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INSIDE JEB

Manta rays bank like planes to take turns

A manta ray (*Mobula birosris*). Photo credit: Frank Fish.

It might seem like the stuff of 1960s science fiction, but the US Navy is intrigued by the stealth and manoeuvrability of manta rays. These colossal creatures could inspire the next generation of autonomous underwater vehicle designs. Having already filmed the enigmatic rays in captivity in aquaria in Okinawa, Japan, and Georgia, USA, Frank Fish, from West Chester University, USA, knew that the rays unhurriedly flap their fins up and down as they propel themselves effortlessly through the water. But he really wanted to get to grips with how the rays make turns with their massive 9 m pectoral fin span. Explaining that he was unable to film the captive rays from above to capture their turning manoeuvres, Fish decided that the only alternative was to film the rays in their natural surroundings with a pair of cameras to get a 3D perspective of the graceful motion, which meant travelling to the tropical island paradise of Yap in the western Pacific.

As Yap is popular with tourists keen to see the manta rays, Fish was certain that the enigmatic animals would by unconcerned by SCUBA-diving humans filming them as they visited a cleaning station in one of the island's lagoons. He recalls that the main risk was running out of air: 'We were 24 m underwater. The only danger was not watching how long you were down to avoid the bends. There were sharks and moray eels but they really didn't bother you', he laughs. However, it took two attempts for Fish and his dive buddies Michael Dudas and Keith Moored to get the camera setup right. 'The first year we showed that we could film the mantas in stereo, but the cameras were held by hand so there was some error in synchronizing the video to get a 3D reconstruction. The second year we mounted the cameras on tripods set on the bottom and everything went smoothly', he says, recalling how the trio successfully filmed seven manta rays (*Mobula birosris*) as the animals swept around 30 turns ranging from 0.5 to 14 m in radius.

Returning safely from the Pacific, Fish painstakingly reconstructed the manta rays' movements from the movies and teamed up with West Chester University colleagues Allison Kolpas and Andrew Crossett to deconstruct the manoeuvres in fine detail. Analysing the leisurely turns, the team calculated that the rays turned at a maximum rate of 67 deg s^{-1}, with an average turning speed of 18 deg s^{-1}, and realised that the rays have two strategies for making a turn. 'They either beat their fins with the outboard fin beating faster than the inboard fin to turn, or hold the inboard fin motionless with the tip held above the level of the body and the outboard fin beating', says Fish. In addition, the animals bank like a plane as they swing around. However, Fish points out that their rigid bodies make them less manoeuvrable than other ocean behemoths, which can flex their bodies to turn on a dime.

'It was a high-risk project with a high probability of failure', says Fish, who is passionate about diving and is delighted that the experimental work and analysis came together so well. And he is keen to find out more about the manta ray's aquabatics. 'I would like to look at the somersaults that mantas perform to see their vertical manoeuvrability', says Fish, who can't wait to return to the Pacific.

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Fish, F. E., Kolpas, A., Crossett, A., Dudas, M. A., Moored, K. W. and Bart-Smith, H. (2018). Kinematics of swimming of the manta ray: three-dimensional analysis of open-water maneuverability. *J. Exp. Biol.* **221**, doi:10.1242/jeb.166041.

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