

during playback of bottlenose dolphin sounds is similar to the observed behaviour of other species of fish such as Gulf toadfish (Remage-Healey et al. 2006) and silver perch (Luczkovich et al. 2000). Both of these species suppressed vocalizations in apparent response to low-frequency sounds made by bottlenose dolphin. Similarly, Mann et al. (1998) observed that American shad *Alosa sapidissima* are able to detect simulated dolphin echolocations, although at much higher frequencies (100-180 kHz) than we used here.

ACKNOWLEDGMENTS

We thank the Diving and Water Safety Office at East Carolina University and the Institute of Marine Studies at the University of Belize for logistical support (rebreathers and boats).

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PREDICTING CETACEAN AUDIOGRAMS

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INTRODUCTION

Our ability to predict the impact of sound on marine mammals is

limited by our lack of knowledge about the audiogram for many endangered species. Hearing range in virtually all mammals depends on a combination of middle ear and cochlear properties. The low-frequency portion of the audiogram is dominated by the middle ear transfer function, whereas the high-frequency limit is determined by the cochlear frequency-place map. Here we discuss how basilar membrane and middle ear stiffness data can be combined in a computational model that can be used to predict cetacean audiograms.

METHODS

Ear preparation and methods for middle ear stiffness measurements are outlined in Miller et al. (2006). Basilar membrane stiffness measurement methods were described by Naidu & Mountain (1998). All measurements reported here were made using excised tympanoperiotic bones. Samples were obtained postmortem from stranded animals in cooperation with normal stranding-response procedures and under letters of agreement and research permits issued to Harvard University, Woods Hole Oceanographic Institution, and D. R. Ketten. The computational modelling techniques used to predict audiograms were described by Mountain et al. (2003).

RESULTS

Middle ear acoustic stiffness measured in *Tursiops truncatus* and *Phocoena phocoena* had values ($\sim 10^{17}$ Pa/m³) similar to those reported for the mouse *Mus musculus* (Miller et al. 2006). We have been able to measure basilar membrane point stiffness at several locations in three *Tursiops* ears (combined data are shown in Figure 1). The stiffness gradient is similar to that in other mammals, but the absolute stiffness is nearly five times greater than that at equivalent positions in gerbils. When the data are converted from point stiffness to volume compliance by scaling by basilar membrane width, the resulting volume-compliance gradients are similar to those reported by von Békésy (1960) for a number of species including human and mouse.

Preliminary simulations showed good agreement between predicted and experimental audiograms, suggesting that as more data become available, this technique can be extended to multiple cetacean species.

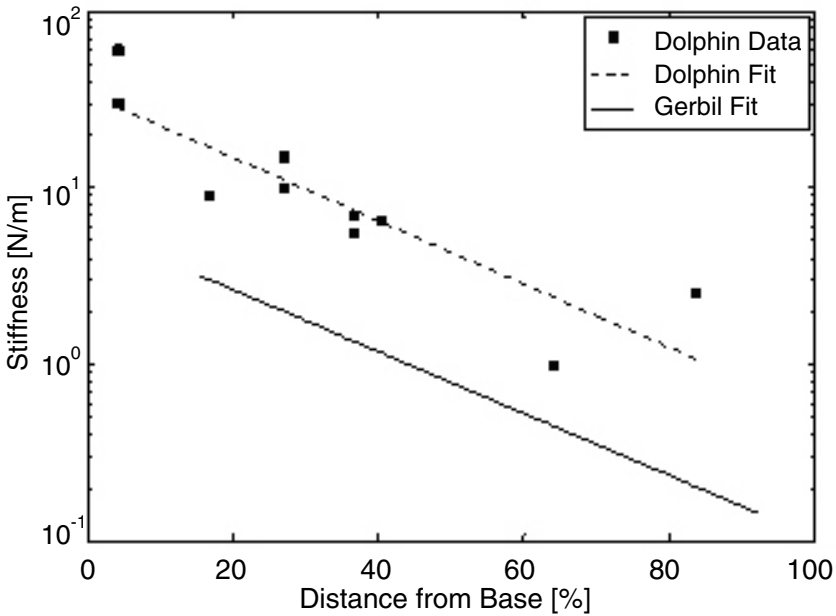


Figure 1. The dolphin stiffness gradient is very similar to that for gerbil (Naidu & Mountain 1998).

DISCUSSION

We have shown that middle ear and basilar membrane stiffness measurements can be made in ears from stranded animals if the ears are extracted promptly and frozen or kept chilled for a short time prior to testing. The use of these measurements in conjunction with computer modelling techniques provides an opportunity to predict audiograms for species that cannot be tested behaviourally. These audiogram predictions can then be used to design playback experiments and evoked-potential experiments that will provide further refinements for predicting audiograms.

ACKNOWLEDGMENTS

This research was supported by the U.S. Office of Naval Research and the International Association of Oil and Gas producers.

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AMPLITUDE-VERSUS-RATE TRANSFER FUNCTIONS TO TONE BURST STIMULI IN THE CALIFORNIA SEA LION *ZALOPHUS CALIFORNIANUS*

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INTRODUCTION

Although audiograms have been published for a number of pinniped species (see Wartzok & Ketten 1999), these data have been restricted to studies comprising a few captive subjects. As a consequence, the National Research Council has recommended that audiometric data should be obtained on multiple individuals in order to better understand intraspecific variation in hearing capabilities (NRC 2000). The measurement of the envelope following response (EFR), composed of auditory-evoked potentials in response to rhythmic stimuli, has shown promise as an efficient method in assessing frequency-specific hearing capabilities in marine mammal populations (e.g., Houser & Finneran 2006). In order to measure hearing thresholds using EFRs evoked by trains of tone bursts, the dependence of EFR fundamental-response amplitude on tone burst repetition rate must first be ascertained. To this end, we report amplitude-versus-rate transfer functions in California sea lions in response to rhythmic tone burst stimuli.

METHODS

Three California sea lions were tested while under anaesthesia at The Marine Mammal Center in Sausalito, California. Stimuli were trains of 8-kHz tone bursts with repetition rates between 125 and 1,500 s⁻¹.