© 2020. Published by The Company of Biologists Ltd | Journal of Experimental Biology (2020) 223, jeb237883. doi:10.1242/jeb.237883

INSIDE JEB

How whale-surfing remoras stay in touch with their steeds

A remora attached to the skin of a blue whale. Photo credit: Stanford University & Cascadia Research Collective. Image collected under NMFS permit #16111.

When it comes to hitching a ride, whale-surfing remoras are perfectly at home latching onto the largest creatures on the planet. 'From static photos, it's easy to assume that the remora is anchored in a single spot on their host for lengthy periods', says Brooke Flammang from the New Jersey Institute of Technology (NJIT), USA. But when she saw Jeremy Goldbogen's movies of blue whale-riding remoras at the 2015 Society for Integrative and Comparative Biology conference, the images blew her mind. 'Jeremy joked that he had, "inadvertently gotten hundreds of hours of remora footage"', she laughs. But the movies, captured by tags attached to the colossal mammals, revealed the inverted fish skating across the whales' skin to different locations. Transfixed, Flammang was frantically trying to figure out how the fish remained in contact with the whales, without being torn free by the fast-flowing water as the massive mammals dived. A few days later, at a lunch with Goldbogen, from Stanford University, USA, and her long-time collaborator Jason Nadler, from Georgia Tech Research Institute, USA, they were also gripped by the mystery. 'We wanted to know how the remoras moved along the whale and why they attached where they did', says Flammang.

But first, David Cade, also from Stanford University, spent hours trawling through the movies for photobombing remoras to figure out where the fish favoured to grip onto their whale steeds. Eventually, it was apparent that the fish favoured three zones on whale bodies: behind the blowhole; behind and next to the mini-fin on the whale's back; and above and behind the pectoral fin. The fish even remained attached when the whales surfaced, clinging on out of the water. In addition, when the remoras lifted off from one location, skimming a few centimetres above the whale's skin to another, they were never torn free by the water rushing past.

Curious to learn how water slides over the whale's body, Michael Beckert and Nadler initially built a computer program. However, to reveal the fine detail of the water movement on the remora's scale, Flammang needed a truly formidable supercomputer. Flammang teamed up with Simone Marras (also from NJIT), in collaboration with Oriol Lehmkuhl, Guillame Houzeaux and Mariano Vázquez at the Barcelona Supercomputer Centre, Spain, to perform the immense 48 h long calculation over more than 9 million points dotted around the 18 m body of a whale swimming at 1.5 m s^{-1}. Analysing the calculations, the team discovered that the drag experienced by the fish sheltering behind the dorsal fin, blow hole and pectoral fins was ∼80% less than the drag if they were swimming freely at 1.5 m s^{-1}. They also revealed drag reductions ranging from 50% to 75% as the remoras lifted off 1 cm from the whale's skin and skimmed across various locations on the mammal's body. The fish manoeuvre with ease in the slow-moving cushion of water carried along by whales as they scythe through the sea.

Erik Anderson and Flammang also investigated how remoras attach to a moving surface in the lab, to find out whether the water sandwiched between the fish and its whale-ride when skimming across the surface might help to hold the fish in place. Impressively, a region of fast-flowing water in the space between the fish and whale effectively sucks the remora toward the whale's body.

So, whale-surfing remoras stay in touch with their steeds by riding in the cushion of water carried by the colossal beasts and Flammang and her colleagues are hoping to use the remora's know-how to keep the cameras used by scientists in place for longer.

10.1242/jeb.237883

Flammang, B. E., Marras, S., Anderson, E. J., Lehmkuhl, O., Mukherjee, A., Cade, D. E., Beckert, M., Nadler, J. H., Houzeaux, G., Vázquez, M. et al. (2020). Remoras pick where they stick on blue whales. *J. Exp. Biol.* **223**, jeb226654. doi:10.1242/jeb.226654

Kathryn Knight
kathryn.knight@biologists.com