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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}.

Stimuli were presented in an aerial direct field with received levels of 74-100 dB peak SPL. EFRs were recorded by amplifying, filtering, and averaging potentials from three subdermal electrodes placed on the subject.

RESULTS

The largest amplitudes of the EFR were 0.7-1.1 µV at the lowest repetition rates and generally decreased with increasing rate. Fourier transforms of the EFRs confirmed highest fundamental-response amplitudes at the lowest repetition rates and revealed multiple peaks at harmonics, especially at lower rates. A representative amplitude-versus-rate transfer function for one subject is shown in Figure 1. The transfer functions obtained for all three subjects resembled the shape of a low-pass filter, with the amplitude of the fundamental response declining rapidly above repetition rates of 625-875 s^{-1}. There was little variation among individuals in the overall shape of the transfer function.

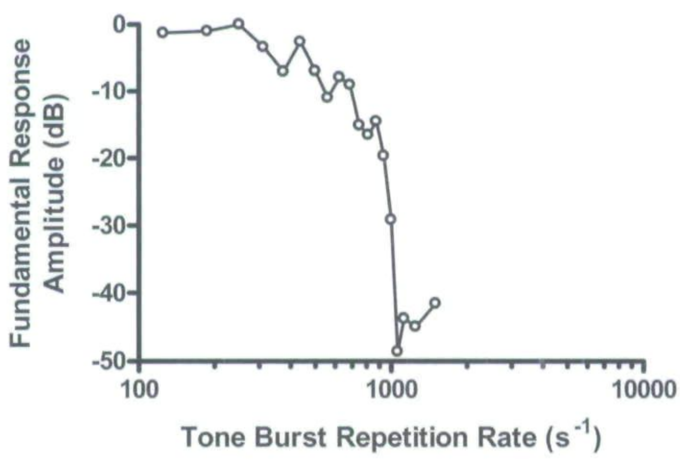

Figure 1. Fundamental amplitude as a function of tone burst repetition rate in a California sea lion. Tone burst repetition rates were tested at 62.5 s^{-1} intervals. Amplitudes are shown as dB re maximum response amplitude.

DISCUSSION

The amplitude-versus-rate transfer functions obtained in this study demonstrate the ability of the California sea lion auditory system to follow tone burst repetition rates up to the region of 625-875 s^{-1}. Robust responses at repetition rates above the region of most extraneous electrical noise may prove optimal in the practice of EFR audiometry in California sea lions.

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RECENT DIRECTIONS IN ODONTOCETE CETACEAN HEARING

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Our initial look at toothed whale hearing (Johnson 1966) showed the amazing range of individual bottlenose dolphins in their ability to detect underwater sound frequencies. Most of the first estimates of the audiograms of odontocete species were based on the data from individual animals (Nachtigall et al. 2000). Extrapolation from individual animals to species estimates led to some errors in determination of upper frequency limit estimations and absolute thresholds (Hall & Johnson 1972; Nachtigall et al. 1995). Much of the limitation on audiometry was caused by the expense and effort involved with the use of behavioural procedures. Animals had to be kept in captive environments and trained to report the presence or absence of sound. The introduction of auditory-evoked potential (AEP) procedures (Supin et al. 2001) in which audiograms could be rapidly determined by measuring the brain wave patterns in response to sound