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Blue Whale-Sized Mouthfuls Make Foraging Super Efficient

How much can a blue whale eat in a single mouthful and how much energy do they burn while foraging? These are the questions that Bob Shadwick from the University of British Columbia, Canada, and his colleagues have asked. They discovered that blue whales can swallow almost 2,000,000kJ (almost 480,000kcalories) in a single mouthful of krill, and eat 90 times as much energy as they burn during a dive.

Diving blue whales can dive for anything up to 15 minutes. However, Bob Shadwick from the University of British Columbia, Canada, explains that blue whales may be able to dive for longer, because of the colossal oxygen supplies they could carry in their blood and muscles, so why don't they?

'The theory was that what they are doing under water must use a lot of energy,' says Shadwick. Explaining that the whales feed by lunging repeatedly through deep shoals of krill, engulfing their own body weight in water before filtering out the nutritious crustaceans, Shadwick says, 'It was thought that the huge drag effect when they feed and reaccelerate this gigantic body must be the cost'. However, measuring the energetics of blue whale lunges at depth seemed almost impossible until Shadwick and his student Jeremy Goldbogen got chatting to John Hildebrand, John Calambokidis, Erin Oleson and Greg Schorr who were skilfully attaching hydrophones, pressure sensors and two-axis accelerometers to the elusive animals. Shadwick and Goldbogen realised that they could use Calambokidis's measurements to calculate the energetic cost of blue whale lunges. They publish their discovery that blue whales swallow almost 2,000,000kJ (almost 480,000kcalories) in a mouthful of krill, and take in 90 times as much energy as they burn during a single dive in The Journal of Experimental Biology.

Analysing the behaviour of each whale, Goldbogen saw that dives lasted between 3.1 and 15.2 minutes and a whale could lunge as many as 6 times during a single dive. Having found previously that he could correlate the acoustic noise of the water swishing past the hydrophone with the speed at which a whale was moving, Goldbogen calculated the blue whales' speeds as they lunged repeatedly during each dive. Next the team had to calculate the forces exerted on the whales as they accelerated their colossal mouthful of water. Noticing that the whales' mouths inflated almost like a parachute as they engulfed the krill, Goldbogen tracked down parachute aerodynamics expert Jean Potvin to help them build a mathematical model to calculate the forces acting on the whales as they lunged. With Potvin on the team, they were able to calculate that the whales used between 3226 kJ of energy during each lunge. But how did this compare with the amount of energy that the whales could extract from each gigantic mouthful of krill?

Goldbogen estimated the volume of the whales' mouths by searching the whaling literature for morphological data and teamed up with paleontologist Nick Pyenson to measure the size of blue whale jaw bones in several natural history museums. He also obtained krill density values from the literature -- which are probably on the low side. Then he calculated the volume of water and amount of krill that a whale could engulf and found that the whales could consume anything from 34,776kJ up to an unprecedented 1,912,680kJ from a single mouthful of krill, providing as much as 240 times as much energy as the animals used in a single lunge. And when the team calculated the amount of energy that a whale could take on board during a dive, they found that each foraging dive could provide 90 times as much energy as they used.

Shadwick admits that he was initially surprised that the whales' foraging dives were so efficient. 'We went over the numbers a lot,' he remembers, but then he and Goldbogen realised that the whales' immense efficiency makes sense. 'The key to this is the size factor because they can engulf such a large volume with so much food in it that it really pays off,' says Shadwick.

Journal Reference: 1. J. A. Goldbogen, J. Calambokidis, E. Oleson, J. Potvin, N. D. Pyenson, G. Schorr, R. E. Shadwick. Mechanics, hydrodynamics and energetics of blue whale lunge feeding: efficiency dependence on krill density. Journal of Experimental Biology, 2010; 214 (1): 131 DOI: 10.1242/jeb.048157