REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
29 September 2006	FINAL TECHNICAL REPORT	February 23, 2004 - January 22, 2006

4. TITLE AND SUBTITLE
NOISE IMPACTS ON PINNIPED HEARING

5a. CONTRACT NUMBER

5b. GRANT NUMBER
N00014-04-1-0284

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
KASTAK, DAVID
REICHMUTH KASTAK, COLLEEN

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
INSTITUTE OF MARINE SCIENCES
UNIVERSITY OF CALIFORNIA SANTA CRUZ
1156 HIGH STREET
SANTA CRUZ, CA 95064

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
OFFICE OF NAVAL RESEARCH
875 NORTH RANDOLPH STREET
SUITE 1425
ARLINGTON, VA 22203-1995

10. SPONSOR/MONITOR'S ACRONYM(S)
ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
DISTRIBUTION UNLIMITED

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The National Research Council, in a series of recent reports on marine mammals and anthropogenic noise, has identified the need to develop and test predictive models of acoustic conditions that would harm marine mammals. The primary aim of the current study was to assess the effects of intense, octave bands of noise on auditory sensitivity in three pinniped species. Specifically, temporary threshold shifts ranging up to 30 dB were induced in trained subjects in order to evaluate the relative effects of noise level and duration. Results showed that TTS onset occurred when noise levels exceeded hearing threshold by 80 dB for 12 minutes or more, irrespective of whether noise exposure occurred in air or under water. This corresponds to exposure levels of about 150-160 dB SEL in air and 183-207 dB SEL under water. Growth of TTS followed a modified exponential model rather than a simple equal energy trading model. Complementary field studies at harbor seal and northern elephant seal breeding areas characterized ambient noise environments and examined whether call features varied as a function of background noise levels.

15. SUBJECT TERMS
HEARING, HEARING LOSS, TEMPORARY THRESHOLD SHIFT, NOISE IMPACTS, PINNIPED, SEA LION, SEAL

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			COLLEEN REICHMUTH KASTAK
NONE	NONE	NONE	NA	3	19b. TELEPHONE NUMBER *(Include area code)* 831-459-3345

FINAL REPORT

GRANT #: N00014-04-1-0284

PRINCIPAL INVESTIGATOR: David A. Kastak, Ph.D.

INSTITUTION: University of California Santa Cruz

GRANT TITLE: Noise Impacts on Pinniped Hearing

OBJECTIVE: To determine whether aerial noise can have a detrimental impact on hearing in three species of pinniped (California sea lion, northern elephant seal, Pacific harbor seal); to measure the degree of noise-induced temporary threshold shift (TTS) caused by different combinations of noise level and duration; to measure variations in naturally-occurring ambient noise and assess its effects on the vocal behavior of free-ranging animals.

APPROACH: Auditory thresholds were estimated using psychophysical procedures in three captive pinniped subjects. The subjects were then exposed to an octave band of Gaussian white noise. The noise levels ranged from 65 to 128 dB above the subjects' baseline thresholds (sensation level), and from 1.5 to 50 min in duration. Following the exposure condition, the subjects were tested again in order to assess the degree of threshold shifts induced by the noise. If thresholds did not return to baseline levels within one day, noise exposure was discontinued until hearing returned to normal levels. Field studies using recording and playback techniques examined the effects of ambient noise on elephant seal vocal behavior at Año Nuevo Reserve.

ACCOMPLISHMENTS: A total of 192 noise exposure and 28 control series were completed for each subject. In all species, TTS was related to the sensation level (SL) and the duration of the fatiguing stimulus. At noise levels below 65dB SL and exposure durations below 1.5 minutes, no threshold shifts could be induced in any of the subjects. At exposure levels above about 80dB SL, and 22 min, all subjects showed some degree of TTS, which increased with both level and duration of the exposure. All thresholds recovered with time, with the longest recovery periods corresponding to the highest sound exposure levels. Relationships between sound exposure level (SEL, in dB // (20uPa)^2-s) and TTS were determined for the three pinnipeds involved in the study. The most pronounced relationship between SEL and TTS occurred in the California sea lion, in which threshold shifts of up to 30 dB were induced.

In the field, ambient noise levels were determined over a range of time periods and the associated source levels of vocalizations emitted by adult male, adult female, and juvenile northern elephant seals were measured. Results indicate a wide range in signal strength, particularly for adult males whose vocalization source levels appear to be correlated with dominance rank and related to ambient noise conditions.

CONCLUSIONS: From the laboratory work, we concluded that estimated TTS onset was about 150 dB SEL for the harbor seal and the elephant seal, and 159 dB for the sea lion. In all cases, the relationship between threshold shift and sound exposure level was curvilinear, with

increasing slope corresponding to increasing exposure levels. Estimated growth of TTS at higher exposure levels was between 1 and 2 dB TTS/dB noise in the seals and about 2.5 dB/dB in the sea lion. Shifts of over 20 dB occurred only in the sea lion. Recovery occurred at a maximum of three days post-exposure.

The specific findings are as follows:

1. There is a curvilinear rather than a linear relationship between the degree of the fatiguing noise and hearing loss; threshold shifts increased more rapidly as the noise levels increase.

2. The pinnipeds are subject to TTS in air, as they are under water. Stimuli of equivalent sensation levels appear to cause equivalent threshold shifts regardless of medium.

3. Patterns of growth of TTS with increasing sound energy in the pinnipeds resemble those of terrestrial mammals.

4. The equal energy trading rule held for exposures that were closely spaced in duration and level but broke down when the exposures were widely spaced (e.g., 104 dB at 12.5 min and 101 dB at 50 min generated very different mean threshold shifts).

5. Recoverable thresholds of up to 30 dB can be induced in pinnipeds; however, recovery time is often on the order of days rather than minutes, suggesting that even relatively low levels of noise with long enough exposure durations can have long lasting and biologically significant impacts on these animals, which raise their young on land and forage in the water.

6. The phocid seals, particularly the harbor seal, appear to have developed a certain degree of voluntary protection from the effects of airborne noise. The mechanisms have not been elucidated.

7. Complementary studies of aerial sound localization show that the effects of simultaneous noise on signal detection in psychophysical tasks vary with the relative position of signal and noise in pinnipeds.

8. Field measurements show that adult male elephant seal vocalizations have specific beam patterns with the lowest frequencies propagating the best in all directions and the higher frequencies propagating best directly in front of the animal.

9. Juvenile male and adult female elephant seals do not appear to alter the level of their vocalizations as a function of increasing ambient noise, but variations in the source levels of adult male vocalizations may be attributed to dominance rank and ambient noise.

SIGNIFICANCE: The data obtained in these experiments will aid in the determination of acceptable limits of anthropogenic noise exposure for marine mammals in coastal habitats. The hearing model predicting TTS onset and growth significantly adds to existing mammalian databases of noise induced hearing loss, and will be useful in predicting potential noise impacts on pinniped hearing.

PATENT INFORMATION: Not applicable.

AWARD INFORMATION: Not applicable.

PUBLICATIONS AND ABSTRACTS:

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