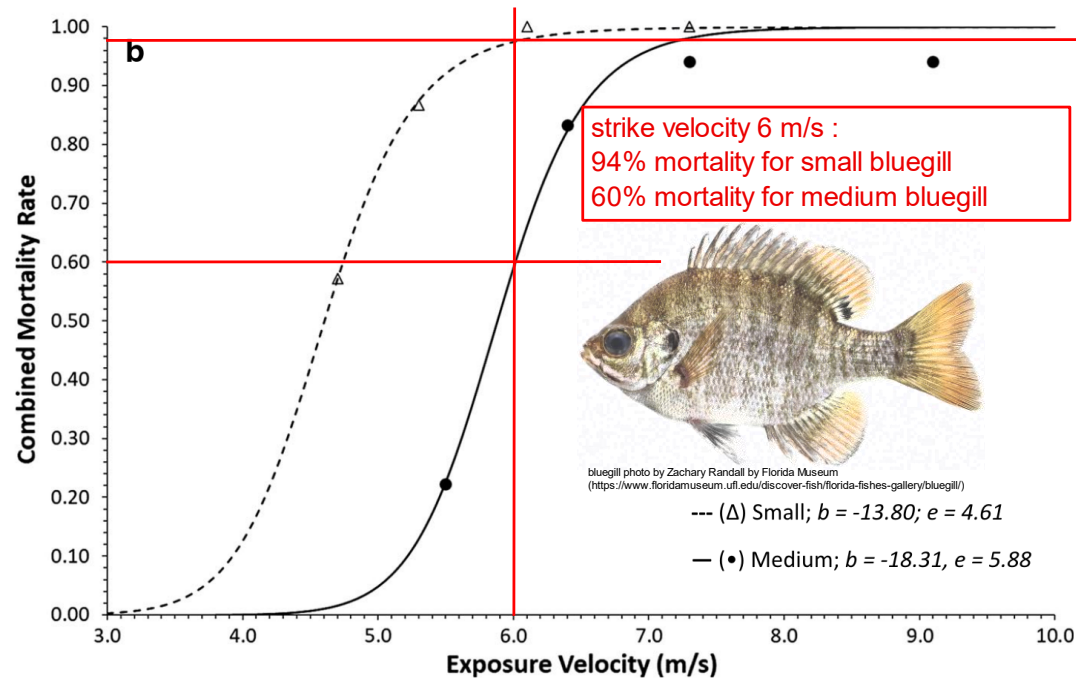
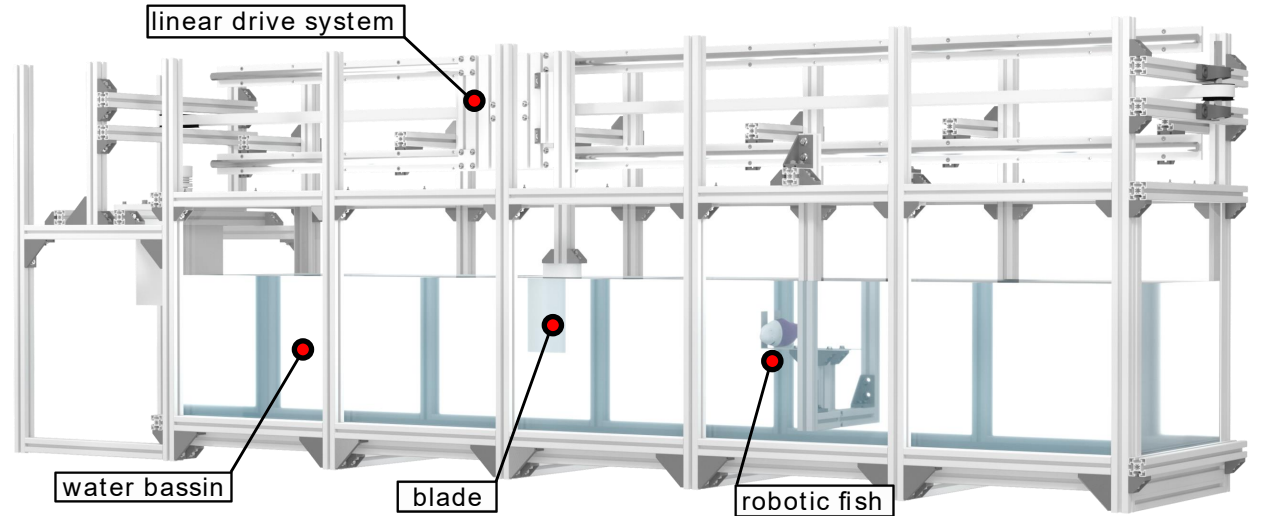
Replacement of live animal tests & integration of new methods in the standards requires **faith by evidence**

lab tests with standardised protocols : **blade strike test rig**



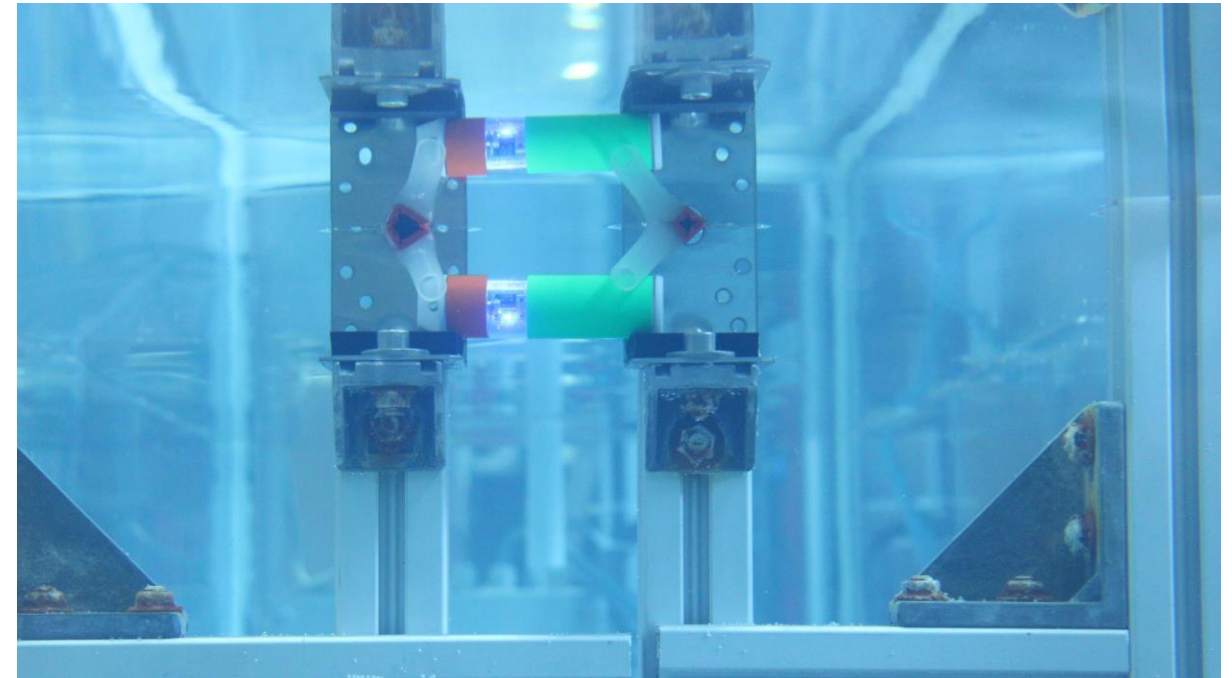
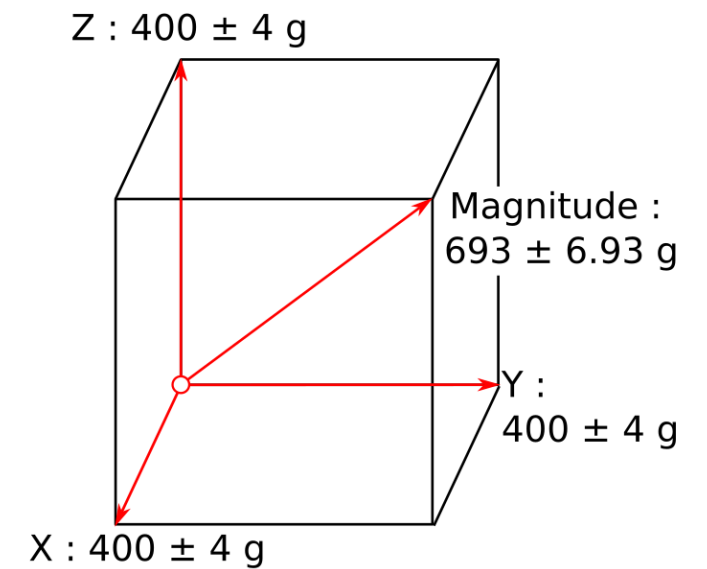
Lab tests with standardised protocols : blade strike test rig

- inspired by ORNL¹ and EPRI² test benches
- motorized fully controlled linear drive system
- high strike repeatability (< 0.02% variation)
- 0-9 m/s strike velocity
- **aim : repetition of fish tests with sensors and correlation to injury**
- e.g. Saylor *et al.* 2019 on bluegill³ :



Lab tests with standardised protocols : blade strike test rig

- RAPID sensors from TalTech
tech specs : 6-axis IMU, magnetic field, absolute pressure
2kHz sampling rate, polycarbonate housing
(see: <https://biorobotics.pages.taltech.ee/edf/en/>)
 - IMU accelerations $400 \text{ g} \pm 0.5\% \text{ F.S.}$ uncertainty per axis (uncertainty retrieved from own lab tests)
 - translatory motion => 3 axis
=> acceleration magnitude = $693 \text{ g} \pm 0.5\% \text{ F.S.}$
- data from 60 samples for each strike velocity: 1 to 9 m/s
- Hypothesis : criteria for severe injury acceleration magnitude > 95 g
(according to Deng *et al.* 2010⁴ , time component to differ from collision to shear was not assessed)



Lab tests with standardised protocols : blade strike test rig

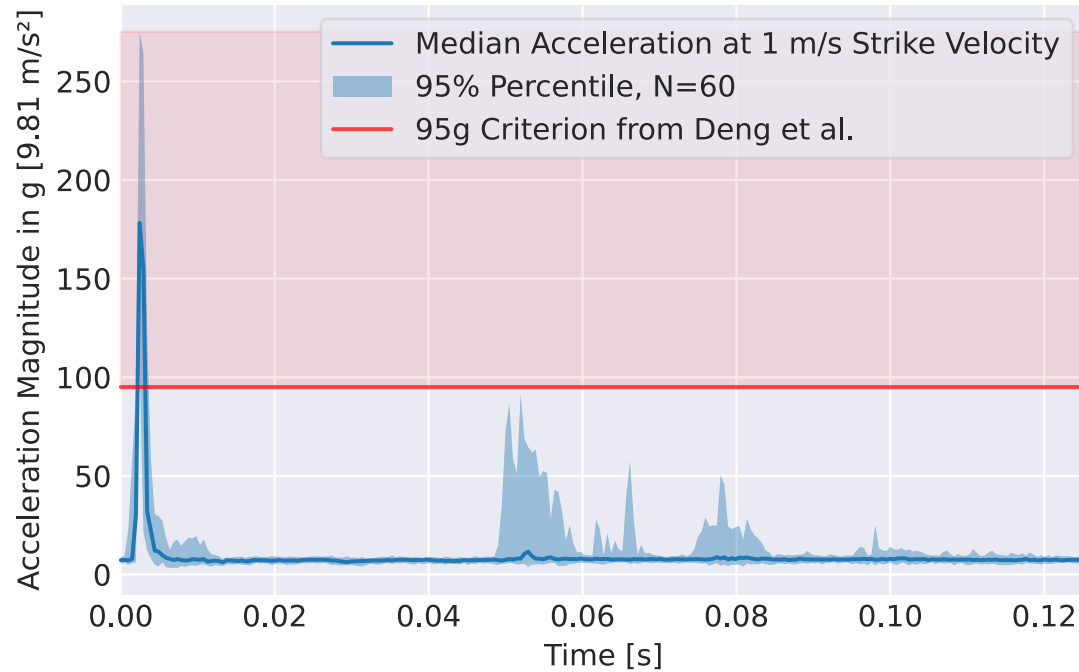


Lab tests with standardised protocols : blade strike test rig

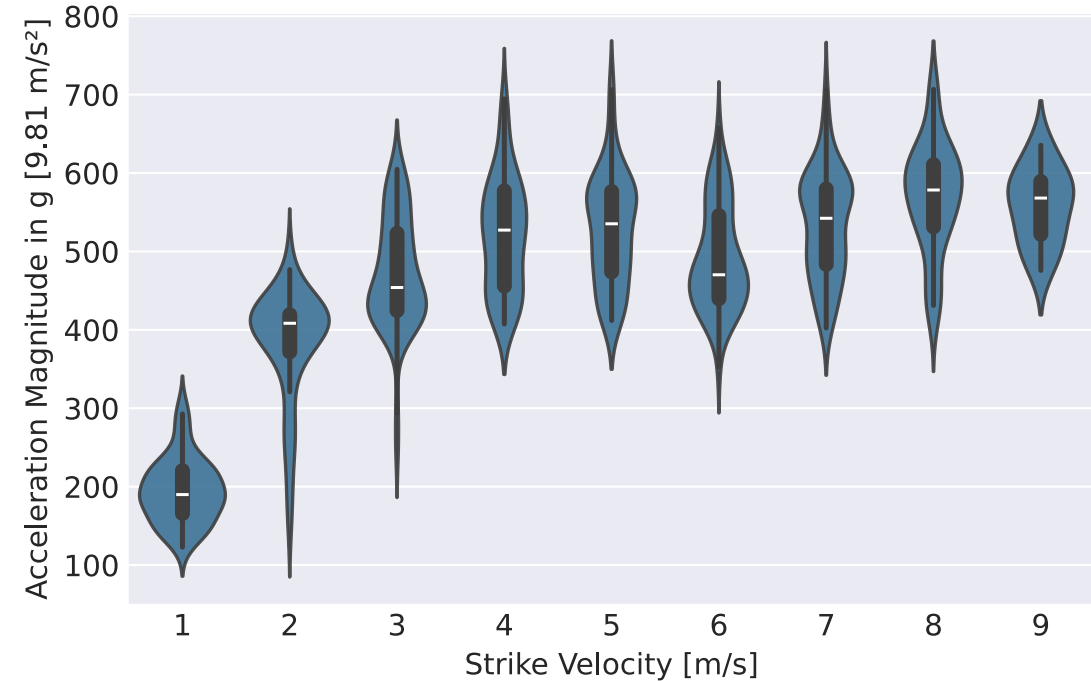


Lab tests with standardised protocols : blade strike test rig

Strike velocity 1 m/s



Strike velocities 1-9 m/s



- for 1 m/s and bluegill mortality 0% : all measured sensor acceleration magnitudes exceed 95 g. Max of the median 178 g (95% data percentile : min 123g/max 275 g, max of all samples= 304 g)
- very fast saturation of the sensors starting from 4 m/s. Strike velocities of more than 4 m/s provide similar magnitudes. Relative strike velocity of 1m/s can produce same acceleration magnitude as 6 m/s
- **conclusions:**
- **(1) acceleration magnitudes cannot provide quantifiable strike velocity data and**
- **(2) the 95 g rule is not applicable (at least for the tested sensors)**

Summary

- standardized tests for collision sensor systems are necessary to provide evidence and faith in the new methods to the community
- a blade strike test rig for repeatable sensor testing has been built (a publication with technical details is in submission)
- up to now no correlated strike acceleration thresholds to estimate injury are available, strike velocities hardly quantifiable
- TalTech RAPID sensor measurements do not match with the 95 g threshold for severe injury (Deng *et al.* 2010⁴) when comparing to live fish data (Saylor et al. 2019¹). What about other market available sensors such as ATS sensor fish ?
- open questions remain :
 - cross-comparability : how do sensors from different vendors behave for the same strike ?
Extended strike testing with standardized protocols on various sensor types are necessary to ensure suitability and cross comparability
 - method suitability : can injury risk probabilities be quantified from acceleration magnitudes in general ?
Do we need other measures ? Are rigid sensor bodies appropriate to replace fish for strike test surrogate systems ?

Outlook

Are flexible bodies closer to fish body characteristics and do they provide better data for risk probability quantification, such as shown in Saylor *et al.* 2021⁵?

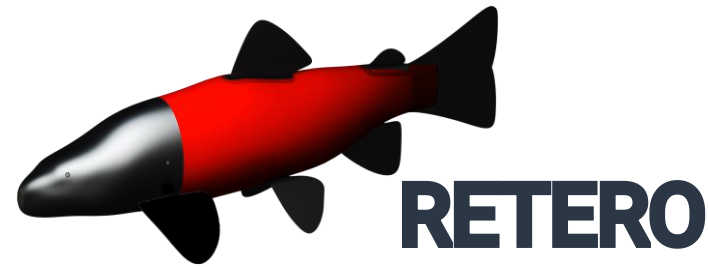


Thank you very much for your attention !

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...there are more RETERO presentations at the congress:

Hoerner et al. - *Towards a reliable and validated toolbox to replace live fish tests for the assessment of injury and mortality...*, Monday, 16:00, Session 11 “Fish screening techniques”

Wagner et al. - *Behavior analysis for fish...*, Tuesday, 14:30, Session 22 “Safe downstream passage”

Abbaszadeh et al. - *Bio-inspired robotic fish for assessment of injury ...*, Wednesday, 11:45 Session 33
“Fishway monitoring & evaluation 1”

Kopecki et al. - *Estimating fish swimming speed using non-invasive backpack sensors...*, Wednesday, 11:15
Session 34 “Fish locomotion in unsteady flow”



References

- ¹ M.S.Bevelhimer, B. M. Pracheil, A. M. Fortner, R. Saylor, K.L. Deck, Mortality and Injury Assessment for Three Species of Fish Exposed to Simulated Turbine Blade Strike, *Canadian Journal of Fisheries and Aquatic Sciences*, 2019
- ² G. E. Hecker, S. V., Amaral, and P.S. Stacy, Investigation of Hydro-Turbine Leading-Edge Shapes Favorable to Fish Survival. 102561. Palo Alto, CA: Electric Power Research Institute, 2007.
- ³ R.Saylor . A. Fortner . M. Bevelhimer, Quantifying mortality and injury susceptibility for two morphologically disparate fishes exposed to simulated turbine blade strike, *Hydrobiologia*, 2019
- ⁴ Z. Deng, T. J. Carlson, J. P. Duncan, M. C. Richmond, and D. D. Dauble, Use of an autonomous sensor to evaluate the biological performance of the advanced turbine at Wanapum Dam, *Journal of Renewable & Sustainable Energy*, 2010
- ⁵ R.Saylor . P.L. Wang, M.S. Bevelhimer, P. Lloyd , J. Goodwin , R. Laughter , D. Young, D. Sterling, P. Mhatre, C. Atkins and B. Post, Creation of a prototype biomimetic fish to better understand impact trauma caused by hydropower turbine blade strikes, *PeerJ Material Science*, 2021