Session 2aAB

Animal Bioacoustics: Marine Mammal Acoustics: Session in Honor of Ron Schusterman I

Whitlow W. L. Au, Chair
Hawaii Institute of Marine Biology, P.O. Box 1106, Kailua, Hawaii 96734

Chair's Introduction—7:55

Invited Papers

8:00

2aAB1. Dr. Ronald Schusterman's contributions to national acoustic policy. Roger L. Gentry (NOAA Fisheries, 1315 East West Hwy., Silver Spring, MD, roger.gentry@noaa.gov)

When the effects of underwater noise on marine mammals became a national issue in the 1990's, the federal government needed people trained in those fields to manage programs. No trained managers with that background existed, so a few scientists took on management roles. Of today's five Washington, DC managers in this issue, three received advanced degrees under Ron Schusterman. One started ONR's comprehensive research program on this topic, and two run NMFS's regulatory policy program on acoustics. Dr. Schusterman intended his students to work in basic science, specifically cognition, learning, sensory perception, and social behavior of marine mammals. Ironically, and despite his aversion to bureaucracy, this background equipped his students to become government decision makers. Such are the twists of history. He also taught his students to rigorously apply the scientific method and to assume nothing. If his science castaways in Washington, DC are worthy of his training, the national noise issue will be the better for it.

8:20

2aAB2. Audiology to ecology: Auditory scene analysis goes underwater. Robert Gisiner (ONR, 800 N. Quincy St., Arlington, VA 22217)

For decades the study of marine mammal audiology was considered an arcane branch of comparative psychophysics with little to offer the marine mammal ecologist. But in the past decade the oval window of the marine mammal ear has effectively become the ecologist's window into a marine ecosystem that truly is a world of sound. We are learning to listen to the ocean as marine mammals do, in order to better understand an environment long hidden from our view. And we are learning about the importance of sound to marine mammals, including the effects of our own noisy entry into their world. The past decade of revolutionary change in the use of sound to study marine mammals, and the associated revolution in our appreciation of marine mammal uses of sound, will be reviewed. We now see the ocean world through a marine mammal's ears, thanks to Ron Schusterman and a few dedicated colleagues who have opened our eyes, and ears, to the importance of audiology in ecology.

8:40

2aAB3. Studying social cognition in marine mammals. Peter Tyack (Biol. Dept., Woods Hole Oceanogr. Inst., Woods Hole, MA 02543, ptyack@whoi.edu)

Ron Schusterman has played an important role in broadening the perspective of marine mammal cognition studies from narrow comparisons to human language to more general cognitive concepts. He has also contributed to our understanding of learning mechanisms for individual recognition in pinnipeds, linking naturalistic observations with controlled studies in captive settings. I discuss how odontocetes learn to develop signals for individual and group recognition. Bottlenose dolphins use vocal learning to develop individually distinctive whistles in the first 1–2 years of life, but they also maintain the ability to imitate whistles throughout their lifetime. As maturing males form a coalition, their whistle repertoires converge. Species with more stable groups than dolphins use vocal learning to develop repertoires that are group distinctive. Schusterman has recently developed theoretical approaches to thinking about how animals form categories of social knowledge such as coalition or group. Depending upon the social context, animals that modify their vocalizations based upon auditory input and social relationships may use similar vocal learning mechanisms to develop quite different vocal repertoires. I will discuss the interaction between communication, social knowledge, and cognition in marine mammals from the approaches suggested by Schusterman for the study of social knowledge.

9:00

2aAB4. How acoustic signals become meaningful to listeners: An experimental approach. Colleen Reichmuth Kastak, Kristy Lindemann, and Ronald Schusterman (UCSC Long Marine Lab., 100 Shaffer Rd., Santa Cruz, CA 95060)

Most models of animal acoustic communication describe how vocal cues produced by a signaler influence the behavior of a listener. The response made by a listener depends in large part on the perceived meaning of the signal. But, how do signals become meaningful to listeners? In some cases, such as imprinting, signal meaning can be attributed to structural cues that are perceived and acted upon through an innate releasing mechanism. In other instances, signals may be arbitrarily related to objects, individuals, or species. Equivalence theory provides a model describing how some arbitrary signals may acquire meaning. Here, we describe theory and experimental evidence in the form of cross-modal matching-to-sample tasks showing how acoustic signals can become referents

for visual stimuli. The subject of these behavioral experiments is a California sea lion with extensive experience in performing associative learning tasks. The aim of the experiments is to establish multiple auditory-visual discriminations and then test for the emergence of untrained relationships between disparate visual stimuli linked by a common auditory signal. Preliminary data show successful emergent matching across visual and auditory modalities. These findings suggest that acoustic signals become meaningful to listeners when learned associations lead to the formation of equivalence classes.

9:20

2aAB5. White whale echolocation pulses in the open sea at the surface and at depth. Sam Ridgway and Don Carder (U.S. Navy Marine Mammal Program, Space and Naval Warfare Syst. Ctr., San Diego, 53560 Hull St., San Diego, CA 92152-5001)

Previously we reported on the first ever hearing tests of trained cetaceans in the open ocean demonstrating that zones of audibility for sound were just as great throughout the depths to which white whales dive, down to at least 300 m. The tests also showed that the whale's response whistles changed with increasing depth, overall amplitude decreased and frequency emphasis shifted higher with increasing depth from 5 to 300 m. Subsequently a door was installed in the test apparatus and the whales were taught to whistle in response to the presence of a small cylindrical target 2 m away. When the door opened the whales would utter a train of pulses and then whistle if the target were present. There was no statistical difference in echolocation pulse frequencies or amplitudes between depths of 5, 100, 200, and 300 m. Surprisingly, all pulses recorded at the open ocean test site had peak frequencies between 4 and 40 kHz. These differed markedly from pulses recorded with the same cable and apparatus in San Diego Bay where the whale's pulses usually exhibited two peaks, one in the 30–80 kHz range and the other often around 100–120 kHz.

9:40

2aAB6. Hearing loss and echolocation signal change in dolphins. Patrick W. Moore, James Finneran (SPAWARSYSCEN San Diego, Code 2351, 53560 Hull St., San Diego, CA 92152-5001), and Dorian S. Houser (BIOMIMETICA5750, La Mesa, CA 91942)

Recent studies and ongoing research have shown that echolocating dolphins can change the structure of their emitted echolocation signals during active echo-investigation of targets. The presumption has been that the animal adjusts various parameters (source level, peak frequency, etc.) of the emitted signal to maximize the information return in the target echo as a function of task or environmental constraints and requirements. Other work has suggested that the frequency range over which this dynamic control is exerted may change due changes in the animals hearing ability. Specifically, dolphins that develop high frequency hearing loss, for example from age, noise exposure or ototoxic drugs, shift the center frequency of the emitted echolocation click to lower frequency ranges. Observations of several Navy Marine Mammal Program animals with known high frequency hearing loss have demonstrated these frequency shifts. In this paper we will elaborate and extend ongoing analysis of emitted echolocation signals of several dolphins that show hearing loss associated changes in emitted signal structure, discuss the implications of these measures and suggest approaches that may prove useful for evaluating basic hearing capabilities from collected echolocation signals.

10:00–10:10 Break

10:10

2aAB7. Relationship between auditory evoked potential (AEP) and behavioral audiograms in odontocete cetaceans. Dorian S. Houser (BIOMIMETICA, 7951 Shantung Dr., Santee, CA 92071), James J. Finneran, Donald A. Carder, Sam H. Ridgway, and Patrick W. Moore (SPAWARSYSCEN San Diego, San Diego, CA 92152)

Auditory evoked potentials (AEPs) offer an alternative to behavioral methods of determining auditory sensitivity in marine mammals. The technique can be performed without the need for animal training, substantially expediting the process, and has the potential for application to stranded and rehabilitating marine mammals, thus providing an opportunity to determine hearing sensitivity in animals not likely to be kept in captivity. As an emerging technology in the field of marine mammalogy, the equivalence of AEP and behavioral thresholds remains to be quantitatively assessed. Human and laboratory animal AEPs are typically -5 to $+20$ dB of behaviorally determined thresholds and vary by technique and frequency tested. To be an effective tool in the field of marine mammalogy, the expected variation in AEP thresholds relative to behavioral thresholds in marine mammal species needs to be determined. We compare the behavioral and AEP audiograms of several odontocetes covering a range of normal hearing to profound hearing loss and demonstrate the offsets between results obtained with the two methods. Thresholds determined by the two methods show generally good agreement and demonstrate the utility of AEPs as an emerging technology in the study of marine mammal audiometry.

10:30

2aAB8. Acoustic basis for fish prey selection by echolocating odontocetes. Whitlow W. L. Au, Kelly J. Benoit-Bird (Hawaii Inst. of Marine Biol., Univ. of Hawaii, P.O. 1106, Kailua, HI 96734), Ronald Kastelein, and Sander van de Heul (SEAMARCO, 3843 CC Harderwijk, The Netherlands)

Acoustic backscatter data were obtained from four fish species, sea bass (*Dicentrarchus labras*), pollack, (*Pollachius pollachius*), grey mullet (*Chelon labrosus*), and Atlantic cod (*Gadus morhua*), using broadband bottlenose dolphin and narrow-band harbor porpoise signals. The fishes were anesthetized and attached to a monofilament net that was in turn attached to a rotor so echoes could be collected along the lateral axis of each fish. The echo waveforms were complex with many highlights and varied with the orientation of the fish. The highlight structure was determined by calculating the envelope of the cross-correlation function between the incident signal and the echoes. The strongest echo occurred when the incident angle was perpendicular to the long axis of the swim bladder, however, the number of highlights was the fewest at this perpendicular orientation and increased as the fish orientation moved