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INSIDE JEB

Blue whale heart rate immortalised in motion sensor trace

The tagged blue whale (*Baleanoptera musculus*) in the coastal waters off California, USA. Photo credit: Duke University Marine Robotics and Remote Sensing Lab under permit NMFS 16111/21678 and MULTI-2017-007.

Scientists have been attaching motion sensors to penguins, whales and other marine animals for decades, recording their flipper and fluke beats and every twist and turn to learn about their extraordinary aquatic lifestyles. But could other details about these animals' lives also be preserved in the jagged acceleration traces they recorded? 'Last July, James Fahlbusch and I were going through tag data from a blue whale with a fine-toothed comb looking for night-time breathing behaviour', says Max Czapanskiy from Stanford University, USA, when the duo stumbled across something unexpected. 'We noticed repetitive, gentle noise in the accelerometry record during resting dives', Czapanskiy recalls. And when the pair measured the time between the barely perceptible peaks in the noisy traces, they realised that it correlated with the period between each of the mighty beast's heart beats. Could the motion sensors have inadvertently measured the iconic creature's heart rate? Czapanskiy sent a quick screenshot to Paul Ponganis (Scripps Institution of Oceanography, USA) and Jeremy Goldbogen (Stanford University), who confirmed that his hunch could be correct. But, before they could be sure, the team needed to test their theory on killer whales at SeaWorld of California, USA, where they could simultaneously measure the animal's heart rate while recording its manoeuvres.

Working with Todd Schmitt (SeaWorld) the team attached an ECG monitor and motion sensor to a killer whale and recorded the animal's heart beats and movements. Then, Czapanskiy and Ponganis analysed a 14 s portion of the killer whale's acceleration trace when the animal was stationary to search for any sign of a pulse. After months of patient investigation, the duo successfully revealed the soft throbbing motion as the animal's body gently recoiled in response to its heartbeat. And when they compared the movement trace with the killer whale's ECG record, they found the two corresponded perfectly. It is possible to extract heart rate records from the acceleration traces recorded by motion sensors when the animal is static, but could the team apply their novel technique to the manoeuvres of freely roaming wild whales?

The researchers returned to the movement data collected by the motion sensor located behind the blue whale's flipper, close to its heart, as the animal dived to rest repeatedly at ∼20 m. Sure enough, the accelerations generated by the whale's mighty movements overwhelmed the gentle body jiggle produced by the animal's powerful heartbeat, so the team focused on 30 s to 2 min segments when the whale was clearly resting at the bottom of its dive. Czapanskiy and Ponganis were able to identify the gentle shuttling motion of the whale's body in response to its heartbeat, recording a heart rate ranging from 4 to 8 beats min^{-1}, in agreement with the only ECG ever recorded from a blue whale. And when the team plotted the animal's heart rate over several dives, it increased gradually from ∼4.1 beats min^{-1} when the animal began its descent, to ∼8.3 beats min^{-1} as the whale returned to the surface.

'As accelerometer tags have been deployed on many cetacean species for multiple decades, this method may be applied to mine existing datasets and better understand how heart rate scales with body size and other biological factors', says Czapanskiy. And the team suggests that the technique could help researchers and conservationists better understand the impact of human noise pollution on these sensitive animals. One thing is sure, there is already a treasure trove of heart rate measurements buried in the movement traces of whales, dolphins and other aquatic mammals waiting to be unearthed by scientists to learn more about the physiology of these depth-defying animals.

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Czapanskiy, M. F., Ponganis, P. J., Fahlbusch, J. A., Schmitt, T. L. and Goldbogen, J. A. (2022). An accelerometer-derived ballistocardiogram method for detecting heart rate in free-ranging marine mammals. *J. Exp. Biol.* **225**, jeb243872. doi:10.1242/jeb.243872.

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