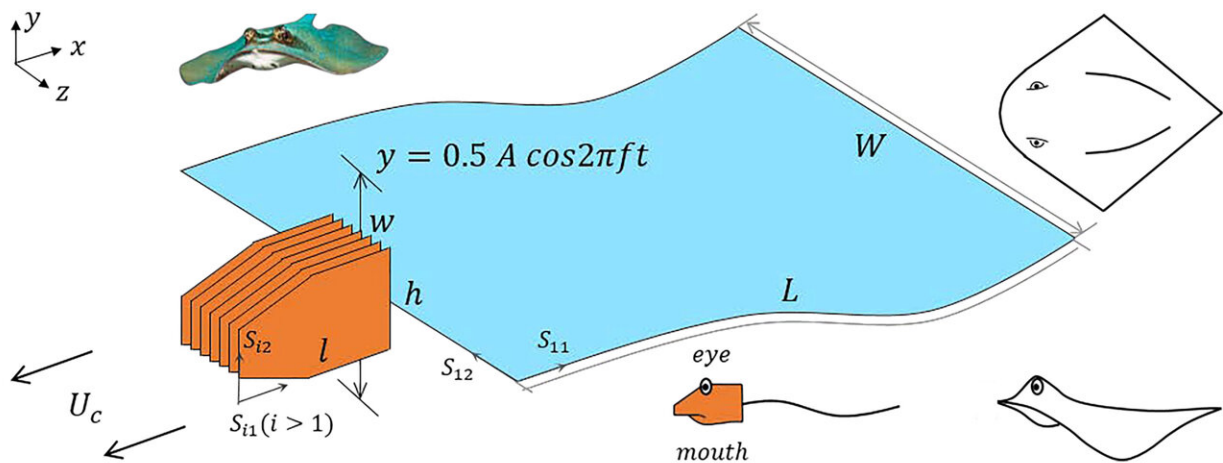


Protruding eyes, mouth make stingrays more hydrodynamically efficient

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Schematic of the self-propelled flexible plate with eyes and mouth. Credit: Qi-an Mao

With their compressed bodies and flexible pectoral fins, stingrays evolved to be among nature's most efficient swimmers. Scientists have long wondered about the role played by their protruding eyes and mouth, which one might expect to be hydrodynamic disadvantages.

In *Physics of Fluids*, Chinese and South Korean researchers detail how such features on simulated stingrays affect a range of forces involved in propulsion, such as pressure and vorticity. Despite what one might expect, the group found these protruding features to help streamline stingrays even further.

"The influence of 3D protruding eyes and mouth on a self-propelled flexible stingray and its underlying hydrodynamic mechanism are not yet fully understood," said author Hyung Jin Sung, from the Korea Advanced Institute of Science and Technology. "In the present study, the hydrodynamic benefit of protruding eyes and mouth was explored for the first time, revealing the hydrodynamic role of protruding eyes and mouth."

To illustrate the complex interplay between hydrodynamic forces, the researchers set to work creating a computer [model](#) of a self-propelled flexible plate. They "clamped" the front end of the model and then forced it to mimic the up-and-down harmonic oscillations stingrays use to propel themselves.

To re-create the effect of eyes and mouth on the surrounding water, the team simulated multiple rigid plates on the model. They compared this model to one without eyes and mouth using a technique called the penalty immersed boundary method.

"Managing random fish swimming and isolating the desired purpose of measurement from numerous factors are difficult," Sung said. "To overcome these limitations, the penalty immersed boundary method was adopted to find the hydrodynamic benefits of the protruding eyes and mouth."

The group discovered the eyes and mouth generated a vortex of flow in the forward-backward, which increased [negative pressure](#) at the

simulated animal's front, and a side-to-side vortex that increased the pressure difference between above and below the stingray. The result was increased thrust and accelerated cruising.

Further analysis showed the eyes and [mouth](#) increased overall propulsion efficiency by more than 20.5% and 10.6%, respectively.

Sung and his team hope their work, driven by curiosity, further stokes interest in exploring fluid phenomena in nature. They are looking to finding ways to adapt this for next-generation water vehicles designs based more closely on marine animals.

More information: "Hydrodynamic benefits of protruding eyes and mouth in a self-propelled flexible stingray" *Physics of Fluids*, aip.scitation.org/doi/full/10.1063/5.0061287

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