Advancing Fish Swimming Studies: Methodology and Insights

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Overview

More than **1 million barriers** fragment Europe's rivers. Fish need fishways to overcome anthropogenic structures. In this context, estimating fish swimming abilities becomes highly relevant.

Problem statements

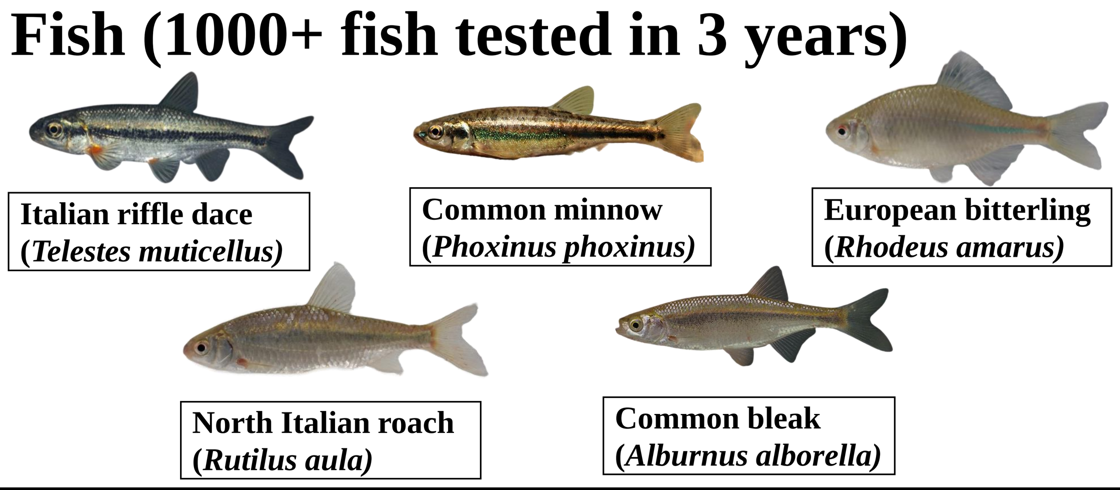
Procedural choices: Methods and procedural choices for estimating fish swimming performance vary from paper to paper.
Theoretical support: Lack of physical understanding for fish swimming performance.

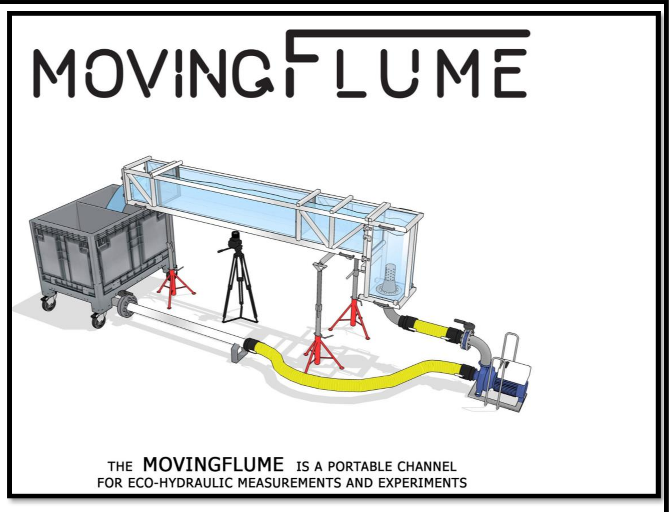
Research objectives

Procedural choices: Study the (1) effect of test flume length and fatigue definitions, (2) effect of habituation time and swim behaviour on fish swimming performance.
Theoretical support: Formulating and verifying the scaling relationship between fatigue time and flow velocity in burst swimming mode.

Materials and methods

Fish (1000+ fish tested in 3 years)





Experimental protocol

- Fixed velocity test
- Constant water temperature (± 1°C)

(1) *Effect of flume length and fatigue definitions*
- Three different test flume lengths (15, 30, and 100 cm)
- Two different fatigue definitions (tapped vs. untapped)

(2) *Effect of habituation time and fish behaviour*
- Three different habituation times (0.5, 5, and 20 mins)
- Two different fish positions (in flume or on grid)
- Poke vs. no poke at the start of test velocity

(3) *Validating scaling relationship b/w fatigue time and flow velocity*
- 626 successful fish trials with consistent protocol (all 5 species)

Scaling formulation

Drag: is resistance to the motion of a body (fish moving in a fluid)

$$F_d \sim \rho L T C_d U_r^{\,2}$$

Drag force; water density; Fish length; Fish thickness; Fish drag coefficient; Relative fish speed

3 cases for scaling fish drag force

1. C_d taken as constant — $F_D \sim \Gamma_2 U_r^2$ where $\Gamma_2 = \rho L S$
2. C_d depends on Re (motionless fish body) — $F_D \sim \Gamma_1 U_r^{9/5}$ where $\Gamma_1 = \rho L^{4/5} S\, \nu^{1/5}$
3. C_d depends on Re (undulating fish body) — $F_D \sim \Gamma_3 U_r^{26/15}$ where $\Gamma_3 = \rho S^{5/3} L^{1/15} \left(\frac{L}{A}\right)^{1/3} \nu^{4/15}$

Scaling relationship b/w fatigue time and flow velocity

$$\overline{T}_f \sim U_r^{-m(\beta+1)}$$ *Power law type relationship*

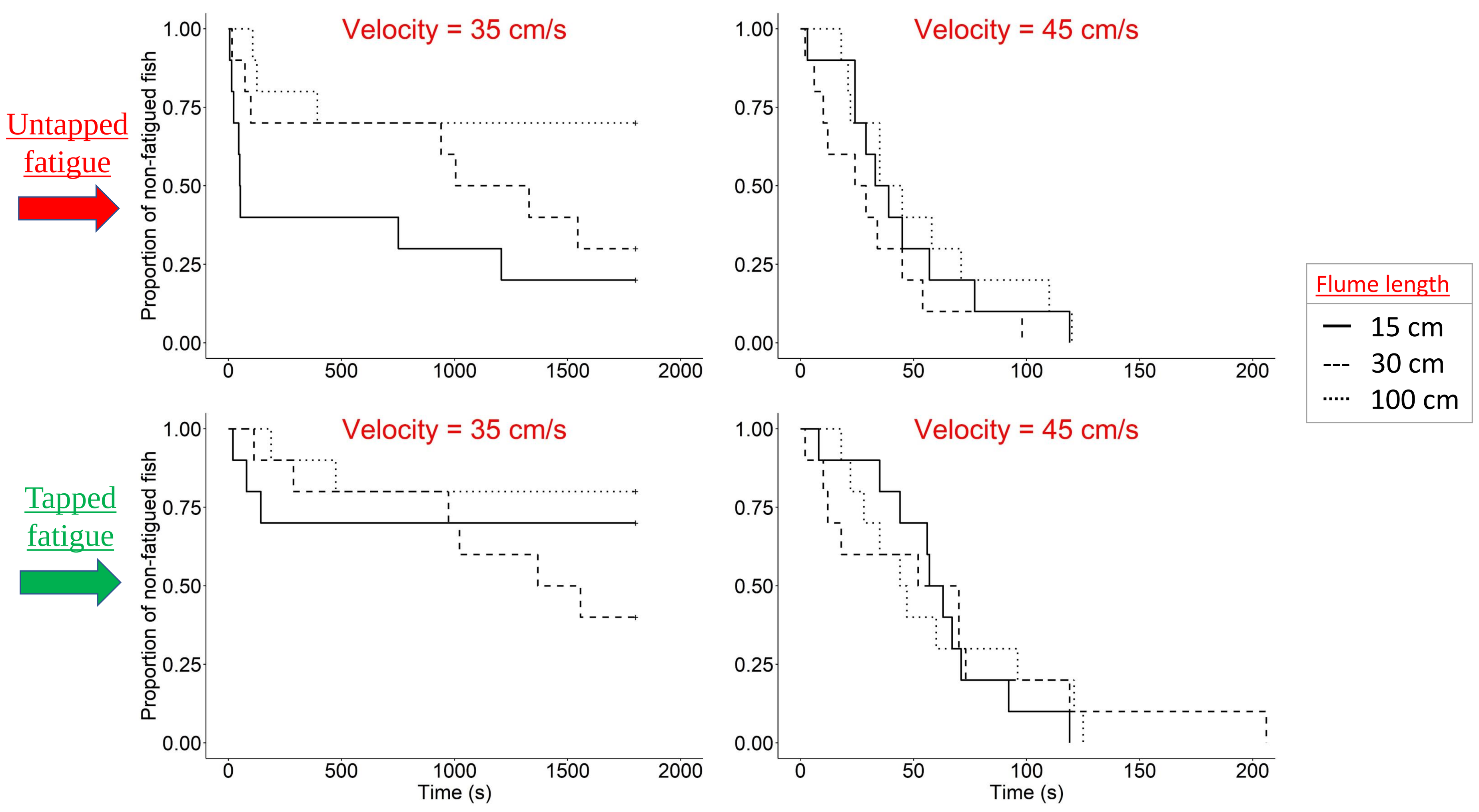
Fatigue time data contains enormous variation.

$$\text{Precision Index} = \text{PrI} = \mathbf{p} \ln\left(\frac{\mathbf{U_M}}{\mathbf{U_m}}\right)$$

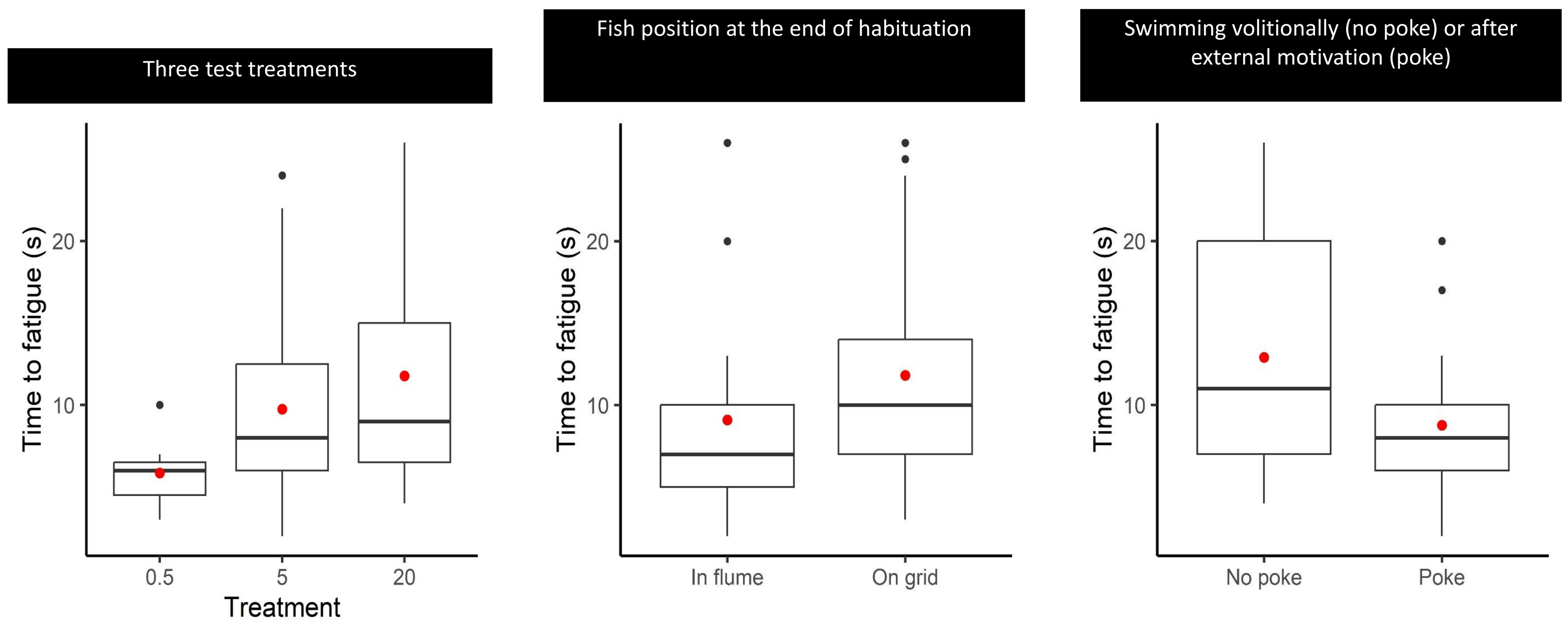
Where **p** is the total number of individual fish data points used
U_M and U_m are the maximum and minimum tested velocities

Results

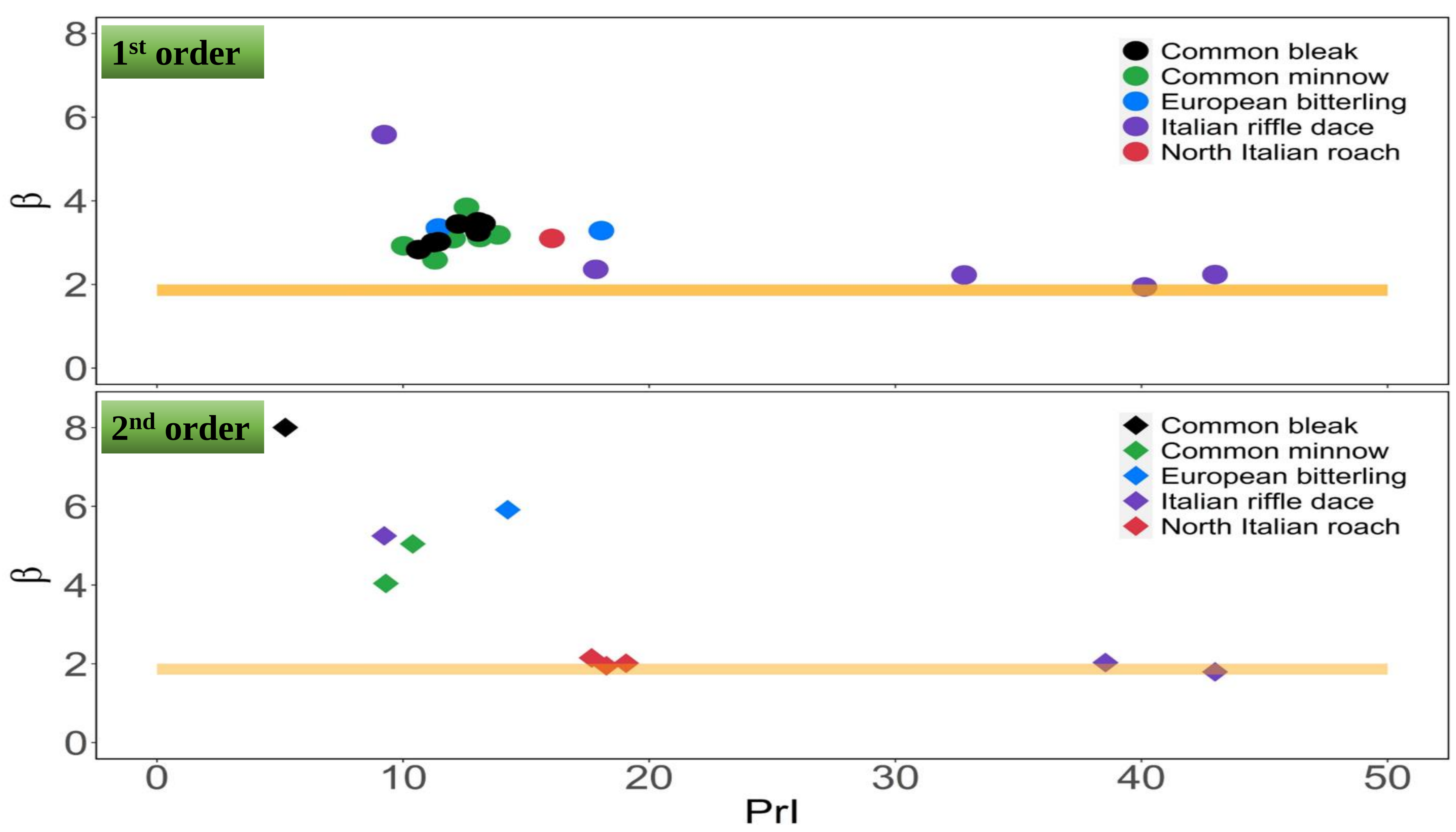
(1) Effect of test flume length and fatigue definitions



(2) Effect of habituation time and fish behaviour



(2) Validating scaling relationship



To remember

- Fish behaviour plays a key role in swimming performance
- Fatigue definition may compromise performance results
- Test flume length influence behaviour as well as performance
- Habituation time is very important in performance tests
- 5-min habituation may be sufficient or at least as effective as 20-min, at least for small-sized fish
- Power law type relationship exist between fatigue time and flow velocity, as supported by experimental data
- Promising universal applications; however, more data on different species is needed to strengthen the argument

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