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Low Frequency Hearing in Odontocetes and Evoked Auditory Potentials Measuring Recovery from Temporary Threshold Shifts in the Bottlenosed Dolphin *Tursiops truncatus*

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Most toothed whales and dolphins echolocate and specialize in high frequency hearing while most anthropogenic noise is of lower frequencies. In all vertebrate species that have been studied, the animal's sensitivity to sound varies as a function of frequency. Most species show low sensitivity at very low frequencies and at very high frequencies (the meaning of very low and very high is different for different species) in a kind of U-shaped pattern. An audiogram shows the minimum detectable sound intensity as a function of frequency. Dolphins and small whales generally hear very well at frequencies that humans consider ultrasonic. Of the ten odontocete species so far tested (NACHTIGALL et al. 2000) most of them hear very well in the general area between 20 and 90 kHz, with the possible exception of the Killer Whale *Orcinus orca* (HALL & JOHNSON 1972). The one audiogram published for this species may be based on an animal with high-frequency hearing loss. Another unpublished study reported suggestive evidence that this species also hears frequencies above 100 kHz. The reliance on measurements obtained from one or at most a very few individuals highlights one of the difficulties with psychophysical investigations using cetaceans. Behavioural psychophysical measures, though very reliable and essential, are expensive and time consuming. The animal must be trained very well and the behaviour must be stable and reliable before an audiogram can be measured. Because of these necessary limiting conditions, data have frequently been gathered on a single animal and these data have been assumed to represent the species. This assumption is sometimes questionable

Much of what we know about the hearing of odontocetes began with the audiogram obtained for the Bottlenosed Dolphin (JOHNSON 1966). It should be noted that this audiogram is generally accepted as a standard, with other studies of *Tursiops* and other marine mammal species routinely compared with Johnson's results. The subject of Johnson's experiment, an approximately 8-9 year old male Bottlenosed Dolphin, *Tursiops truncatus,* was trained to respond to individual pure tone acoustic stimuli between 75 Hz and 150 kHz presented to the subject for a period of three seconds. The subject was trained on a go/no-go staircase procedure to measure thresholds at each frequency. False alarm responses were followed by a 90 sec "time-out" which probably induced the animal to be very conservative, potentially elevating its thresholds. The lowest thresholds occurred near 50 kHz at a level around 45 dB re μPa, with 10 dB-down band-width extending from 15 to 110 kHz. Below the frequency region of maximum sensitivity thresholds increased continuously up to a level of 137 dB at 75 Hz. Above 50 kHz, thresholds increased slowly up to a level of 55 dB at 100 kHz, then increased rapidly above this to about 135 dB at 150 kHz.

My colleagues and I at the Hawaii Institute of Marine Biology have examined odontocete abilities to hear low frequency sounds and looked at the effects of loud sounds on hearing. Temporary reduction in the ability to hear can occur following exposure to loud sounds similar to human experiences attending rock concerts. These temporary threshold shifts can be short-lived in the Bottlenosed Dolphin and therefore difficult to measure with conventional trained behavioural psychophysical techniques. We, along with A. Supin, measured the time course of recovery from temporary threshold shifts using evoked auditory potentials collected from a Bottlenosed Dolphin trained to wear rubber suction cups containing human EEG skin surface electrodes. During each session, following an initial measure of hearing thresholds using the evoked auditory potential procedure, the animal voluntarily positioned within a hoop 1 m under water while a 160 dB re 1 μPa one and a half octave band of noise between 4 and 11 kHz was presented for 30 minutes while the animal was in the hoop. Immediately following the noise exposure, thresholds were again obtained using the evoked potential technique. Suction cups were attached on the surface at the vertex and near the dorsal fin. The dolphin swam down into a second hoop located one meter in front of a calibrated hydrophone. Evoked potential thresholds were obtained 5, 10, 15, 25, 45 and 105 minutes following the exposure for amplitude modulated pure tones of 8, 11.2, 16, 22.5, and 32 kHz. Maximum temporary threshold shifts occurred 5 minutes following exposure and rapidly recovered. As has been observed with other animals and humans, threshold shifts depended on frequency. Shifts occurred at 8, 11.2, and 16 kHz but no shifts were detected at 22.5 and 32 kHz. Following the collection of the evoked auditory potential thresholds, the dolphin's thresholds were also re-examined using a conventional standard behavioural psychophysical procedure. The data show very similar thresholds using the two different procedures.

References

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