False killer whales use acoustic squint to target prey

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Hunting in the ocean's murky depths, vision is of little use, so toothed whales and dolphins (odontocetes) rely on echolocation to locate tasty morsels with incredible precision. Laura Kloepper from the University of Hawaii explains that odontocetes produce their distinctive echolocation clicks in nasal structures in the forehead and broadcast them through a fat-filled acoustic lens, called the melon.

"Studies by other people showed odontocetes have the ability to control the shape of the echolocation beam and it has always been assumed that they are using the melon to focus sound," explains Kloepper. "However, no one had ever tested this directly, so Kloepper and her PhD supervisor, Paul Nachtigall, decided to tackle the question." They publish their discovery that false killer whales are able to focus their echolocation beams on targets in The Journal of Experimental Biology.

So, how did the team make this amazing discovery? Fortunately, the duo is based at the Marine Mammal Research Program at the University of Hawaii, which is home to Kina the false killer whale. Kloepper explains that Kina is extremely adept at working with marine biologists after decades of dedicated work by Marlee Breese and her training staff. On this occasion, Kina had been trained to recognise a 37.85-mm-wide cylinder with 6.35-mm-thick walls by echolocation, signalling that she had recognised the cylinder by touching a button in return for a fish reward. However, when Kina encountered other cylinders – with different wall thicknesses – she was trained to remain still before receiving her fishy prize. The team then selected two other cylinders to test her echolocation abilities: one with much thicker walls (7.163mm) that Kina could detect with ease and another with only marginally thicker walls (6.553mm) that Kina had more difficulty distinguishing from the 6.35mm cylinder. Then, over a period of weeks, Nachtigall, Breese and Kloepper randomly presented the cylinders to Kina at distances ranging from 2.5 to 7m, while noting her success rate and recording the cross-sectional area of her echolocation clicks with an array of hydrophones located between her and the cylinder.

But there was a problem: the width of an acoustic beam is determined by the frequency of the sound. So how could the team tell whether a change in beam width was due to Kina focusing the sound or simply due to the physics of acoustics? They turned to statistician Megan Donahue. "Using statistics, we can account for the natural relationship that exists between beam area and frequency," says Kloepper, "allowing them to correct for the frequency-related beam width variation." Plotting the adjusted beam area against the distance to the target, Kloepper discovered that Kina's echolocation beam became wider when she was having difficulties distinguishing between the 6.553mm and 6.35mm cylinders and when the cylinders were more distant. The false killer whale was effectively 'squinting' and adjusting the size of her echolocation beam in response to the more difficult tasks.

But was she actually focusing on the objects, because the beam width seemed to be getting wider rather than focusing in? Kloepper realised that the beam only appeared wider at the cluster of hydrophones because the array was close to Kina. When she plotted the path of the acoustic beams as they emerged from the animal's melon and passed through the hydrophone array, it was clear that the beams that appeared widest at the hydrophones were focused furthest away while the narrowest beams must be focused on the nearest objects.

"This is the first time that someone created a basic design to show that there is differential focusing of the beam under different target and echolocation conditions," says Kloepper, who is keen to find out whether other species use Kina's focusing strategy.

More information: Kloepper, L. N., Nachtigall, P. E., Donahue, M. J. and Breese, M. (2012). Active echolocation beam focusing in the false killer whale, Pseudorca crassidens. J. Exp. Biol. 215, 1306-1312. jeb.biologists.org/content/215/8/1306.abstract

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