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Hydrodynamics and Hydro-acoustics of Fish Schools: Insights from Computational Models

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Abstract : Fish move in groups for foraging, reproduction, predator protection, and hydrodynamic efficiency. Schooling's predator protection involves the "many eyes" theory, which increases predator detection probability in a group. Reduced visual signature in a group scales with school size, offering per-capita protection. The ‘confusion effect’ makes it hard for predators to target prey in a group. These benefits, however, all focus on vision-based sensing, overlooking sound-based detection. Fish, including predators, possess sophisticated sensory systems for pressure waves and underwater sound. The lateral line system detects acoustic waves, while otolith organs sense infrasound, and sharks use an auditory system for low-frequency sounds. Among sound generation mechanisms of fish, the mechanism of dipole sound relates to hydrodynamic pressure forces on the body surface of the fish and this pressure would be affected by group swimming. Thus, swimming within a group could affect this hydrodynamic noise signature of fish and possibly serve as an additional protection afforded by schooling, but none of the studies to date have explored this effect. BAUVs with fin-like propulsors could reduce acoustic noise without compromising performance, addressing issues of anthropogenic noise pollution in marine environments. Therefore, in this study, we used our in-house immersed-boundary method flow and acoustic solver, ViCar3D, to simulate fish schools consisting of four swimmers in the classic ‘diamond’ configuration and discussed the feasibility of yielding higher swimming efficiency and controlling far-field sound signature of the school. We examine the effects of the relative phase of fin flapping of the swimmers and the simulation results indicate that the phase of the fin flapping is a dominant factor in both thrust enhancement and the total sound radiated into the far-field by a group of swimmers. For fish in the “diamond” configuration, a suitable combination of the relative phase difference between pairs of leading fish and trailing fish can result in better swimming performance with significantly lower hydroacoustic noise.

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