EFFECTS OF AMBIENT WIND OR WATER FLOW ON LOCOMOTION

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INTRODUCTION

Ambient currents and waves in aquatic habitats, and wind in terrestrial habitats, impose forces on organisms. The locomotory performance of organisms swimming in the water column, of animals flying or gliding in the air, and of creatures moving across the substratum is affected by these environmental fluid dynamic forces. Therefore, the functional significance of morphological features and kinematics of locomoting organisms can best be understood if studied under the range of flow conditions they experience in their natural habitats. Examples studied by my students and me will be discussed.

METHODS

Water or air movement can be measured in field habitats on spatial scale scales relevant to a locomoting organism using techniques such as acoustic doppler velocimetry and hot-wire anemometry (1,2). These flow conditions can be recreated in laboratory flumes, wave tanks, or wind tunnels in which locomotory performance and fluid dynamic forces can be measured (1,3,4,5), and fine-scale fluid movements can be quantified using techniques such as planar laser-induced flourescence (Fig.1), particle image velocimetry, and laser Doppler anemometry (1,6).

RESULTS AND DISCUSSION

Many bottom-dwelling marine animals produce microscopic larvae that are dispersed to new sites by ambient water currents. How do these weakly-swimming larvae carried in wavy, turbulent water flow manage to land in suitable habitats? We addressed this question using larvae of a sea slug, *Phestilla sibogae*, which must land on reefs where their prey coral, *Porites compressa*, are abundant. By combining measurements of larval behavior with data about spatially and temporally varying patterns of water velocities and odor concentrations above a reef, we calculated that rates of transport of larvae to a reef by the ambient flow are enhanced by larval responses to coral odor (1,6).

Horseshoe crabs gather in the surf zone to mate. How can they crawl in the waves without being pushed in the wrong direction or overturned by the back-and-forth flow of the waves? We found that their body shape passively resists being pushed backwards or sideways by water flow, but enhances being pushed forward by the waves, so they harness ambient flow to enhance their directional locomotion. Furthermore, if a horseshoe crab is dislodged or overturned, its body shape causes it to land right side up.

Shore crabs, *Grapsus tenuicrustatus,* also live on wave-swept shores, where they spend part of their time in air and part underwater. The kinematics of their running in air, where gravity predominates, is very different from their kinematics when running underwater, where hydrodynamic forces predominate. Drag, lift, and acceleration reaction forces limit when and where these crabs can be active (3).

"Flying frogs", which have evolved in two lineages of tree frogs, have enlarged webbed hands and feet that were thought to enhance their glide distance. Instead, we found that these features make flying frogs unstable, but highly maneuverable (4,5). They must maneuver through complex forest canopies as they parachute to breeding pools, which they do at night when wind gusts in the forest rarely occur (2).

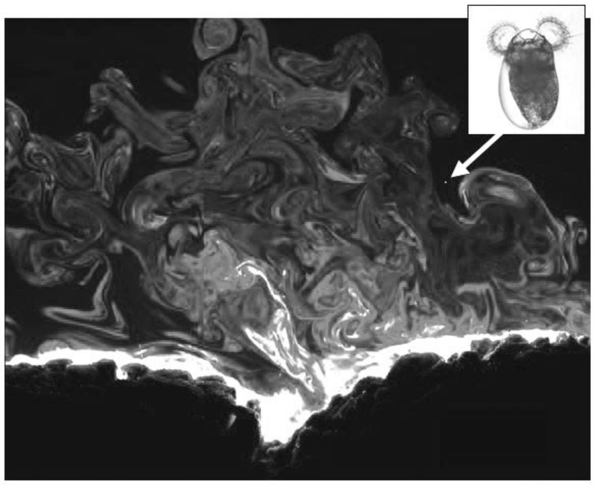

Figure 1: Frame of a video of planar laser-induced fluorescence (PLIF) imaging of concentrations of dissolved odor released by a coral reef into turbulent wave-driven water flow in a flume (image width = 24cm). Dark objects at the bottom of the image are corals, *Porites compressa*; light swirls are odors from the corals dispersing in the water above the reef (the lighter the pixel, the higher the concentration). Inset: Planktonic veliger larva (230µm long) of a sea slug, *Phestilla sibogae.*

CONCLUSIONS

Ambient fluid motion is utilized in the locomotion of microscopic marine larvae and by horseshoe crabs, and it affects the locomotion of shore crabs and gliding tree frogs.

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