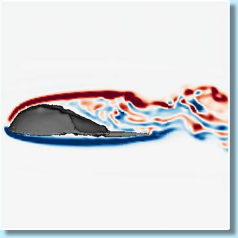

Simulated vorticity around a horseshoe crab

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Hydrodynamics of the American Horseshoe Crab *(Limulus polyphemus)*

The intertidal zone is a turbulent landscape where organisms face numerous mechanical challenges from powerful waves. A model for understanding the solutions to these physical problems, the American Horseshoe Crab *(Limulus polyphemus)*, is a marine arthropod that mates in the intertidal zone, where it must contend with strong ambient flows to maintain its orientation during locomotion and reproduction. Strategies to maintain position include for the shell to produce negative lift, or to minimize positive lift, in flow. To quantify flow over the shell and the forces generated, the 3D shape of a horseshoe crab shell was scanned, and the resulting digital reconstruction was used to 3D-print a physical model. We then recorded the movement of tracking particles around the shell model, under flow. Our time-lapse image series were analyzed by particle image velocimetry (PIV), which allowed for experimental visualization of the flow structure for comparison to simulations. The velocity vector fields were used to validate numerical simulations performed using the immersed boundary (IB) method. We used IB to simulate fully-coupled fluid-structure interactions (FSI) to solve for the forces on the shell, as well as velocity, pressure, and vorticity around the object. IB simulations and PIV analysis of vorticity and velocity at a flow speed of 13 cm/s reveal that there is a turbulent area downstream of the joint between the carapace and the abdomen. In this area of alternating vorticity, there is upward fluid motion (negative lift). We predict that this negative lift maintains the orientation of the crab during locomotion and mating. This study provides a foundation for assessing the relationship between documented morphological variation and potential environmental variation for distinct populations of horseshoe crabs along the Atlantic Coast. Additionally, quantifying the forces generated by the shell in flow may inform the engineering design of manmade structures that require lift reduction, as well as improve our understanding of the adaptive morphology of the shell.