waters with many acoustic sources. Hearing was measured using auditory evoked potentials. Click and amplitude modulated tone stimuli were presented at nine locations on the head and body using a jawphone transducer. Thresholds were compared to anatomical dissections and CT scans of porpoise heads. Minimum thresholds and best hearing locations were at the cheek-fat-pad and distal to the porpoise bulla. However, thresholds were not substantially different at locations from the rostrum tip to the ear (11.6 dB). This minimal variation is quite different from the 30–40 dB differences found across the head of bottlenose dolphins and belugas suggesting differences in how divergent odontocetes receive sound. Porpoises may have relatively less "shading" of sounds and are potentially more susceptible to masking effects.

9:05

2aABa4. Noise-induced temporary threshold shift in marine mammals. James J. Finneran (US Navy Marine Mammal Program, SSC Pacific Code 71510, San Diego, CA 92152, james.finneran@navy.mil) and Carolyn E. Schlundt (ITT Corp., San Diego, CA 92110)

In 1996, Dave Kastak and Ron Schusterman reported the first observations of noise-induced temporary threshold shift (TTS) in a marine mammal [D. Kastak and R. J. Schusterman, "Temporary threshold shift in a harbor seal (Phoca vitulina)," J. Acoust. Soc. Am. **100**, 1905–1908 (1196)]. Since that time, a number of studies have been conducted to characterize the effects of noise on the hearing abilities of pinnipeds and odontocete cetaceans. These studies compare hearing thresholds before and after subjects are exposed to intense sounds and relate feature of the noise exposure to the observed threshold shift. The results are analogous to data from terrestrial mammals, where TTS depends on the frequency, amplitude, duration, and temporal pattern of the noise exposure, as well as the hearing test frequency and the recovery time. This talk reviews the major findings related to the growth and recovery of TTS in marine mammals, with an emphasis on recent data from high-frequency tonal exposures in bottlenose dolphins. The relationship between onset-TTS levels across a range of frequencies and proposed auditory weighting functions will also be discussed. [Work supported by the ONR.]

9:25

2aABa5. Temporary hearing threshold shifts and recovery in a harbor porpoise (*Phocoena phocoena*) and harbor seals (*Phoca vitulina*) exposed to white noise in a 1/1-octave band around 4 kHz. Ronald Kastelein, Robin Gransier, Ron van Mierlo, Lean Hoek (Sea Mammal Res. Co. (SEAMARCO), Julianalaan 46, 3843 CC Harderwijk, The Netherlands, researchteam@zonnet.nl), and Christ de Jong (TNO Sci. and Industry, 2600 AD Delft, The Netherlands)

To set safety criteria for levels of sounds produced during pile driving for offshore wind parks, temporary hearing threshold shifts (TTSs) were studied in a harbor porpoise and two harbor seals. A psychoacoustic behavioral technique was used to quantify TTS and hearing recovery in the animals exposed to underwater sounds (white noise in a 1/1-octave band around 4 kHz). Hearing thresholds were determined once a day for a narrow-band frequency swept sine wave (3.9–4.1 kHz) before and after exposure to the fatiguing noise, which was offered at two sound pressure levels (131 and 119 dB *re* 1 μPa for the porpoise and 151 and 139 dB *re* 1 μPa for the seals) each at four durations (15, 30, 60, and 120 min). Recovery was quantified by measuring hearing thresholds at 4, 8, 12, and 48 min after the noise exposure. The results show that TTS in harbor porpoises occurred at a sound exposure level threshold approximately 20 dB below the threshold for which TTS occurred in harbor seals.

9:45

2aABa6. Behavioral reactions of dolphins and sea lions to sonarlike sound exposures. Dorian S. Houser, Laura Yeates (Natl. Marine Mammal Foundation, 2240 Shelter Island Dr. #200, San Diego, CA 92106, dorian.houser@nmmpfoundation.org), Daniel E. Crocker (Sonoma State Univ., Rohnert Park, CA 94928), Steve W. Martin, and James J. Finneran (SSC Pacific, San Diego, CA 92152)

Colleagues Ron Schusterman and Dave Kastak were instrumental in the advancement of marine mammal cognition and sensory biology studies. In the past 2 decades, their work was heavily concerned with the potential impact of anthropogenic sound on pinnipeds. Behavioral reactions of marine mammals to anthropogenic sound exposure are one impact with a large range of potential consequences. Recently, 30 dolphins and 15 sea lions were exposed to sonarlike pings used in antisubmarine warfare. Exposures occurred while animals performed a behavior in which they traveled from one location to a second where they touched a paddle, and then returned for a food reward at the starting location. Subjects performed a ten trial baseline session followed by a ten trial experimental session in which sound exposures occurred. Each subject was randomly assigned a receive level from near ambient to 185 dB sound pressure level. For each subject, received levels were consistent across all experimental trials. Behavioral reactions were anticipated prior to the study and assigned a severity score by a panel of anonymous reviewers. Scores were used to explore relationships between the received level and the severity of the behavioral response.

10:05—10:25 Break

10:25

2aABa7. Auditory habituation as a diagnostic measure of domoic acid toxicosis in wild sea lions. Peter Cook (Dept. of Psych., Univ. of California, Santa Cruz, CA 95060), Colleen Reichmuth (Univ. of California, Santa Cruz, CA 95060), and Frances Gulland (The Marine Mammal Ctr., Sausalito, CA 94965)

Habituation measures are instrumental in behavioral neuroscience, but they have seldom been applied to research with marine mammals. In this study, an auditory habituation paradigm was applied as a diagnostic tool in California sea lions with suspected brain damage resulting from neurotoxic exposure to domoic acid. Domoic acid is a glutamate agonist that causes damage to the hippocampus and surrounding medial temporal areas. Such damage is typically revealed only by brain imaging or *postmortem* histology, and is therefore difficult to diagnose in a veterinary setting. Studies of laboratory animals suggest that habituation of defensive responses to aversive stimuli does not generally rely on hippocampal function, while habituation of orienting responses to non-aversive stimuli has been shown to rely on this brain area. Here it was found that behavioral orienting responses to a series of non-aversive sounds habituate more slowly in sea lions with domoic acid toxicosis than in sea lions with no apparent neurological deficits. A signal detection analysis indicates that a measure based on this habituation shows significant diagnostic value. Preliminary results of a follow-up procedure probing habituation and dishabituation to auditory stimuli presented from multiple locations are also discussed. [Work supported by NSF Graduate Fellowship].

Contributed Papers

10:45

2aABa8. Preliminary investigation of sound reception in southern sea otters (*Enhydra lutris nereis*). Asila Ghoul and Colleen Reichmuth (Univ. of California, Santa Cruz, Long Marine Lab, 100 Shaffer Rd., Santa Cruz, CA 95060, asila@ucsc.edu)

Due to their dependence upon a highly restricted coastal habitat, sea otters are vulnerable to a variety of environmental and anthropogenic threats. Among these is the potential disturbance from human-generated sources of noise. Presently, there are no data on the auditory sensitivity of sea otters, and little evidence to suggest what sounds may be most relevant to these animals. As an initial step toward describing the acoustic sense of sea otters, we conducted a controlled exposure experiment, adapted from sound exposure studies used in behavioral field research, to efficiently measure the aerial frequency range of hearing in four captive sea otters. This approach was designed to determine which frequencies were audible to each animal, rather than to provide direct measures of auditory sensitivity. The maximum range of aerial hearing determined using this method was 0.125 to 32 kHz. These are the first direct measurements of hearing obtained for sea otters, and the results are relevant to improving understanding of their acoustic communication, evolutionary biology, and behavioral ecology, as well as in supporting ongoing conservation efforts. This research effort draws from the work of Kastak and Schusterman, especially with respect to the value of behavioral baselines in captive studies of marine mammals.

11:00

2aABa9. Developing auditory weighting functions in a bottlenose dolphin (Tursiops truncatus). Carolyn E. Schlundt (ITT Corp., 3276 Rosecrans St., San Diego, CA 92110) and James J. Finneran (Space and Naval Warfare Systems Ctr., San Diego, CA 92152)

The variation in susceptibility to noise as a function of frequency is handled by "weighting" sound exposures to emphasize frequencies where auditory sensitivity is highest. This technique allows the use of single, weighted numeric values for impact or damage-risk criteria, regardless of the sound frequency. Human weighting schemes were derived from measurements of equal loudness curves obtained from subjective experiments where listeners directly compare the loudness of sounds at different frequencies. Response times to acoustic detection tasks provide an indirect method to construct equal-latency contours in terrestrial mammals that are analogous to equal-loudness contours. The need for empirical measures of loudness contours or auditory weighting functions in marine mammals became especially apparent following experiments of temporary threshold shift (TTS) in dolphins that revealed frequency-dependent effects for onset-TTS levels. The objective of this effort was to develop auditory weighting functions for *Tursiops truncatus* by directly measuring subjective loudness as a function of the sound frequency. The resulting equal-loudness contours emphasize frequencies at which auditory sensitivity is highest and lessen the importance of other frequencies, similar to human A- and C-weighting networks. [Work supported by the ONR.]

11:15

2aABa10. The effect of age-related hearing loss on echolocation: Changes in click parameters and echolocation discrimination abilities are initiated by changes in auditory filters. Laura N. Kloepper, Paul E. Nachtigall, and Marlee Breese (Hawaii Inst. of Marine Biology Marine Mammal Res. Program/Dept. of Zoology, Univ. of Hawaii at Manoa, P.O. Box 1106, Kailua, HI 96734)

High-frequency hearing loss has been correlated with a reduction both in echolocation click parameters and in echolocation discrimination abilities in a false killer whale. During a 15-year time period, the whale demonstrated a significant decrease in peak frequency, center frequency, and source level of outgoing clicks between two studies. Echolocation clicks were analyzed from the most recent phase of the discrimination study to determine if there were significant differences for click parameters according to target condition. The whale consistently produced clicks with the same peak and center frequencies and source levels but varied the number of clicks according to experimental condition. The data suggest that the whale does not use spectral adaptations during discrimination. Likely, a gradual shift in click parameters resulted from a change in the auditory filtering processes initiated with age-related hearing loss.

TUESDAY MORNING, 24 MAY 2011 ASPEN, 8:00 A.M. TO 12:00 NOON

Session 2aABb

Animal Bioacoustics, Acoustical Oceanography, and Underwater Acoustics: Fish Bioacoustics I

Richard R. Fay, Cochair
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Joseph A. Sisneros, Cochair
Univ. of Washington, Psychology Dept., Seattle, WA 98195

Invited Papers

8:00

2aABb1. Speciation and sounds of fishes: Dividing up the bandwidth. Joseph J. Luczkovich (Inst. for Coastal Sci. and Policy and Dept. of Biology, East Carolina Univ., Greenville, NC 27858, luczkovichj@ecu.edu) and Mark W. Sprague (East Carolina Univ., Greenville, NC 27858)

Fishes in the drum family (Sciaenidae) make sounds to communicate, but they do not make the same sounds. The species-specific calls have different dominant frequencies, are produced in spawning aggregations at different times of the day and season, and there is spatial segregation among the spawning fish populations. We predicted that the pattern of bandwidth use by these species would show low overlap in space, time, and sound frequency. We monitored the seasonal pattern of sound production of Sciaenidae in Pamlico Sound (NC) using autonomous sound recorders that recorded 10 s of sound every 15 min during May–Nov. The observed bandwidth ranges and spawning season for species are weakfish 300–400 Hz in May–Aug, silver perch 800–1500 Hz May–Aug, spotted seatrout