EFFECTS OF NOISE ON SEALS AND SEA LIONS: LABORATORY APPROACHES

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INTRODUCTION

Laboratory-based approaches used to study the effects of noise on aquatic animals can be criticized for using small sample sizes as well as stimuli and controlled surroundings that are often perceived as ecologically irrelevant. We propose that laboratory research, including recent investigations into noise-induced hearing loss in pinnipeds, has ecological and evolutionary implications not often associated with this type of laboratory work. Despite apparent limitations, pinnipeds can serve as excellent subjects in tests of the effects of noise. Furthermore, seals and sea lions are amphibious, allowing tests of hypotheses regarding in-air and underwater hearing sensitivity, susceptibility to noise exposure, and the evolutionary biology of marine carnivores in general. Newer, more rapid technologies and psychophysical methodology can lead to experiments that complement field-based observations and experiments.

METHODS

Three pinniped subjects reside at Long Marine Laboratory at the University of California, Santa Cruz, where they participate in behavioural psychophysical experiments designed to assess hearing sensitivity (temporary threshold shift or TTS), sound localization ability, auditory masking, effects of noise on hearing sensitivity, novel and rapid psychophysical methodology, and habituation and sensitization to underwater sound. The experiments are conducted both in air and in water, where possible, using standard psychophysical approaches and a signal-detection framework. Our facility comprises animal housing areas, one 7-m aboveground tank for underwater testing, and a hemianechoic chamber specially designed to test marine mammals in air.

RESULTS

Temporary Threshold Shift. Pinnipeds exposed to octave bands of white noise have shown threshold shifts ranging from about 2-3 dB

at low stimulus levels (120 dB re 1 μPa^2-s) to up to 30 dB at high stimulus levels (164 dB re 1 μPa^2-s). Recovery from TTS mirrored that occurring in terrestrial animals and can take several days when threshold shifts were greater than 20 dB (Kastak et al., in press). Higher levels of noise are required to induce TTS at lower durations and vice versa. For exposures of equal energy, duration appears to have a greater effect on TTS than level. When related to the subjects' absolute threshold, stimulus levels required to induce threshold shifts were similar in air and underwater, indicating that pinnipeds have not evolved mechanisms that protect the ear from underwater noise relative to in-air noise.

Habituation. Results of habituation/sensitization experiments using pulsed and tonal stimuli show that some species *Zalophus californianus* and *Phoca vitulina* habituate readily to some acoustic stimuli (on the second presentation), whereas the northern elephant seal *Mirounga angustirostris* showed extreme aversive reactions to pulsed sounds. Sensitization was demonstrated when this subject showed a similar aversive response to both auditory and visual stimuli that were previously neutral or positively conditioned.

Audiometry. Tracking or Békésy audiometry has shown promise as a rapid psychophysical technique for use with pinniped subjects. Thresholds obtained from one subject in a preliminary assessment were similar to those obtained using discrete-trial techniques but with slightly greater variability. Many thresholds measured in this fashion were obtained in less than two minutes.

DISCUSSION

All of the laboratory approaches described here have ecological relevance despite the limitations of small sample sizes and arbitrary, somewhat "unnatural" testing situations. For example, bands of noise and tones can simulate exposure to shipping noise and sonar, respectively; a lab setting is the only way that hearing effects from these exposures can be assessed.

Habituation to sounds with little consequence may explain why many marine mammals seemingly fail to respond to loud noises. Sea lions, for example, are often seen in the vicinity of large vessels. It is unclear whether these animals suffer auditory effects in the absence of clear avoidance responses. Some species, however, for reasons such as predator avoidance based on passive acoustics, may be repelled by similar sounds.

The auditory characteristics that are influenced by noise extend well beyond hearing sensitivity. These include frequency and temporal resolution, temporal summation, and detection and masking of complex and conspecific signals. All of these can be best tested in the

laboratory using conventional psychophysics and electrophysiological approaches. Additionally, habituation/sensitization and habituation/dishabituation paradigms (which do not depend on associative learning) have already shown promise in the laboratory setting where the responses of subjects to neutral and aversive stimuli can be assessed and replicated. Results of many current studies have both ecological and evolutionary ramifications. Future laboratory studies will continue this trend.

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SHORT-TERM BEHAVIOURAL RESPONSE OF BOTTLENOSE DOLPHINS *TURSIOPS ADUNCUS* TO RECREATIONAL POWERBOATS

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INTRODUCTION

Inshore delphinids may be subject to anthropogenic activities, particularly small motorised vessels that may result in either short- or long-term disturbance. The disturbance may be measured in terms of change in behaviour and may be species specific, with the response of delphinids to vessels being highly variable. Investigations of coastal delphinids have focused on surface responses, with little research examining both acoustic and surface behaviour. Moreover, much has been observational rather than experimental, making it difficult