11:00

4aABb2. Sound production by pinnipeds can be modified by contingency learning. Ronald J. Schusterman (UCSC Institute of Marine Sciences, Long Marine Lab - University of California, 100 Shaffer Road, Santa Cruz, CA 95060, USA, rjschust@ucsc.edu), Colleen Reichmuth (UCSC Institute of Marine Sciences, Long Marine Lab - University of California, 100 Shaffer Road, Santa Cruz, CA 95060, USA, coll@ucsc.edu)

In contrast to terrestrial mammals, pinnipeds (seals, sea lions and walruses) have remarkable flexibility in the ways that they can learn to use and modify their amphibious sound emissions. The experiments that we will describe are drawn from captive studies which show that changes in sound production can occur as a result of contingency learning, using food as positive reinforcement. A range of specialized physiological and anatomical adaptations appear to play a critical role in controlling sound production in pinnipeds. These adaptations include breath-holding and buoyancy mechanisms, as well as fine muscular control of the mouth, lips and tongue that may be used primarily in feeding. The manipulation and modulation of air flow through these components of the vocal tract and associated super-laryngeal filters appears to be susceptible to some of the same reinforcing consequences that are routinely used to establish reliable control over motor behaviors, such as flipper waving, in operant conditioning contexts.

11:20

4aABb3. Inertial and cochlear constraints for high-frequency hearing in phocid and otariid pinnipeds. Sirpa Nummela (University of Helsinki, Department of Biological and Environmental Sciences, PO Box 65 (Viikinkaari 1), FI-00014 Helsinki, Finland, snummela@fastmail.fm), Simo Hemilä (University of Helsinki, Department of Biological and Environmental Sciences, PO Box 65 (Viikinkaari 1), FI-00014 Helsinki, Finland, simo.hemila@welho.com), Annalisa Berta (San Diego State University, Biology Department, LS 250, San Diego, CA 92182-4614, USA, aberta@sciences.sdsu.edu), Tom Reuter (University of Helsinki, Department of Biological and Environmental Sciences, PO Box 65 (Viikinkaari 1), FI-00014 Helsinki, Finland, tom.reuter@helsinki.fi)

In air-borne hearing, mammals rely on sound transmission through the tympanic membrane and middle ear ossicles between the surrounding air and the cochlea. The high-frequency hearing limit (HFHL) is determined by the ossicular inertia, and also by the cochlear sensitivity. Due to coevolution, the sensitivity ranges of the middle and inner ear structures generally overlap, and the roles of inertial and cochlear constraints for the HFHL are difficult to discern. For studying this question we considered anatomical and experimental data for two phocid and two otariid pinnipeds. While any detailed mechanism for pinniped underwater hearing remains unclear, an underwater HFHL exceeding that in air is possible. Published in-air and underwater audiograms provide an opportunity for comparing the roles of ossicular mass inertia and cochlear sensitivity in HFHL. Phocid ossicles are very heavy, and their inertia explains the lower HFHLs in air - according to underwater audiograms the phocid cochlea is sensitive to higher frequencies. Otariids have normal-sized mammalian ossicles, and their inertia should allow underwater hearing at higher frequencies than in air. However, the HFHL is approximately equal in air and water for otariids, hence their underwater HFHL is apparently set by the cochlea alone.

11:40

4aABb4. Evoked potential audiometry in sea lions. Jason Mulsow (UCSC Institute of Marine Sciences, Long Marine Lab - University of California, 100 Shaffer Road, Santa Cruz, CA 95060, USA, jmulsow@ucsc.edu), Colleen Reichmuth (UCSC Institute of Marine Sciences, Long Marine Lab - University of California, 100 Shaffer Road, Santa Cruz, CA 95060, USA, coll@ucsc.edu)

Auditory sensitivity in the otariid pinnipeds (sea lions and fur seals) has traditionally been studied using a relatively small number of trained subjects and psychophysical techniques. Recent refinement of auditory evoked potential techniques with odontocete cetaceans has elevated interest in adapting these methods for sea lion subjects, with the goal of increasing sample size and efficiency in audiometric studies. To date, several basic electrophysiological characteristics of the California sea lion (*Zalophus californianus*) auditory system have been described, and these findings have allowed for the development of more advanced techniques in investigations of sea lion hearing. Most notable is the recording of the envelope following response (EFR) evoked by narrow-band, sinusoidally amplitude-modulated tones. This method can provide significant advantages in the detection of low-amplitude electrophysiological signals in noise using Fourier analysis and objective statistical detection of responses. Currently, EFR audiometry in the California sea lion and Steller sea lion (*Eumetopias jubatus*) is proving to be a promising method for rapidly assessing the variation of hearing capabilities among individuals, including the detection of hearing loss.

12:00

4aABb5. Air and bone conduction evoked potential audiometry in the northern elephant seal. Dorian S. Houser (Biomimetica, 7951 Shantung Dr., Santee, CA 92071, USA, dhouser@spawar.navy.mil), Daniel Crocker (Sonoma State University, Department of Biology, 1801 East Cotati Avenue, Rohnert Park, CA 94928, USA, crocker@sonoma.edu), James J. Finneran (US Navy Marine Mammal Program, Space and Naval Warfare Systems Center, 53560 Hull St., Code 71510, San Diego, CA 92152, USA, james.finneran@navy.mil)

Elephant seals (*Mirounga angustirostris*) are the largest and most aquatic of the pinnipeds, spending up to eight months of the year at sea diving to depths as great as 1600 m. The pinna is absent in the elephant seal and the middle ear cavity and auditory canal are lined with a cavernous tissue, both of which are likely adaptations to deep diving. Elephant seals demonstrate a greater sensitivity to low frequency sounds than do other pinnipeds and an overall greater sensitivity to underwater sound than to airborne sound. The relative importance of sound conduction pathways in the elephant seal is undetermined, although it has been speculated that bone conduction pathways are important to underwater hearing in this species. To compare the sensitivity of the elephant seal to both air and bone conducted stimuli, auditory evoked responses were recorded in seals exposed to signals presented through headphones and via a bone vibrator. In comparison to airborne stimuli, bone conduction methods provide an opportunity to more effectively study sensitivity to low frequency sounds, but are challenged by a lack of reference equivalent threshold sound pressure levels. Future efforts should compare bone conduction and direct field audiometry results obtained within the same individual.