



PRO-TIDE 

FISH FRIENDLINESS OF ULTRA LOW-HEAD TIDAL TURBINES


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PRO-TIDE FINAL CONFERENCE


Standard Low Head Tidal Technology



La Lance 1966




Sihwa, 2011



Swansea, 2015

Bottle-necks for ultra low head (~ 1 meter)


1. Low head, low energy density:
2. High flow rate, big machines ► high costs
3. Fish friendliness: 90-95 % = Not good enough



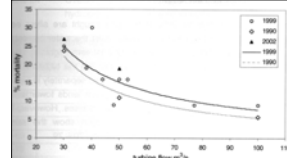
Preliminary Research:

**Experimental and numerical analysis HPP
Linne (Meuse, NL)**


Voest-Alpine Bulb turbine 1989, ~ 4 meter head



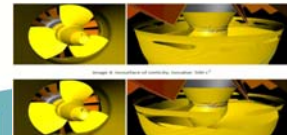
1. Mortality for Eel : 10-20 %
depending on flow rate




2. No mutilation observed due to
pressure-differences



3. No mutilation observed due
to fluid shear

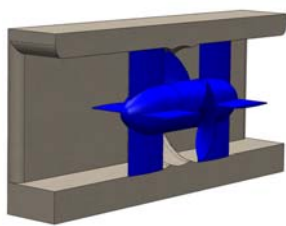




For Ultra Low Head Tidal Turbines:

1. Blade strike is most important.
2. Blade strike velocity is determining (size and rpm).
3. Leading edge curvature is important.

Fish Friendliness of an 8 meter
diameter tidal turbine ?



Dutch project:
Ultra Low Head Tidal Power
(Specifically for the Brouwersdam 4000 m³/s @ 1m)



Brouwersdam Springersdiep

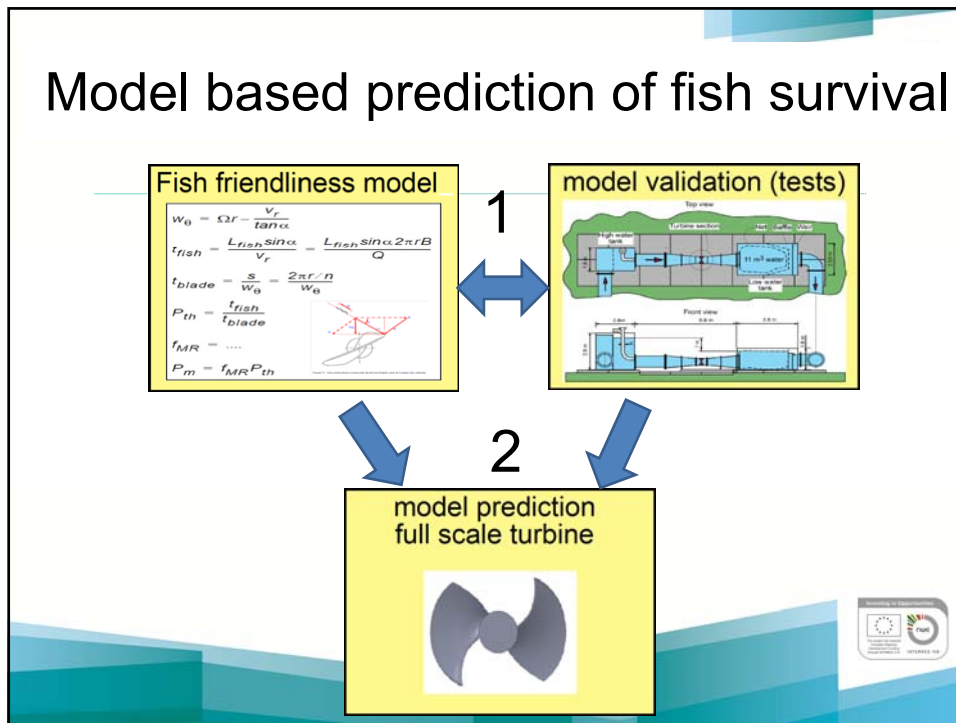


Eastern Scheldt: 40000 m³/s, 1 meter head

MODEL BASED PREDICTION
OF
FISH SURVIVAL:
+ EXPERIMENTAL VALIDATION



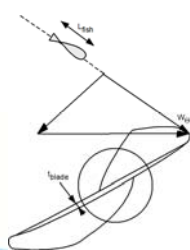
Model based prediction of fish survival



Bladestrike model

Mortality =

Blade strike probability x Mutilation ratio



$$W_0 = \Omega r - \frac{v_r}{\tan \alpha}$$

$$t_{fish} = \frac{L_{fish} \sin \alpha}{v_r} = \frac{L_{fish} \sin \alpha 2\pi r B}{Q}$$

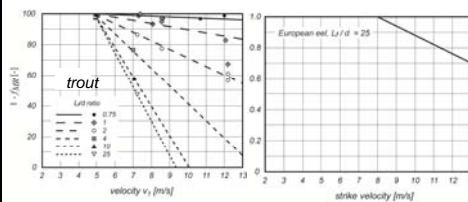
$$t_{blade} = \frac{s}{W_0} = \frac{2\pi r / n}{W_0}$$

$$P_{th} = \frac{t_{fish}}{t_{blade}}$$

$$f_{MR} = \dots$$

$$P_m = f_{MR} P_{th}$$

$$f_{MR} = \left[a - b \left(\frac{L_{fish}}{t} \right) + c \right] (v_r - 4.8)$$



Electric Power Research Institute (EPRI), 2011, Fish Passage through Turbines: Application of Conventional Hydropower Data to Hydrokinetic Technologies, Final Technical Report No. 1024638

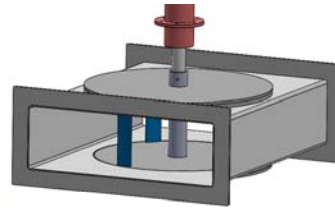
Van Esch, B.P.M., Spierts, I.L.Y., 2014, Validation of a Model to Predict Fish Passage Mortality in Pumping Stations, Canadian Journal of Fisheries and Aquatic Sciences

Best candidates for Ultra Low Head Tidal Power

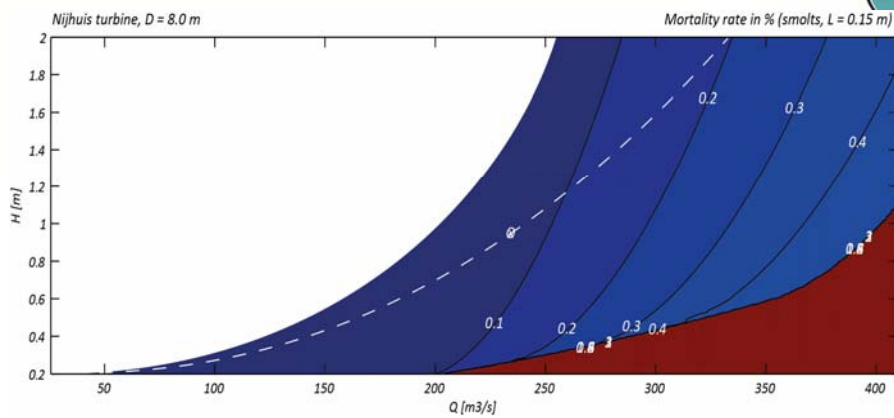
Propeller Turbine:
Pentair-Fairbanks-Nijhuis



Cross-flow Turbine:
Water-2-Energy



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Graphs predict mortality in specific operation points

**Subject to validation, by comparing with
scale model experiments !**











Benchmark Fish (scale model)

Pike-perch, length ~17 cm

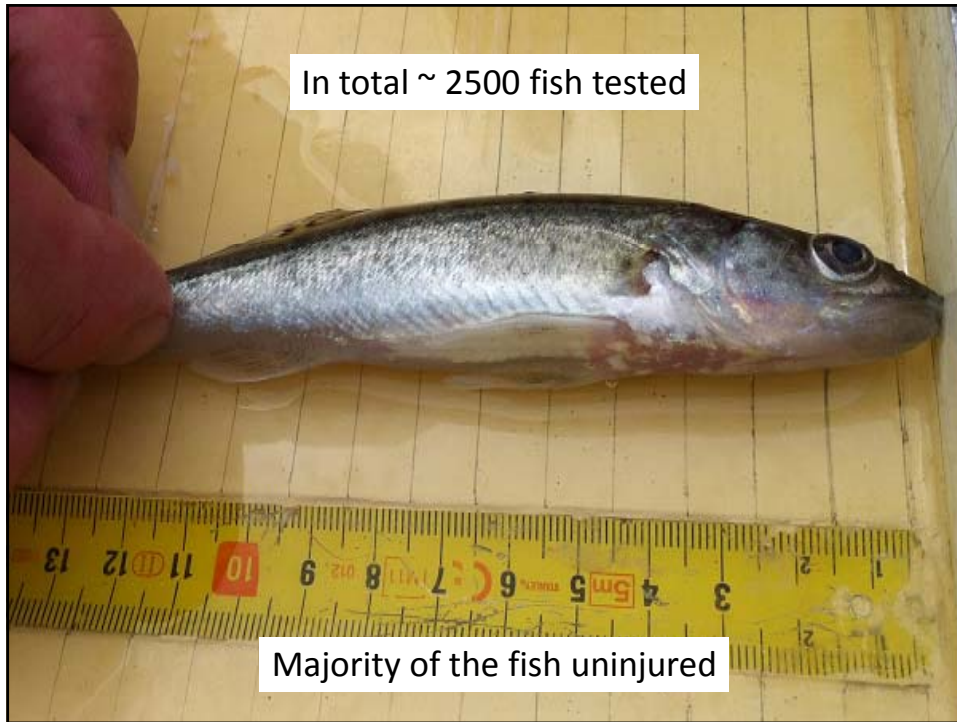



Trout, length ~ 17 cm




Yellow Eel, length ~ 20 cm 

A slide titled "Benchmark Fish (scale model)" with a lightbulb icon. It lists three fish species with their approximate lengths: Pike-perch (~17 cm), Trout (~17 cm), and Yellow Eel (~20 cm). Each species is accompanied by a small image of the fish. The slide has a blue and white geometric design at the bottom.




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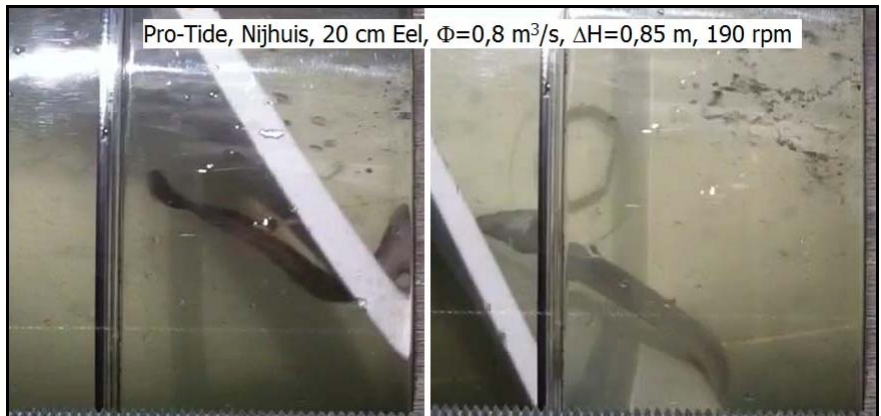


20 cm Yellow Eel passing safely the propeller turbine at $0,7 \text{ m}^3/\text{s}$, 175 rpm
(blade tip speed = $4,6 \text{ m/s}$).




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Pro-Tide, Nijhuis, 20 cm Eel, $\Phi=0,8 \text{ m}^3/\text{s}$, $\Delta H=0,85 \text{ m}$, 190 rpm



20 cm Yellow Eel struck by a propeller turbine blade at $0,8 \text{ m}^3/\text{s}$, 190 rpm
(blade tip speed = 5 m/s). The Eel survived without damage




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Stand-in fish




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20 cm Trout passing the vertical axis cross-flow turbine at 0,6 m³/s,
75 rpm (blade speed = 2,8 m/s).

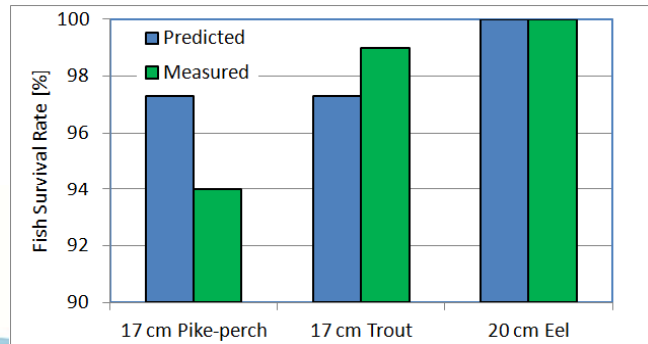


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Model validation: Propeller turbine



Scale 1:16, measured @ 0,8 m³/s, 0,7 m, 190 rpm

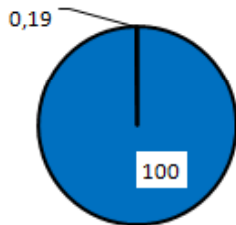


Note: @ 100 batch size, 95 % confidence Interval ~ > 88 %

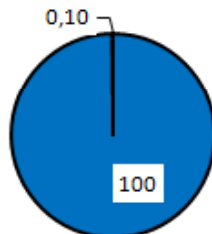
Full Scale Prediction:

Ø 8 m propeller turbine @ 13 rpm

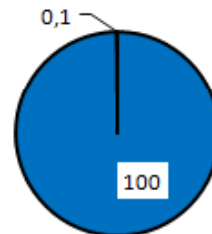
25 cm Seabass




15 cm Smolts



75 cm Eel







Main Conclusions Fish Tests

1. Model based prediction of fish friendliness for 8 m diameter tidal turbines > 99,8 %
2. For Ultra Low Head, velocities can be dangerously low: Fish may swim upstream through the rotor.
3. Pikeperch seem more vulnerable than Trout?
4. **Large Ultra Low Head Tidal Power systems can be fish friendly**

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Thanks!
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