Fish Swimming Performance: Insights from Theory and Experiments

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Abstract

Fish swimming performance is crucial for activities like migration, habitat selection, reproduction, and predator-prey interactions, as well as in designing fish passage systems. Estimating fish swimming performance, using different experimental facilities, is influenced by subjective choices made by scientists. This includes use of different fatigue definitions, flume lengths, and habituation times, among others. These subjective choices not only hinder the comparison of results across studies but also impede the development of a unifying methodology for studying fish swimming performance. Moreover, fish fatigue curves, which quantify swimming performance as a relationship between time-to-fatigue and steady flow velocity, rely solely on empirical observations as obtained from time-consuming and expensive experiments, without much theoretical support. And lastly, there exists a significant knowledge gap in our understanding of fish swimming patterns and behaviour in fast-moving waters, commonly experienced by fish when navigating velocity barriers or holding position in swift streams.

In this PhD work, systematic experiments were carried out to test over 1100 juvenile fish belonging to five small-sized Cypriniformes using a fixed velocity testing protocol. Experiments were conducted to study the effect of different flume lengths, fatigue definitions, and habituation times on fish swimming performance and behaviour. Results show that fish swimming performance is a product of both capability and behaviour and is influenced by all three studied variables. Moreover, a theoretical framework is proposed that builds upon concepts of fish hydrodynamics to derive scaling laws linking statistical properties of time-to-fatigue to flow velocity in burst range. Experimental data on five fish species supports theoretical predictions reasonably well. Finally, fish velocity data was analysed for fish swimming in burst activity level, revealing persistent swimming patterns at time scales of about 1 sec, which are consistent with fish reaction times to visual stimuli.