

9:50

3aABa9. Planning for a pilot census of marine life in the Gulf of Maine: The role of acoustics. Kenneth G. Foote (Woods Hole Oceanogr. Inst., Woods Hole, MA 02543, kfoote@whoi.edu)

Preparations are being made for a pilot census of marine life in the Gulf of Maine ecosystem. The role of acoustics as a rapid, remote sensing tool is elaborated. Potential target organisms for acoustic surveying range from mesozooplankton and macrozooplankton to fish and cetaceans. A number of methodological problems must be addressed. These are illustrated for the echo integration method as applied to a stock of Atlantic herring (*Clupea harengus*) [J. Acoust. Soc. Am. **105**, 995 (1999)]. Particular problems of determining target strength and compensating for possible behavioral effects are also general to the method. [Work supported by the Alfred P. Sloan Foundation.]

10:05

3aABa10. Localizing marine animals and how marine animals might localize sound. Gerald L. D'Spain and Paul A. Lepper (Marine Physical Lab., Scripps Inst. of Oceanogr., La Jolla, CA 92093-0704)

We can locate vocalizing marine animals, and the animals themselves might locate sound sources, in one of several ways. Time-of-arrival (phase) differences and amplitude differences of a single arrival between spatially separated "ears" are well-known techniques. However, they become ineffective in multipath environments and as the frequency of the sound and/or spatial separation between ears decreases. Another approach is to sense properties of the acoustic field in addition to acoustic pressure. This approach, based on a simple Taylor series expansion of the field and " $f=ma$," apparently is exploited by fish, making them biological equivalents of DIFAR sonobuoys. However, do they also measure acoustic strain rate? An additional method, used by humans, is to take advantage of

time-of-arrival (phase) differences between multipath arrivals. The information on source location contained in the resulting interference patterns can be understood in terms of waveguide invariants. These speculations will be illustrated with numerical simulations and actual ocean acoustic data. [Work supported by ONR.]

10:20

3aABa11. Acoustic identification of female Steller sea lions. Gregory S. Campbell (Cetacean Behavior Lab., San Diego State Univ., San Diego, CA 92182-4611), Robert Gisner (Code 342, Office of Naval Res., Arlington, VA 22217), and David A. Helweg (Code D351, SPAWARSCEN San Diego, San Diego, CA 92152)

Steller sea lions (*Eumetopias jubatus*) breed and rear their young in coastal rookeries dispersed along the northern tier of the North Pacific. Population densities are high and no allomaternal behavior occurs, providing strong selection pressure for mother-pup recognition processes. Mothers and pups establish and maintain contact with individually distinctive vocalizations. Our objective is to understand the acoustic features that serve to identify individual females, and develop a ruggedized computer system to perform acoustic recognition of females in the field. We have cataloged almost 2000 contact calls from 46 females in 1998 and 25 in 1999. Each female is visually identified by marking patterns, which provides the ground truth for acoustic identification. Acoustic properties of the calls were measured and presented to several statistical classifiers. Representations of the calls had to be robust with respect to acoustical variability introduced by motivational changes as the mother and pup regained proximity. The calls, classifiers, and results of generalization tests will be described, and a concept for the field system will be discussed. [Research supported by ONR Research Opportunities for Program Officers award N00014-00-1-0114 to R. H. DeFran, Cetacean Behavior Laboratory, SDSU.]

WEDNESDAY MORNING, 6 DECEMBER 2000

SCHOONER/SLOOP ROOMS, 10:50 TO 11:55 A.M.

Session 3aABb

Animal Bioacoustics: General Topics in Bioacoustics

Lawrence F. Wolski, Chair

Hubbs-Sea World Research Institute, 2595 Ingraham Street, San Diego, California 92109

Chair's Introduction—10:50

Contributed Papers

10:55

3aABb1. Infrasonic and low-frequency vocalizations from Siberian and Bengal tigers. Elizabeth von Muggenthaler (Fauna Communications Res. Inst.)

Tigers have many vocalizations including chuffing, growling, prusten, gurgling, grunting, and roaring. It has been well documented that the tiger's high-amplitude, low-frequency roars, which are thought to be territorial in nature [C. Packer and A. E. Pusey, *Sci. Am.* **276**, 52–59 (1997)] transmit for miles. It has been suggested that because some tigers inhabit dense jungles with limited visibility, the capacity to hear low frequency may be beneficial for sensing and locating prey [G. T. Huang, J. J. Rosowski, and W. T. Peake, *J. Comp. Physiol. A* (2000)]. In an effort to understand more about these low-frequency vocalizations and to provide data to other researchers testing hearing in anesthetized felids, 22 tigers, both Siberian and Bengal, are being recorded. A portable system can record from 3 Hz to 22 kHz. On-site real-time analysis of vocalizations is performed using a portable computer. Real-time and edited playback of sonic and infrasonic tiger vocalizations is facilitated by car audio speakers

capable of producing frequencies from 10 Hz–22 kHz. Initial findings have documented fundamental frequencies of some roars at 17.50 Hz. Other vocalizations, including chuffing, have fundamental frequencies of 35 Hz \pm 5. Playback of both real-time and edited vocalizations appear to illicit behavioral responses, such as roaring, from male tigers.

11:10

3aABb2. On the sound of snapping shrimp: The collapse of a cavitation bubble. Michel Versluis, Anna von der Heydt,^{a)} Detlef Lohse (Dept. of Appl. Phys. and J. M. Burgers Res. Ctr. for Fluid Dynam., Univ. of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands), and Barbara Schmitz (TU Munchen, 85747 Garching, Germany)

Snapping shrimp produce a snapping sound by an extremely rapid closure of their snapper claw. They usually occur in large numbers providing a permanent crackling background noise, thereby severely limiting the use of underwater acoustics for active and passive sonar, both in scientific and naval applications. Source levels reported for *Alpheus hetero-*

chaelis is as high as 220 dB (peak-to-peak) $re 1 \mu\text{Pa}$ at 1 m distance. Recent ultra-high-speed imaging of the snapper claw closure [Versluis *et al.*, Science (in press)] revealed that the sound is generated by the collapse of a cavitation bubble formed in a fast flowing jet of water forced out from between the claws during claw closure. In this work, we develop a theoretical model for a bubble under such conditions. The dynamics of the bubble radius and the emitted sound can be described by the Rayleigh–Plesset equation. The calculated results are compared with the experimental data. The model fully reproduces the bubble dynamics and it quantitatively accounts for the time dependence of the bubble radius and for the emitted sound. ^{a)} Also at Dept. of Physics, Philipps-Univ. Marburg, Renthof 6, 35032 Marburg, Germany.

11:25

3aABb3. A unique way of sound production in the snapping shrimp (*Alpheus heterochaelis*). Barbara Schmitz (Dept. of Zoology, TU Muenchen, Lichtenbergstr. 4, 85747 Garching, Germany), Michel Versluis, Anna von der Heydt, and Detlef Lohse (Appl. Phys., Univ. of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands)

Sound production is known in more than 50, mostly stridulating, crustacean genera. These acoustic signals occur in agonistic interactions as well as for mate attraction. The mechanism of sound production in snapping shrimp, which also serves to stun or even kill small prey, is especially interesting. The current assumption was that the sound is produced by cocking and then rapidly closing the enlarged modified snapper claw. Snapping shrimp sounds contribute most to coastal biological noise, may be heard up to 1 mile away, and resemble the crackling of dry twigs in fire or the sizzle of frying fat. Recent hydrophone measurements close to tethered shrimp (*Alpheus heterochaelis*) revealed pulse-like signals of 500-ns duration, comprising frequencies beyond 200 kHz, and showing enormous sound pressure levels of up to 220-dB $re 1 \mu\text{Pa}$ (peak to

peak) at 1-m distance. Such high intensities are very unlikely to be produced by the mechanical contact of two claw surfaces. Ultra-high-speed video recordings and simultaneous hydrophone measurements reveal that claw closure results in a water jet, the high velocity of which (25 m/s) leads to the formation of a cavitation bubble, which emits the extremely loud sound upon its collapse.

11:40

3aABb4. Lack of species-specific vocal recognition in Amazonian manatees: *Trichechus inunguis*. Renata S. Sousa Lima and Vera M. F. da Silva (Laboratório de Mamíferos Aquáticos, INPA, C.P. 478, Manaus, AM, Brasil 69083-000, pboi@inpa.gov.br)

Playback experiments were conducted in order to test for the existence of species-specific vocal recognition in Amazonian manatees. The animals were isolated in pools while acoustic stimuli were played from a tape recorder and transmitted underwater through a loudspeaker. Nine animals were monitored for response to playback vocalizations from eighteen different individuals, nine from each species (*Trichechus inunguis* and *T. manatus manatus*). No significant differences were detected in the response of manatees exposed to the different stimuli. Only the time spent close to the speaker was greater when the animals were exposed to conspecific vocalizations ($p=0.375$). This result suggests that Amazonian manatees cannot recognize differences between their own and another manatee species' vocalization. The methodology was also tested and no difference in the response of animals exposed to silence or to tape hiss (blank tape used as control) was found. Testing the response to the presence or absence of vocalizations, significant differences were found in time elapsed between the playback and the response ($p<0.001$) and in the time spent next to the speaker ($p=0.032$), confirming their great ability to perceive sounds underwater. [Work supported by FBPN, MacArthur Foundation, CI, FINEP, MCT/PPG7 and CNPq.]

WEDNESDAY MORNING, 6 DECEMBER 2000

CALIFORNIA SALON 3, 7:20 A.M. TO 12:05 P.M.

Session 3aAO

Acoustical Oceanography: Special Topics

Thomas K. Berger, Cochair

Scripps Institute of Oceanography, University of California, San Diego, 9500 Gilman Drive, La Jolla, California 92093-0238

Christopher D. Jones, Cochair

Applied Physics Laboratory, University of Washington, 1013 NE 40th Street, Seattle, Washington 98105

Chair's Introduction—7:20

Contributed Papers

7:25

3aAO1. The F factor: Ocean climatology and internal-wave acoustic effects. Stanley M. Flatté and Kimberly J. Noble (Phys. Dept. and Inst. of Marine Sci., Univ. of California at Santa Cruz, Santa Cruz, CA 95064)

The strength of acoustic fluctuations due to internal waves is affected by the temperature-salinity relation of an oceanic region. We define an acoustic fluctuation strength parameter F as the ratio of the fractional potential-sound-speed change to the fractional potential-density change. F is calculated at three depth levels (275, 550, and 850 m), on a one-degree grid of latitude and longitude, using NODC/OCL's World Ocean Atlas 1994. Representative values of F in upper waters range between 5 and 35. Results for intermediate depths range from 5 to 60. In general, F exhibits higher values in the Atlantic Basin than in the Indian or Pacific, and has a maximum at 550 m. The main use of F will be the prediction of travel-

time fluctuations in acoustic propagation experiments, which will be proportional to the value of F , given a universal strength of internal waves.

7:40

3aAO2. Imaging acoustic fluctuations in shallow water using dislocation theory. D. P. Williams, G. L. D'Spain, W. S. Hodgkiss, and W. A. Kuperman (Marine Physical Lab., Scripps Inst. of Oceanogr., Univ. of California at San Diego, La Jolla, CA 92093-0238)

The distribution of the amplitude of a moderate-frequency sound field in a shallow ocean is considered in relation to the existence of dislocations in the phase front [Nye and Berry (1974)] where the amplitude is close to zero. Phase front dislocations strictly occur when the amplitude is zero; in actual ocean acoustic measurements, only low-field amplitudes at a minima can be distinguished due to the interference of background noise.