# Dolphin-power sufficient for propulsion without tricks

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For 60 years the world has believed that dolphins did not have enough muscle to propel them at high speed and that they were resorting to some fluid-flow trickery to pull off their impressive performance. But Frank Fish from West Chester University, USA, never believed it and now he has proved that not only do dolphins have sufficient muscle power, but also they routinely produce ten times more power than the fittest human athletes.

When Mr E. F. Thompson stood on a ship cruising through the Indian Ocean in the 1930s and observed a dolphin speed past the vessel in 7 seconds, he had no idea that this single observation would lead Sir James Gray to formulate the enduring paradox that bears Gray's name to this day. Based on Thompson's anecdote, Gray estimated the power required to propel the boisterous mammal through the waves at 20 knots (10.3 m/s) and concluded that the animal did not have enough muscle to pull off the feat. Puzzled by the paradox, Gray concluded that dolphins must use a trick of fluid mechanics to sustain the remarkable performance.

And there the paradox stood until Frank Fish from West Chester University, USA, got his teeth into the problem 60 years later. 'I said, "Let's see how much power a dolphin can produce," so I used some hydrodynamics models that looked at the motion of the flukes and came up with the realisation that dolphins could produce very high amounts of power', recalls Fish. But these were only theoretical calculations. To really sound the paradox's death knell he would have to measure directly the force exerted by the animal on water and, although there is a method

– known as digital particle image velocimetry (DPIV) – to visualise eddies in the water in order to measure the forces exerted by fish, it wasn't clear how the same approach could be used on dolphins: 'No one is going to let you put a 55 gallon drum of glass beads in with a dolphin and no one is going to let you shine a laser beam at a dolphin', says Fish.

That was until Fish met Timothy Wei, from the University of Nebraska, USA, at a conference. Wei had encountered the same technical problems when working with Olympic swimmers, but he had got round it by asking the Olympians to swim through a curtain of microscopic bubbles. Could the same approach work for dolphins? Fish contacted his long-time friend Terrie Williams and asked if he could test the method on her dolphins, Primo and Puka.

Arriving at the University of California at Santa Cruz with a SCUBA tank of compressed air and a garden soaker hose to produce the curtain of bubbles, Fish teamed up with Wei, graduate student Paul Legac and Williams to put the dolphins through their paces. Filming the animals as they swam along the length of the bubble curtain, the team could clearly see the vortices set spinning by the dolphins' flukes demarcating the powerful jet of water propelled backwards as the animals surged forward. 'We were in this concrete underwater viewing area… it was cold and damp, but you would get really excited and forget about that as you saw the animal go past and you'd see the vortices come out so nicely', recalls Fish.

And when Legac and Wei calculated the amount of power produced by the animals as they cruised at a leisurely 3.4 m/s, the animals were producing an impressive 549 W – approximately 1.4 times the power that a fit amateur cyclist can sustain flat out for an hour – rocketing to an eye-watering 5400 W when accelerating rapidly. The team publishes their discovery that there is no paradox in the *Journal of Experimental Biology*.

So, the dolphins did have enough muscle to power their impressive swimming performance because they are simply stronger than humans. And, having proved that the method works for dolphins, Fish is keen to test it out on even larger animals. 'If I can do it for a dolphin, can I do it for a whale? Can I do it for a manta ray?' he grins.

**More information:** Fish, F. E., Legac, P., Williams, T. M. and Wei, T. (2014). Measurement of hydrodynamic force generation by swimming dolphins using bubble DPIV. J. Exp. Biol. 217, 252-260. jeb.biologists.org/content/217/2/252.abstract

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