Abstract Submitted
for the DFD19 Meeting of
The American Physical Society

Sources of drag and optimizing strategies in fish employing undulatory swimming GEN LI, DMITRY KOLOMENSKIY, Japan Agency for Marine-Earth Science and Technology, HAO LIU, Chiba University, Japan, ULRIKE MLLER, California State University Fresno, USA, CEES VOESENEK, JOHAN VAN LEEUWEN, Wageningen University, Netherlands, BENJAMIN THIRIA, RAMIRO GODOY-DIANA, ESPCI Paris-PSL Research University, Sorbonne Universit, Universit Paris Diderot 7, France — Fish undulatory kinematics is not only a means to overcome drag, but also a source of it. By utilizing a computational approach that couples the Navier-Stokes equations with the equations of undulating body motion, we decomposed thrust and drag in swimming fish, and found that the scaling trend of drag during undulatory swimming follows that of a rigid three-dimensional object, while the drag magnitude is strongly influenced by the undulatory kinematics, much exceeding that of a rigid fish gliding at the same speed. By constructing a simulation-based performance map in the frequency-amplitude parameter space, we obtained the speed-specific optimal strategy that minimizes the cost of transport (CoT) during cyclic swimming. The derived optimal strategies for various types of swimmers all suggest that fish should change tail-beat frequency to control speed with a nearly constant tail-beat amplitude. Because drag during coasting is much less than that during undulatory propulsion at the same speed, properly switching between undulatory propulsion and coasting may reduce the cost of transport. We quantitatively investigated the burst-and-coast gaits that minimize CoT in transport with and without target distance , as well as in swimming at various speeds.

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Date submitted: 30 Jul 2019 Electronic form version 1.4