

Paradox in a Box

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Bio 21

Sam Von Wassenburgh taps his pencil against his clipboard in anticipation. This is it. Before him sits an aquarium, whose only inhabitant is a fist-sized piece of plastic roughly resembling a cube. The object is suspended by a thin metal rod, it spins and tilts as water flows through the tank, each miniscule movement recorded by sensors.

He lets out a cautious sigh. If all went well, he might find the answer to a problem that has baffled experts for decades. A creature with a square shaped body that, while seemingly not hydrodynamic, seemed to glide through the water with little drag. A creature capable of wild and chaotic turns at the blink of an eye, yet, as many scientists had described, whose movements seemed self-correcting. The combination of easily turning while stabilizing, moving without resistance while resisting unwanted movement. This is the great paradox. A paradox so curious and intriguing that Mercedes-Benz designed a car after it. A paradox that maybe, just maybe, he would be the one to solve.

Almost 10,000 miles away, a little yellow boxfish deftly navigates a maze of coral. It careens around obstacles, using its back fins as a rudder to expertly avoid collision. As it scans rocks for algae and plucks juicy shrimp from the sand, a long, streamlined shadow approaches from above. A silvertip shark spies the square-shaped animal and quickly descends, too hungry to be deterred by the bright yellow skin and black polka dots which loudly signal danger. For a moment, the two fish resemble a high-speed car chase. The boxfish, turning corners, and quickly changing direction, with the faster but less nimble shark in hot pursuit. Per body length, the boxfish is faster than the silvertip, but in overall speed it is no comparison and the shark closes in. But the boxfish has one more trick up its sleeve, or should I say, up its skin.

In its frantic state the boxfish releases an invisible cloud of mucous from each of its six sides. The toxic mucous foams and froths in the water, leaving a trail of bubbles in the boxfish's wake. As the shark races along behind, the bubbles enter its gills, and something strange happens. When the soapy toxins reach the bloodstream they dissolve the membranes of the shark's blood cells, causing them to burst. Without red blood cells to carry oxygen, the shark starts suffocating from the inside out. The silvertip flees in shock, swimming far from this dangerous would-be-prey, and the yellow boxfish continues its day pattering about.



Late at night, in the harsh glow of a computer screen, a wide grin spreads across Sam Von Wassenburgh's face. If he did not exclaim "aha!" he was certainly thinking it, for in the numbers and graphs and charts before him, a trend had finally emerged.

The boxfish's rounded corners and lightly curved sides were far better at speeding through the water than a perfect cube (not to mention remarkably fast given that the boxfish is essentially encased in a ridged shell) but they were not at all close to the efficiency of a more



traditional "fish-shaped" fish (as many had claimed). Perhaps most surprisingly however, was that the long sought after stabilizers – the root of the paradox – were nowhere to be seen! Not only was there no evidence for any sort of shape induced stabilization during turns, the cube-like body was actually *destabilizing*! But if this was truly the case, how do we explain the boxfish's ease and control of motion?

When designing his experiment, Von Wassenburgh was focusing on the fish's body shape, as this was conventionally believed to be the cause of these paradoxical properties. In doing so, however, he overlooked something very important: the fins. While the boxy body shape makes sharp turns fast and easy, the fin position and dexterity are what keep the fish stable and on course. Body and fins work together to make the swift, high-precision movements we see in the wild. As Von Wassenburgh showed, boxfish are eye-catching, but they are so much more than meets the eye.

Sources:

Van Wassenbergh, Sam, et al. "Boxfish swimming paradox resolved: forces by the flow of water around the body promote manoeuvrability." *Journal of The Royal Society Interface* 12.103 (2015): 20141146.

Thomson, Donald A. "Ostracitoxin: an ichthyotoxic stress secretion of the boxfish, *Ostracion lentiginosus*." *Science* 146.3641 (1964): 244-245.