INSIDE JEB

# Leaping small fish out-power breaching whales

A breaching humpback whale. Photo credit: Gregory 'Slobirdr' Smith [CC BY 2.0 (https://creativecommons.org/licenses/by/2.0)].

When Emmett Johnston from Queen's University, Belfast, UK, attached a motion sensing tag to a basking shark off the Irish coast, he expected the piece of kit to have a sedate ride. Nothing prepared Johnston and colleagues for the rollercoaster that the sensor went on in practice. 'Having retrieved it, we watched the video and, to our amazement, the movie ended with the shark suddenly accelerating up through the water column, hitting the water surface at 5 m $s^{-1}$ and breaching for about a second', says Lewis Halsey from the University of Roehampton, London, UK. The massive fish was behaving more like cavorting gray whales or leaping salmon than the lethargic filter feeder it was meant to be. The team calculated that each leap could use up to 1/17th of the animal's daily metabolic budget (doi:10.1098/rsbl.2018.0537). However, after reviewing movies of breaching basking sharks filmed by observers on land, Halsey suspected that it might be possible to calculate the amount of energy an aquatic animal requires to make it into the air from the footage. 'I thought there must be lots of video available of other aquatic species breaching', says Halsey. Could he find a way to calculate how much power it takes for fish, whales and dolphins to surge out of the water from movies shot by citizen scientists?

Halsey turned to the millennials' TV channel of choice. 'I kept searching YouTube with names of fish and cetaceans and various words for jumping until I couldn't find any more', he chuckles, recalling how, eventually, he ended up with almost 30 clips of species ranging from a 20 cm long African tetra to a 13 m long humpback whale. Then Halsey teamed up with Gil Iosilevskii from the Technion, Israel, to calculate the animals' sheer power and speed as they burst out of the water. 'Gil did the hardcore maths', recalls Halsey, adding, 'He is one of the few people around with the capacity to develop the equations we used to estimate power output from the videos'. Halsey then estimated the animals' sizes, measured the length of time each animal was airborne and determined several other values before plugging them into Iosilevskii's equations.

Amazingly, the common bottlenose dolphins and spinner dolphins (both ∼2 m long) hit the highest take-off speeds of ∼10.7 m $s^{-1}$ (38.5 km $h^{-1}$), with the smaller species achieving progressively lower speeds; the slowest leaps were performed by the diminutive African tetra, which took off at only 4.4 m $s^{-1}$. Meanwhile, the largest creatures, including the basking shark, great white shark and massive humpback whale hit speeds ranging from 5.8 to 9.1 m $s^{-1}$; they didn't come close to challenging the dolphins' speed. However, when the duo compared the peak muscle power of the animals, it was clear that the smaller species – including mackerel, mullet and the common bottlenose dolphin – generated the highest muscle powers of over 50 W per kg of muscle when jetting out of the waves. In contrast, the heftier great white shark, orca and humpback whale, managed less than 10 W per kg of muscle.

Halsey suspects that the smaller species' powerful departures 'represents an estimate of a universal upper limit to power output', adding that their pound-for-pound power was very similar to that of top human athletes performing right at their physical limits. 'When these animals are breaching at their fastest, they might well be performing at maximum effort', says Halsey.

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**Halsey, L. G. and Iosilevskii, G.** (2020). The energetics of 'airtime': estimating swim power from breaching behaviour in fishes and cetaceans. *J. Exp. Biol.* **223**, jeb216036. doi:10.1242/jeb.216036

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