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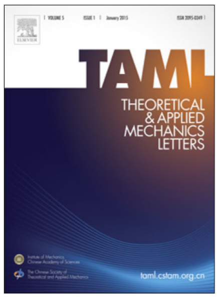

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Passive forces aiding coordinated groupings of swimming animals

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Introduction

When studying fish swimming, as other self-propelled motion, the first point to note is that for steady motion in an infinite inviscid fluid, the forces have to cancel out. So, if a locally backwards moving wake is produced as a reaction to the forward force the fish motions produces, other parts of the field will be moving relatively forwards.

As a result, a second swimmer may then orient itself into this forward moving part of the flow-field. The pressure differences at the borders between these forward and rearward moving streams will indicate to this "hitchhiker" where to go. These gradients will also allow it to stay within the preferred area, and when multiplied by the fish surface area will serve as the "passive forces" mentioned.

The passive force approach will be different in two situations. First, for steady flow situations or for direct interaction between the bodies involved, which we shall call SP. The second, which we shall call time dependent passive forces, or TP, occurs, for example ,when the first body (FB) produces a periodic wake and the second body (SB), which is moving at the same speed as the first, is subjected to periodic forces as the periodic vortices pass it by .

SP will occur for example, when two flexible filaments move in close lateral proximity, and "synchronize" their motions, while TP would occur between individuals in a moving school, as well as in drafting, such as a mother cetacean and her calf [1]. TP would also occur when moving in the wake of a fixed body in a stream (sometimes referred to as the von Karman swimming gait [2] [3]).

As we concentrate on schooling, we examine the TP interaction only in this note. Here the term "passive forces" relates to the effects of the flow-field felt by the follower animal. Such passive forces have been hinted at for many years [5] who called it "follow the leader", i.e, when the leading fish make a change such as a turn of stop, this immediately radiates through the whole scholl, even when vision is impaired.

The schooling model discussed in the 1973 and 1975 papers mentioned previously and quoted in the book "Mathematical Biofluid Dynamics" [5] was highly simplified. First by looking at a small part of a mathematically infinite school, then by assuming that a three dimensional school could be separated into horizontal layers in the direction of motion. Next, the model takes fish that use the are body-caudal fin (BCF) propulsive mode [6] and have large aspect ratio "lunate" tail-fins. As these fins oscillate, the almost rectangular vortex rings shed during each cycle [7] are taken to