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MITRANI DEPARTMENT OF DESERT ECOLOGY

Hydrodynamic constraints on the feeding mechanism of fish larvae during the critical period

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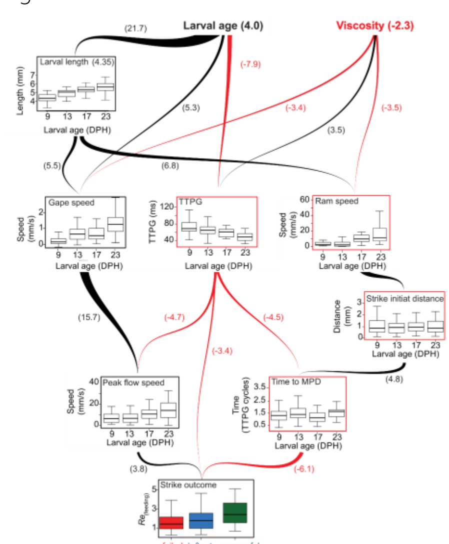
Larval fishes experience extreme mortality rates, with up to 90% of a cohort perishing within days after starting to actively feed. Over a century ago, Hjort (1914) famously attributed this "critical period" of low survival to the larvae's inability to obtain sufficient food. However, no consensus has emerged regarding the role of different mechanisms in determining larval mortality, and specifically in explaining the larvae's inability to obtain food. Here, I explored the proximal mechanisms that govern the ability of larval fishes to capture their prey: specifically, the role of hydrodynamics in structuring these predator-prey interactions. Using feeding experiments and modeling, as well as high-speed video observations of larval feeding behavior, I characterized feeding success and feeding rates in Sparus aurata larvae throughout the critical period. Dynamic-scaling experiments, in which larvae were allowed to forage in viscous medium, were used to examine how older larvae feed in a hydrodynamic regime equivalent to that experienced by younger larvae. I found that hydrodynamic constraints on the ubiquitous suction-feeding mechanism in first-feeding larvae limit their ability to capture prey, thereby reducing their feeding success and feeding rates. Dynamic-scaling experiments revealed that larval size is the primary determinant of feeding rate, independent of other ontogenetic effects. Successful strikes were characterized by Reynolds numbers that were an order of magnitude higher than those of failed strikes. The pattern of increasing strike success with increasing age was driven by the ontogeny of traits that facilitate the transition to higher Reynolds numbers. Modeling the performance landscape for larval feeding revealed that larvae climb towards a peak of higher performance as they mature, and that the landscape is not age-specific. Concomitantly, constraints on the kinematics that are associated with successful feeding relax throughout ontogeny, resulting in older larvae displaying a wider kinematic repertoire. I conclude that first-feeding larvae experience a "hydrodynamic starvation", in which low Reynolds numbers mechanistically limit their feeding performance even under high prey densities. Such constraints should be manifested in starvation and decreased survivorship of smaller larvae that operate in low Re. My study demonstrates how understanding an organism's hydrodynamic environment promotes our understanding of ecological processes; and how large-scale ecological patterns can be governed by small-scale physics.



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