

Energetic and behavioral metrics for evaluating multi-slot fishway performance

Fishway success must be evaluated by energy use, not just passage

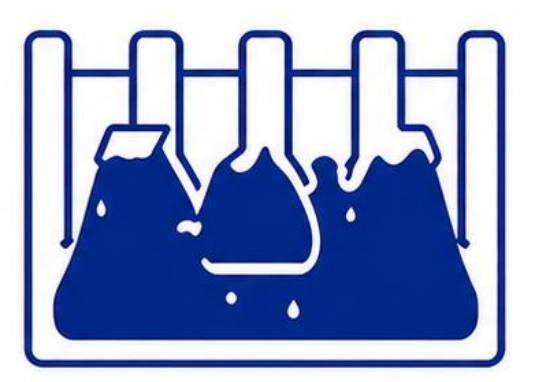
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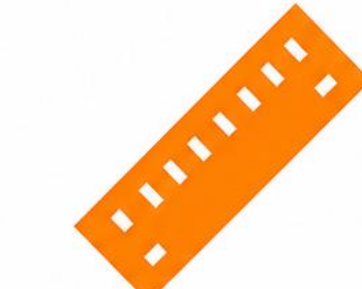
1) Introduction


- Fishway performance is commonly evaluated by the number of fish that pass, ignoring the quality of passage.
- Fish may require multiple attempts and longer durations, increasing fatigue and affecting fitness and survival.
- Low discharge and complex flow (velocity, turbulence) can significantly increase the effort required for successful passage.

2) Methodology

 Experiments in a multi-slot fishway at discharges of 15, 20, and 25 L/s at a slope of 10%.

 Video tracking of individual fish.

 Body length (BL) measured.

 Flow field – Numerical simulation (FLOW-3D).

SWIMMING EFFORT

$$E = \sum_{i=1}^n (U_s + U_f)^{2.8} \cdot \Delta t$$

E = Swimming effort
 n = Number of time steps
 U_s = Fish swimming speed on the track (m/s)
 U_f = Flow velocity at fish location (m/s)
 Δt = Time interval between consecutive steps (s)

3) Results

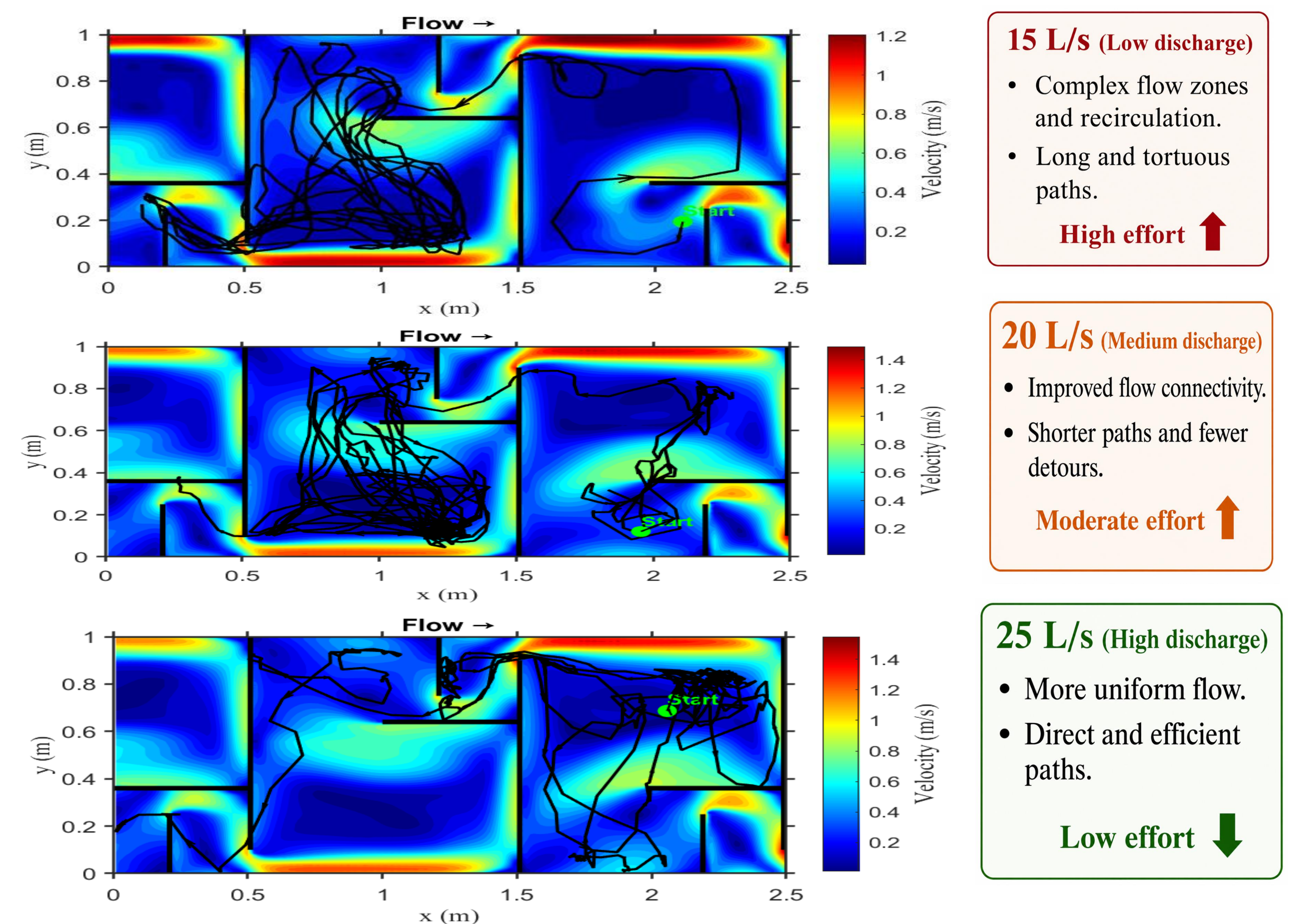


Fig. 1. Flow field and fish trajectory at different discharge

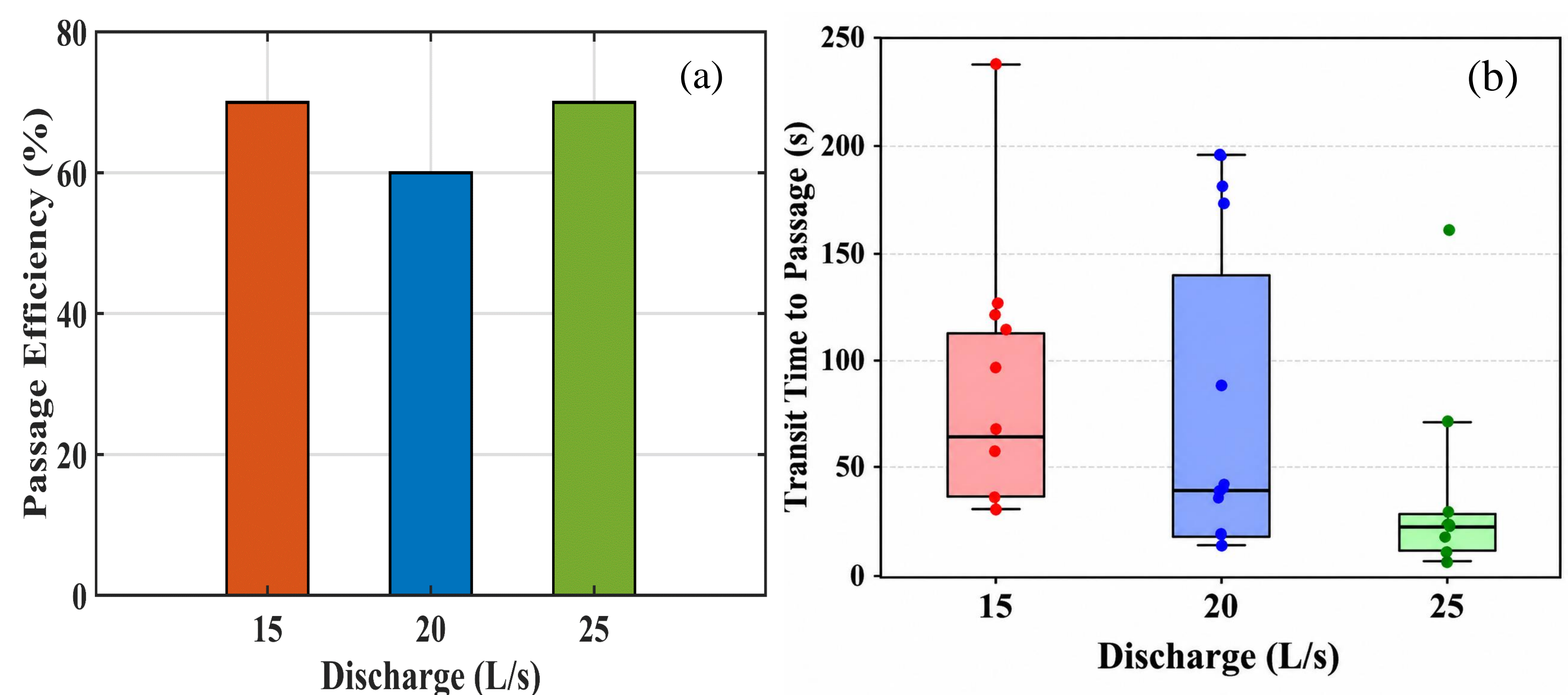


Fig. 2. Comparison of (a) Fish passage efficiency, (b) Transit time, with respect to change in discharge in MSF.

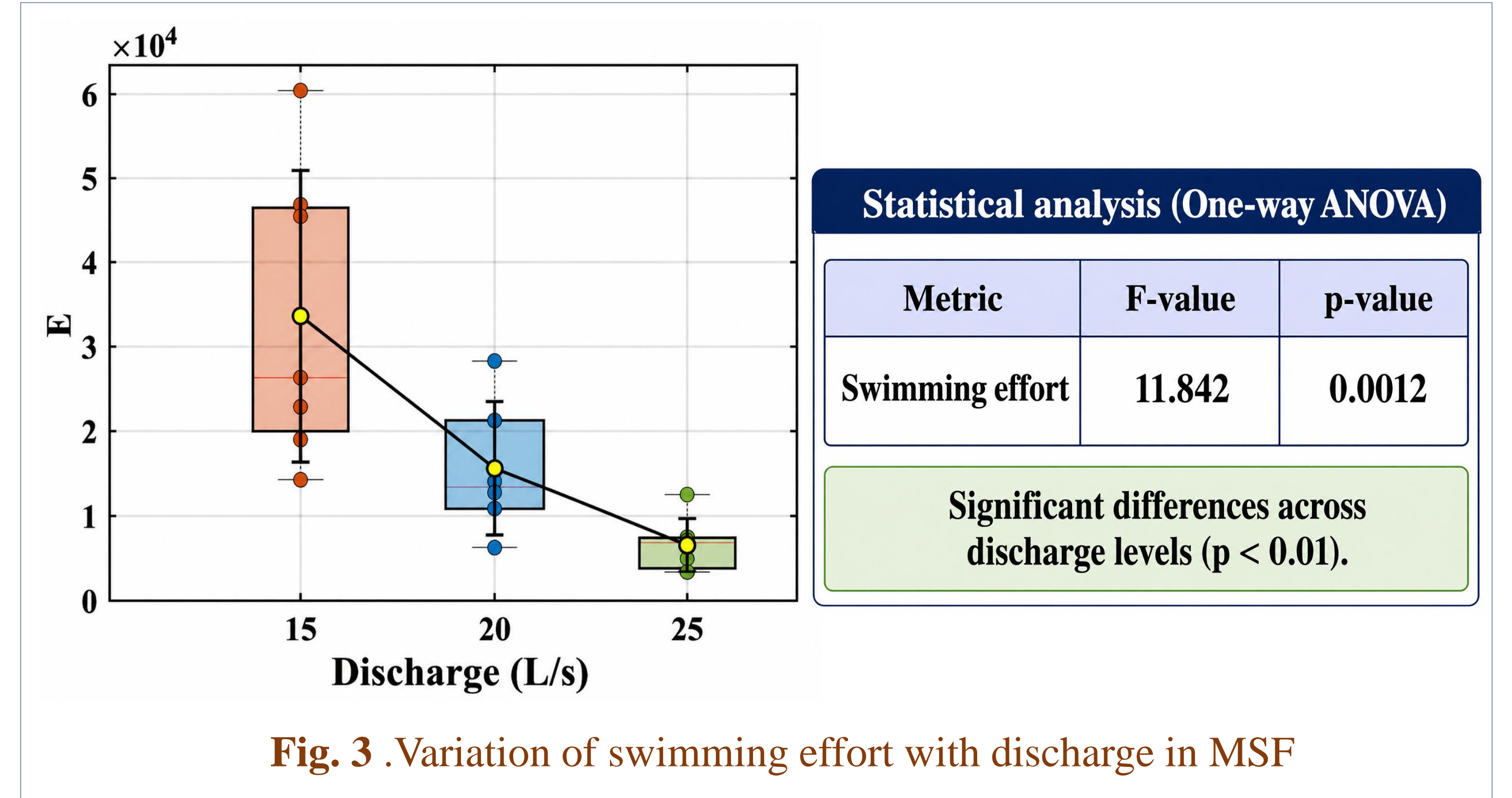



Fig. 3. Variation of swimming effort with discharge in MSF

4) Conclusion

- Energetic and behavioral metrics reveal hidden costs of fish passage that success counts miss.
- Lower discharge creates complex flow, forcing fish to take longer, more energy-intensive routes.
- Combining flow field analysis with fish tracking provides a mechanistic understanding of performance.
- Fishway design and operation should aim to minimize energetic costs, not just maximize passage numbers.

IMPLICATION FOR DESIGN

 Optimize discharge and hydraulic conditions to provide efficient, low-cost pathways that enhance fish fitness and survival.

KEY MESSAGE

 Lower discharge increases energetic cost and passage time, even when fish are able to pass.

PASSAGE EFFICIENCY ≠ PASSAGE QUALITY

Reference

- Castro-Santos, T. R. (2002). Swimming performance of upstream migrant fishes: new methods, new perspectives. University of Massachusetts Amherst.
- Webb, P.W. 1971. The swimming energetics of trout: I. Thrust and power output at cruising speeds. J.Exp.Biol. 55: 189-520.
- Webb, P.W. 1975. Hydrodynamics and energetics of fish propulsion. Bull.Fish.Res.Bd.Canada 190: 1-158.

Key Takeaway: At low discharge, fish expend more energy and take longer, even when they eventually pass. **DESIGN AND OPERATION SHOULD MINIMIZE SWIMMING EFFORT, NOT JUST MAXIMIZE PASSAGE NUMBERS.**