Turbine Design for Fish Inclusion

SUSHP Conference, 14 June 2023

SUSHP 2023

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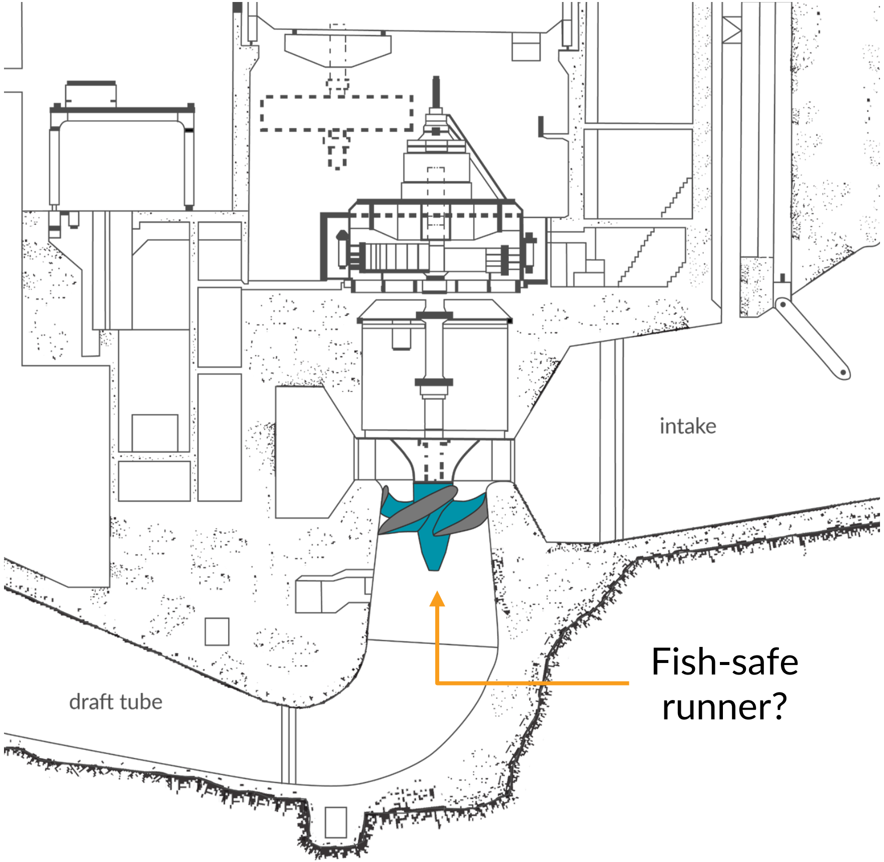
Every hydropower plant has a turbine…

EU Taxonomy:

"There is an absolute requirement to put in place ***all technically and ecologically relevant measures*** *towards achieving good ecological status or* ***good ecological potential…"***

What size, species, life stages will pass through the turbine?

How safe can a turbine be for fish, and under what conditions?



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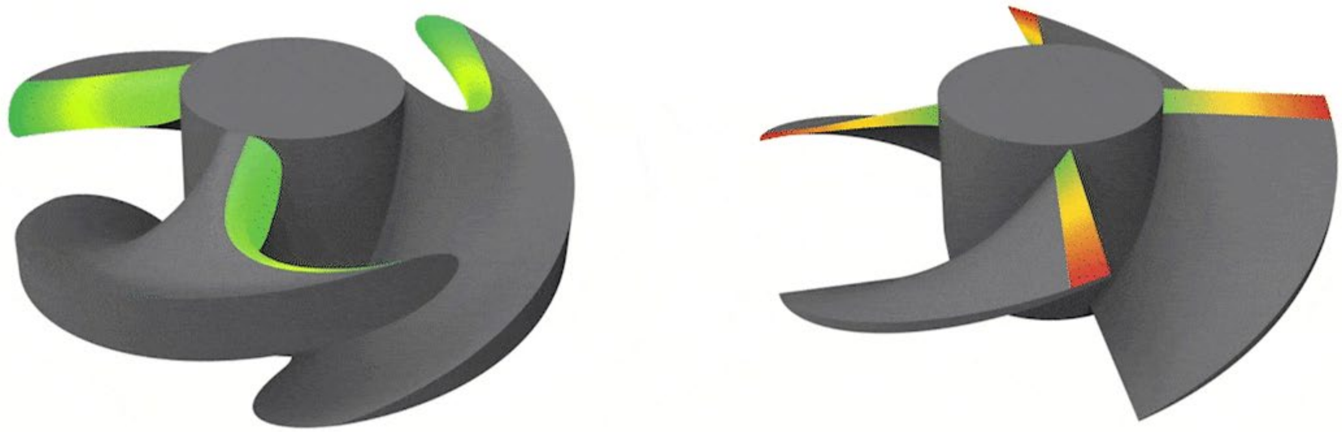
Improved strike survival by design



Thick, slanted blade
Restoration Hydro Turbine

Thin, straight blade
Conventional turbine

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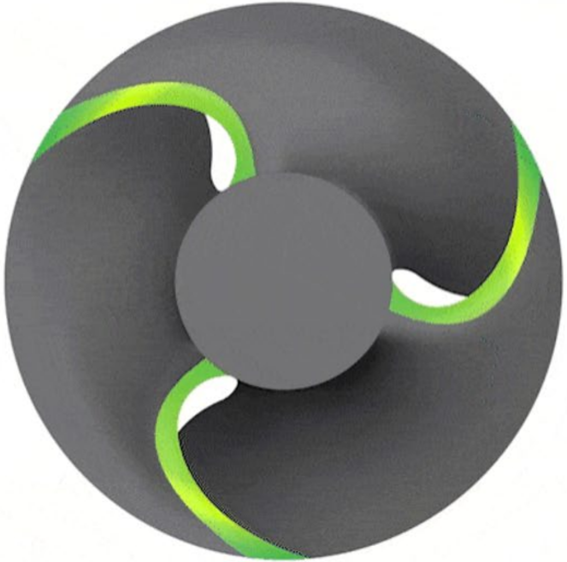
Improved strike survival by design



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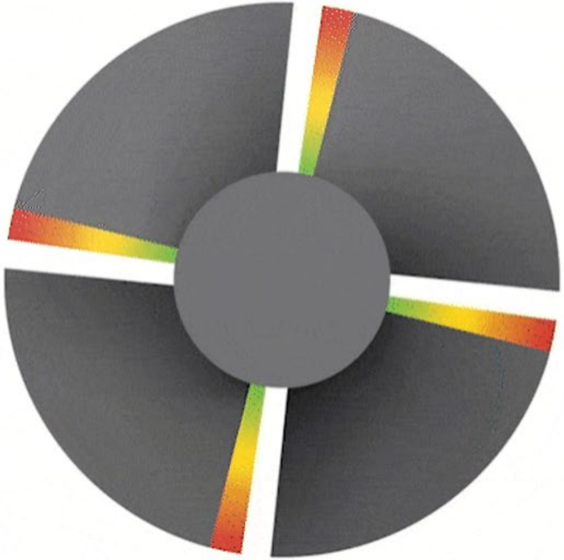
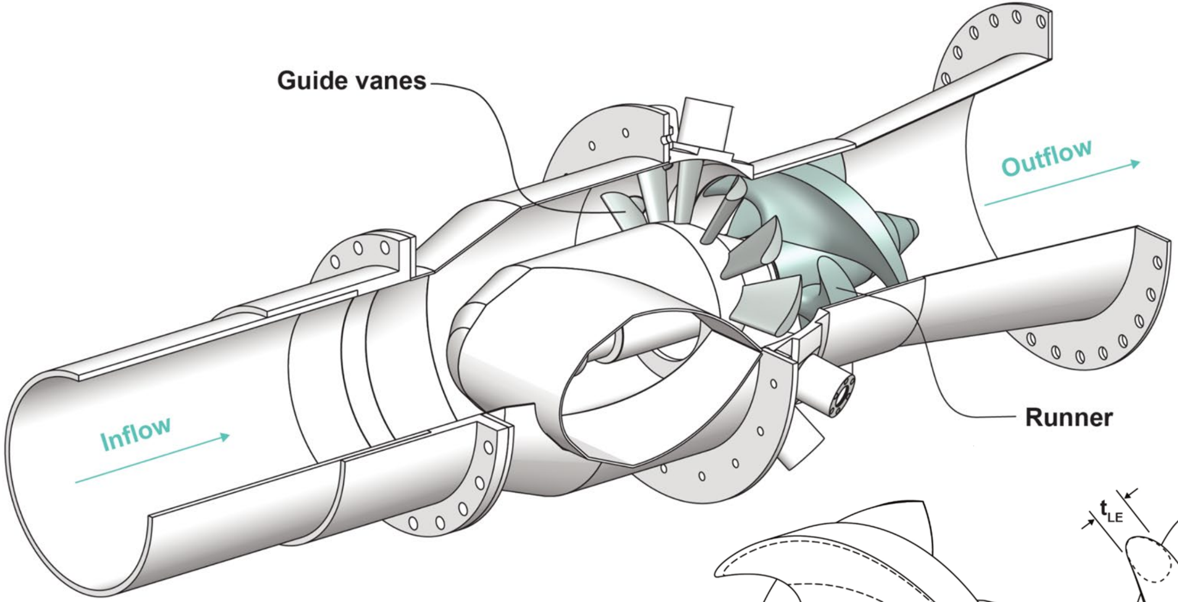


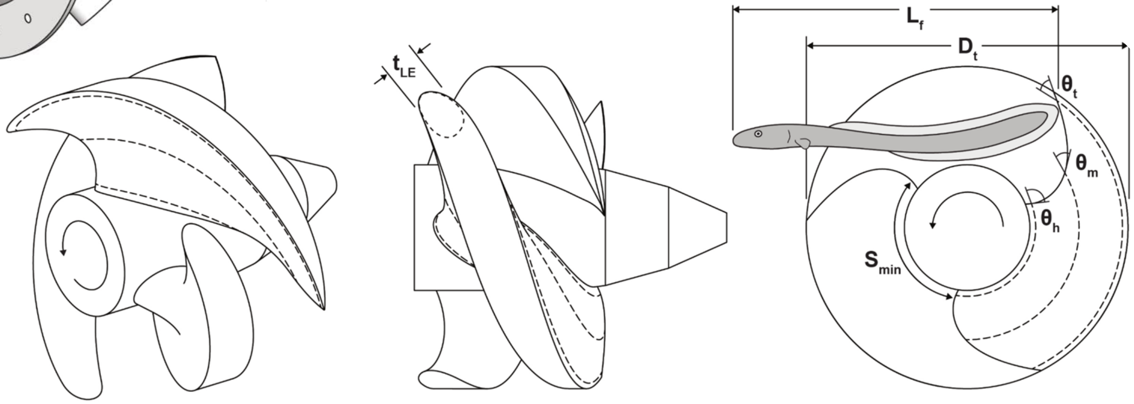
Thin, straight blade
Conventional turbine

Fish-Safe Restoration Hydro Turbine (RHT)



Thick, forward-swept leading edge allows fish to survive blade contact, while maximizing allowable rotating speed (and minimizing turbine size)

No pinch points

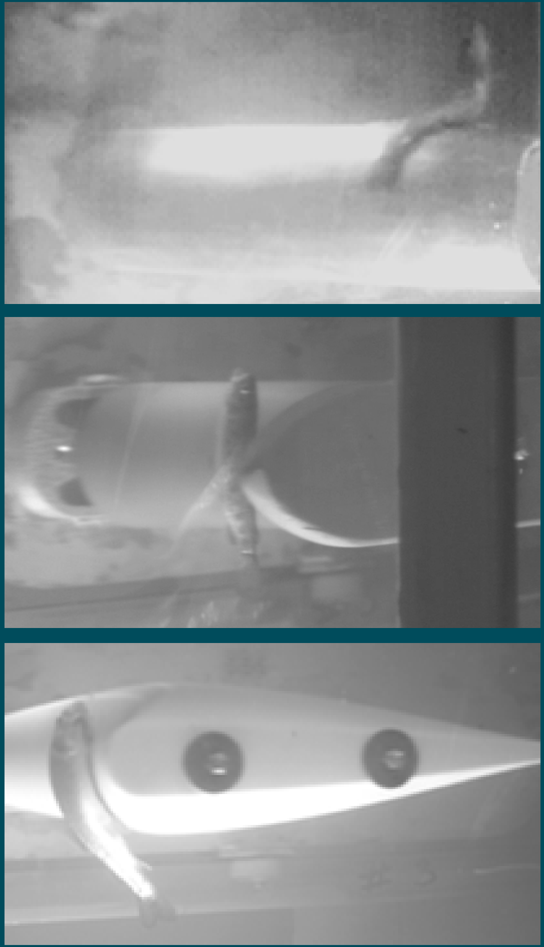


LINEAR STRIKE TESTING AT ALDEN LABORATORY 2019

1700 rainbow trout strikes

High-speed video + 48h hold

Do thick, slanted blades enable higher safe strike speeds?



Stephen V. Amaral, Sterling M. Watson, Abraham D. Schneider, Jenna Rackovan & Andrew Baumgartner (2020) Improving survival: injury and mortality of fish struck by blades with slanted, blunt leading edges, Journal of Ecohydraulics, 5:2, 175-183, DOI: 10.1080/24705357.2020.1768166

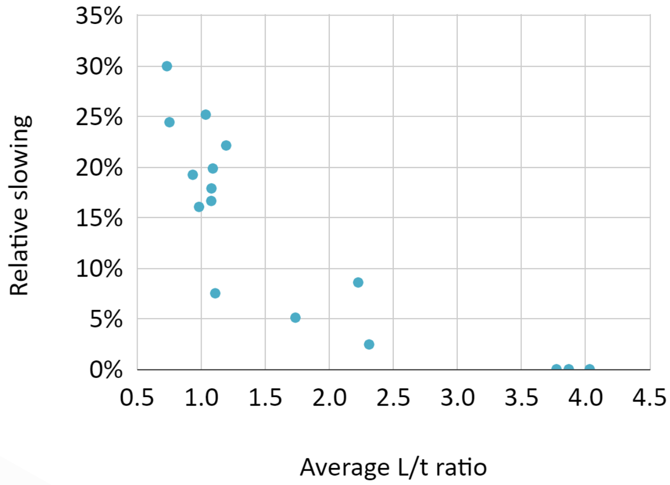
Fish-blade interactions at low *L/t*

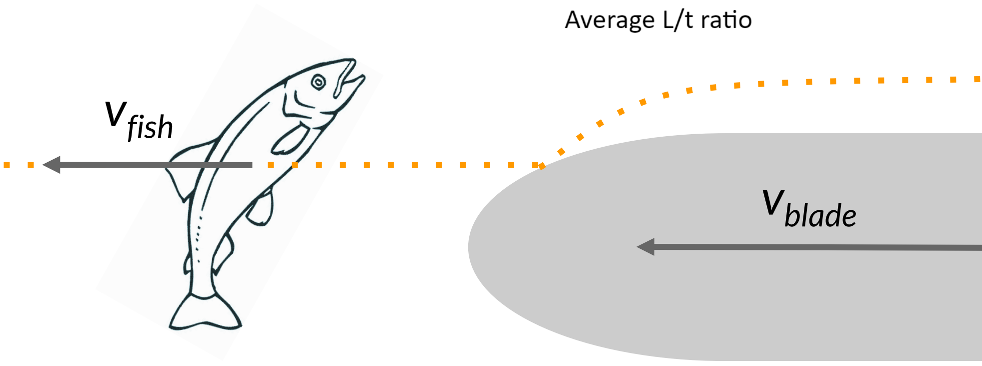
Fish-blade interactions were revealed by high-speed video.

When fish length was similar to blade thickness, fish were slowed (up to 30%) and “pushed away” from the leading edge.

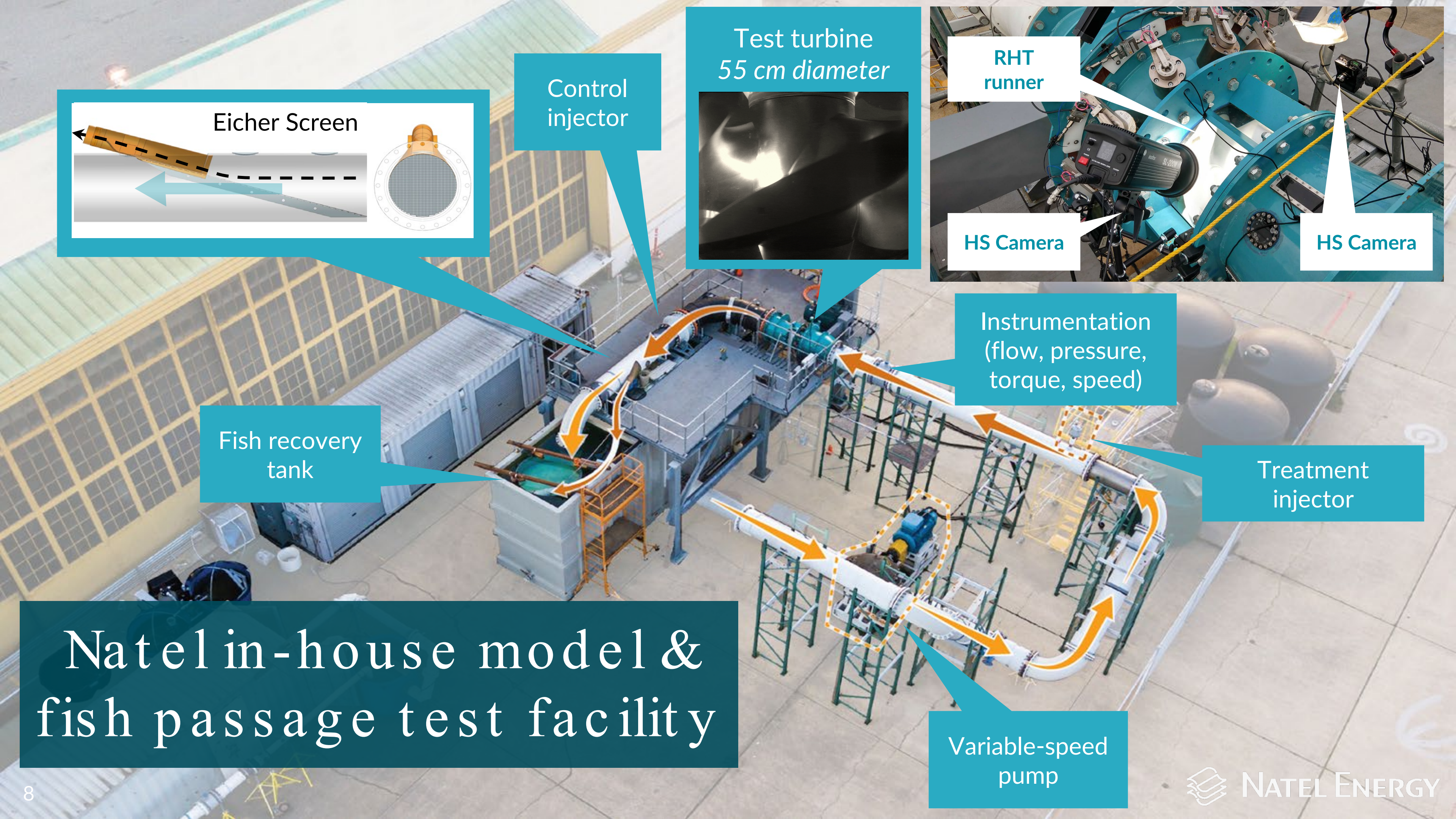
At low *L/t* ratios, the likelihood of severe strike, in which the fish conforms to the blade and moves with it, is diminished.

The safest strike is no strike at all!

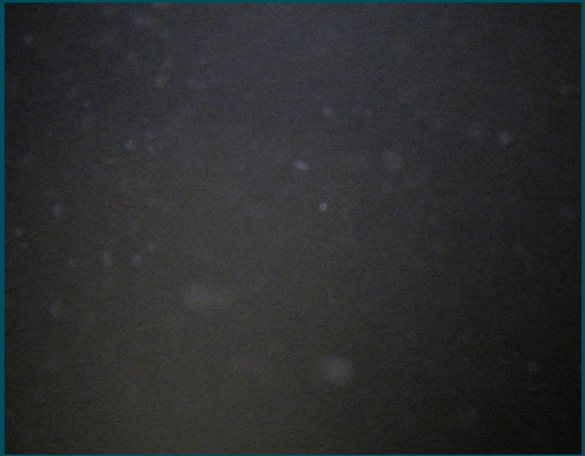




Natel in-house model & fish passage test facility



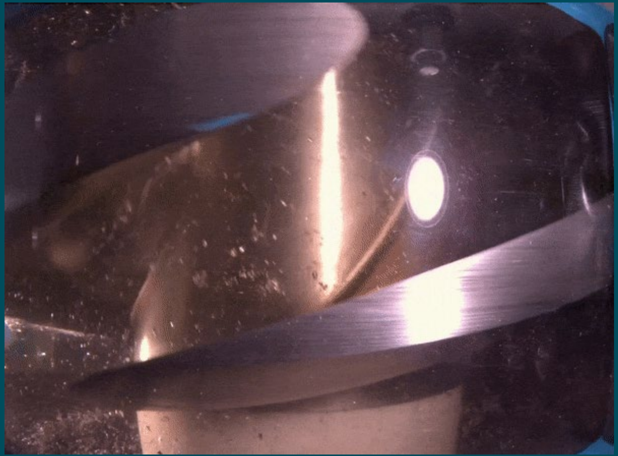
Primary species tested, to date



Rainbow trout: *98-100% survival*

Monroe Hydro Plant, 5 m head
Ø190 cm, 130 rpm (U_{tip} 12.9 m/s) L 20-53 cm (L/t 1-2.7)

In-house test facility, 10 m head
Ø55 cm, 667 rpm (U_{tip} 19.2 m/s)
L 70-155 mm (L/t 1.27-2.8)
In review



Juvenile Alewife: *98-100% survival*

Freedom Falls Hydro, 7 m head
Ø55 cm, 541 rpm (U_{tip} 15.6 m/s)
L 87-132 mm (L/t 1.6-2.4)

Published:

Watson, S., Schneider, A., Gardner, L., Apell, B., Thompson, P., Cadman, G., Gagnon, I., Frese, C., Wechsler, J. (2023). Juvenile Alewife passage through a compact hydropower turbine designed for fish safety. *North American Journal of Fisheries Management*. https://doi.org/10.1002/nafm.10866

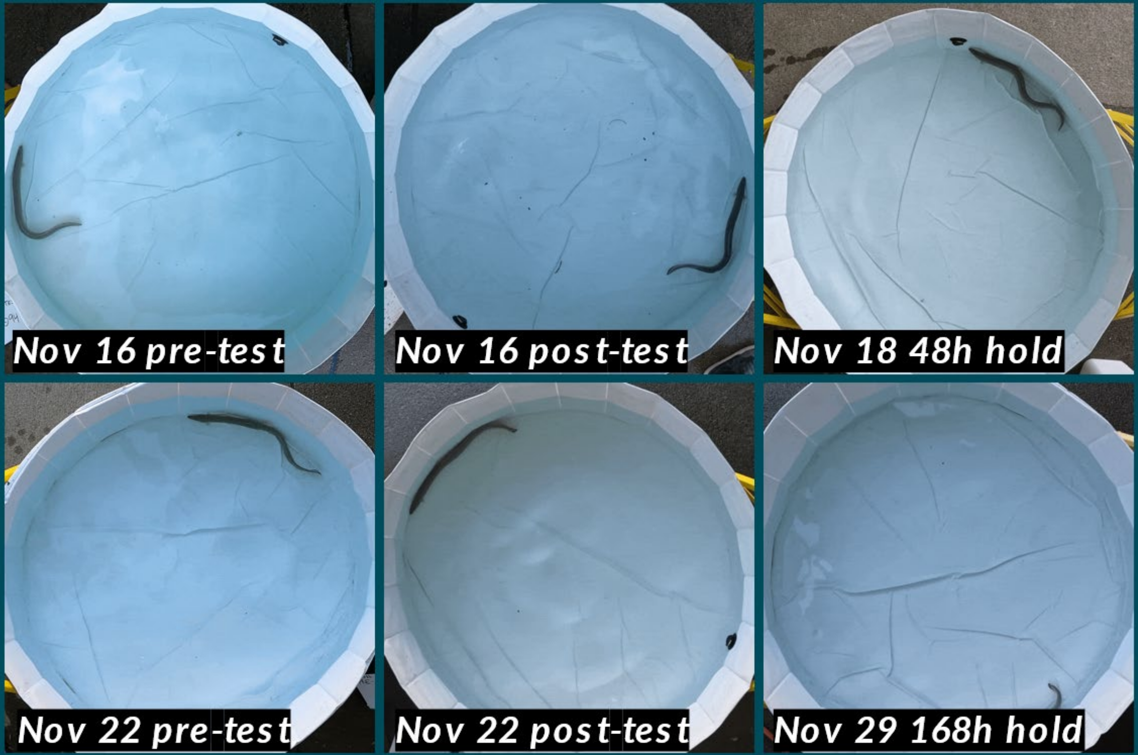
American eel: *100% survival*

In-house test facility, 10 m head
Ø55 cm, 667 rpm (U_{tip} 19.2 m/s)
L 35-65 cm (L/t 6.4-11.8)

Published:

Watson, S., Schneider, A., Santen, L., Deters, K. A., Mueller, R., Pflugrath, B., Stephenson, J., & Deng, Z. D. (2022). Safe passage of American eels through a novel hydropower turbine. *Transactions of the American Fisheries Society*, 151, 711– 1. https://doi.org/10.1002/tafs.10385

Sublethal effects, repeat passages



100% survival after 7-day hold for eels passed **twice** through the RHT.

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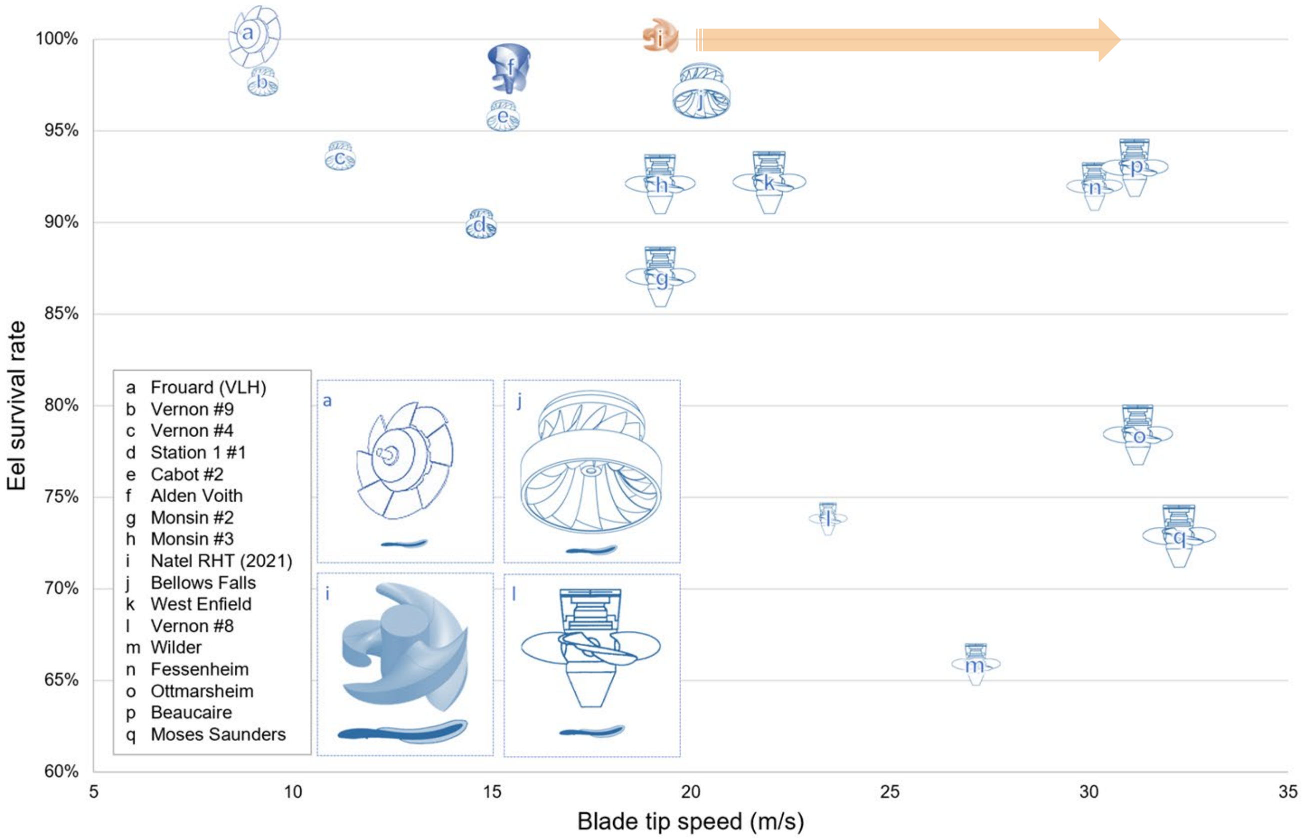
RHT runners improve

Higher speed than other eel-friendly turbines, higher survival than conventional turbines



Sources:

Cook T. C., Hecker G. E., Amaral S.V., Stacy P. S., Lin F., Taft E. P. (2003). – Final report – Pilot scale tests Alden/Concepts NREC Turbine. Report DE-AC07-99ID13733 for U.S. Department of Energy.

Heisey, PG, Mathur, D, Phipps, JL, et al. Passage survival of European and American eels at Francis and propeller turbines. *J Fish Biol*. 2019; 95: 1172– 1183.

Lagarrigue, T., Frey, A. (2010). – Test for evaluating the injuries suffered by downstream-migrating eels in their transiting through the new spherical discharge ring VLH turbogenerator unit installed on the Moselle River in Frouard. E.CO.G.E.A. report for MJ2 Technologies.

Fish-safe designs may be widely applicable

RHT max design head ~30-40 m

“small/micro hydro”

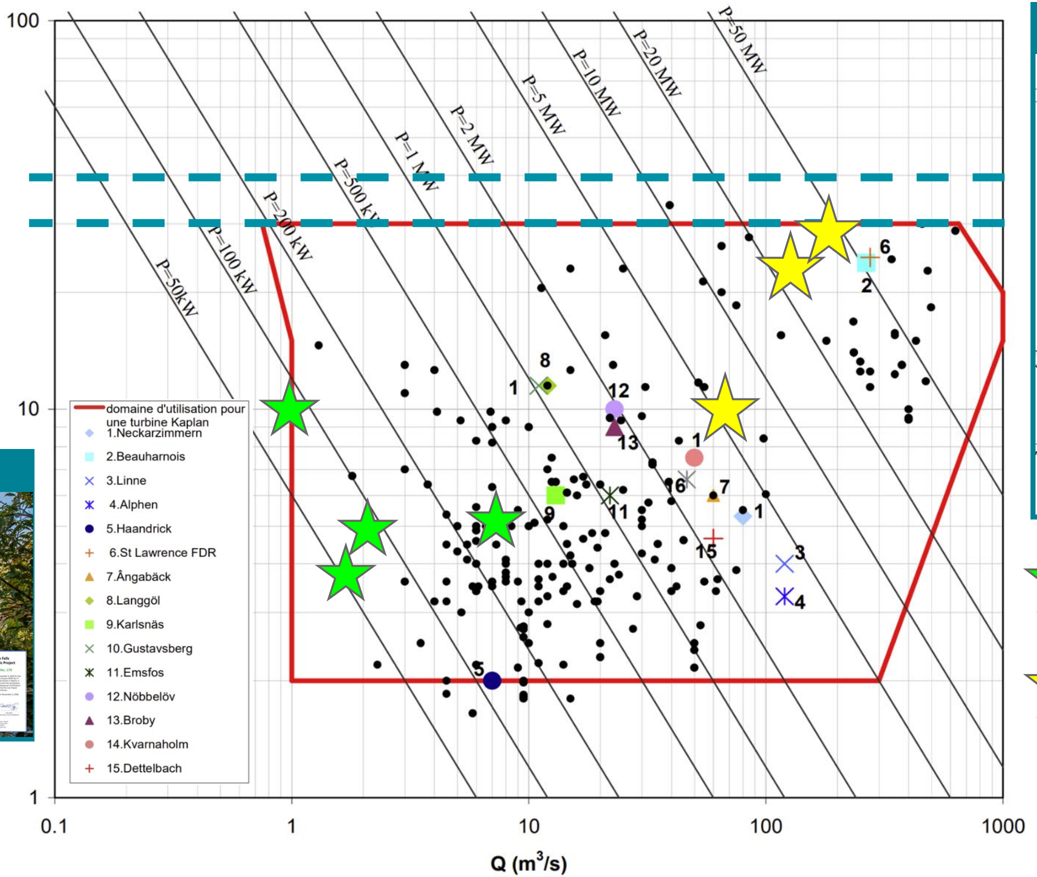
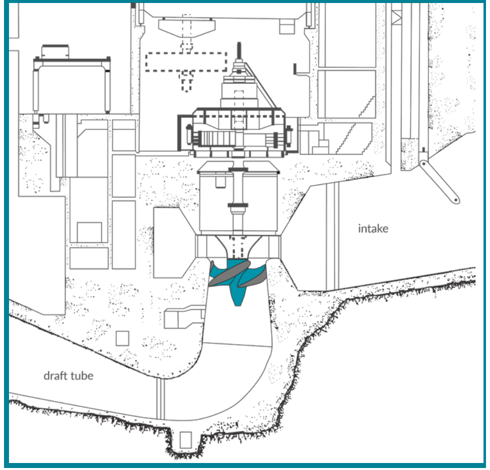


Figure 3: Situation des turbines ayant fait l’objet d’expérimentations dans le domaine d’utilisation des turbines Kaplan (points noirs : turbines Kaplan équipant des cours d’eau concernés par la dévalaison de l’anguille en France)

“(large) hydro”



existing RHT references

new RHT designs (2023)

Gomes, P., Larinier, M. (2008). Dommages subis par les anguilles lors de leur passage au travers des turbines Kaplan – Etablissement de formules prédictives. Report GHAAPPE RA08.05.

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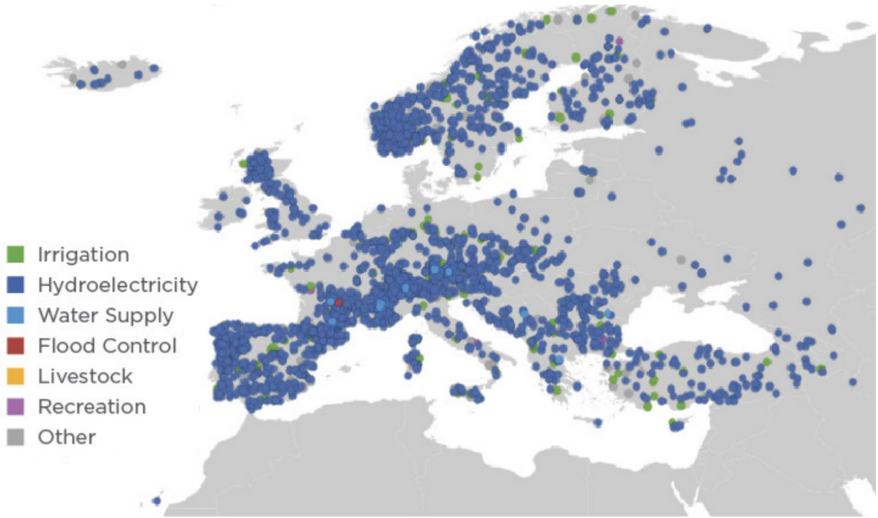
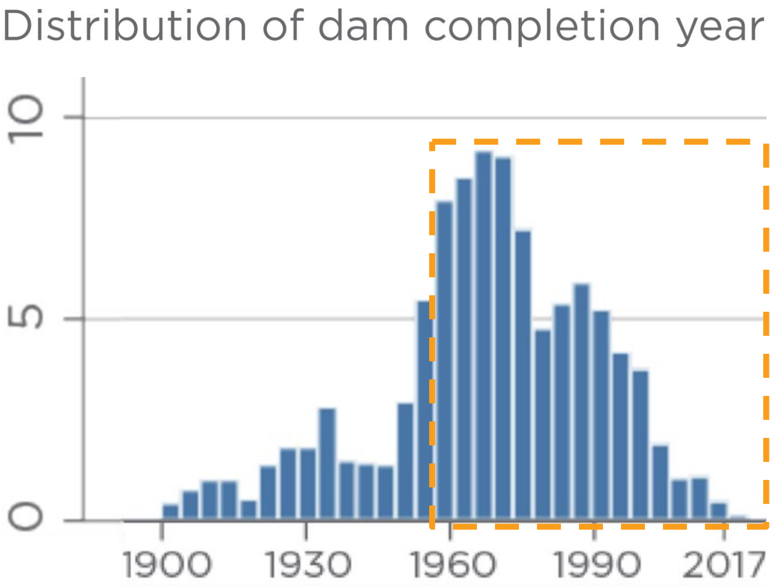
Rehabilitate aging EU hydro with fish-safe runners





Modernization/refurbishment AND permitting both represent an opportunity to implement best practices for downstream passage.

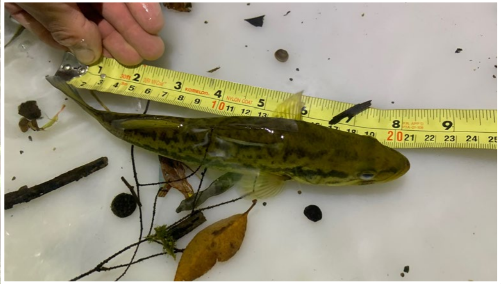
Fish-safe turbines could help achieve Good Ecological Potential

Zhang, Urpelainen, Schlenker. Power of the river: Introducing the Global Dam Tracker (GDAT). 2018.

What's passing through?

All these organisms passed through a 19 mm bar rack, into an 55-cm RHT operating at 7m head, 541 rpm.

All were recovered unharmed: fish, crawfish, mussels, macroinvertebrates



Thank you!

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