Revealing the Hydrodynamics of Fish Schooling: Flow-Mediated Cohesion, Performance Benefits, and Scaling Laws

Keith Moored
Associate Professor, Department of Aerospace Engineering and Mechanics
Lehigh University

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Abstract:

Fish schools are fascinating examples of self-organization in nature. They serve many purposes from enhanced foraging, and protection against predators to improved socialization and migration. Beyond the implications for biology, engineers can take inspiration from the hydrodynamic benefits of schooling to apply to the design of schools of next-generation bio-robotic vehicles. This new class of schooling unmanned underwater vehicles would enable unprecedented efficiency, maneuverability, agility and stealth; as well as unlock novel missions that require distributed tasks or swarming. However, our understanding of the hydrodynamic interactions in schools is primitive. Importantly, the links from the organization, synchronization, and kinematics of individuals to the performance and stability of a school has yet to established.

In this talk I will present recent work examining the influence of school organization and synchronization on the locomotion performance and stability of simple interacting pitching hydrofoils. Experiments and potential flow simulations will detail the flow interactions that occur among pitching hydrofoils with varying synchronization. Significant thrust and efficiency benefits for the whole school are revealed, and the hydrodynamic mechanisms of drafting, body-to-body interactions, and vortex-body interactions that give rise to these benefits will be examined. It is further discovered that schooling interactions can generate cohesive forces between foils and, specifically, that there are two-dimensionally stable equilibrium arrangements that arise. Focusing in on the side-by-side organization, the origin of the forces that produce an equilibrium arrangement are discovered. New physics-based scaling laws are developed for hydrofoils' equilibrium arrangement, thrust generation, and power consumption, which are found to be in good agreement with inviscid simulations and viscous experiments. Stable arrangements for larger schools of foils and in bio-robots will also be discussed.

Biography:

Dr. Keith Moored is an Associate Professor in the Department of Mechanical Engineering and Mechanics at Lehigh University. He received a B.S. in Aerospace Engineering and a B.A. in Physics at the University of Virginia in 2004, and his Ph.D. in Mechanical and Aerospace Engineering also from the University of Virginia in 2010. From 2010-2013, he was a Postdoctoral Research Associate and Lecturer in Mechanical and Aerospace Engineering at Princeton University. Dr. Moored's research interests are in bio-inspired propulsion, unsteady aerodynamics, and fluid-structure interaction. He is currently leading an ONR MURI topic on the hydrodynamics of schooling and has previously been a PI on another MURI topic on non-traditional propulsion. He has received an NSF CAREER award for examining the fluid dynamic interactions among schooling swimmers.

***This seminar counts towards the ME 600 seminar requirement for Mechanical Engineering graduate students.**