spanning 100–2500 Hz. Both acoustic scattering and pulse-echo ultrasound techniques were used to characterize the response of gas bodies to underwater sound exposure and to determine the resonance frequencies of gas bodies in mammalian tissues *in vivo*. A series of investigations has demonstrated that the effects of low frequency (~ 100–2500 Hz) underwater sound can be significant in and near tissues that contain resonant gas bodies. For example, mice exposed to underwater sound at the resonance frequency of their lung exhibited lung damage and the extent of tissue damage increased with increasing pressure amplitude. Similar types of investigations were performed with mammalian lungs of various sizes and with intestinal gas *in vivo*.

Contributed Papers

10:50

3aAO7. Observations of frequency shift associated with schooling fish.
Orest Diachok (Naval Res. Lab., Washington, DC 20375, orest@wave.nrl.navy.mil)

The number of sardines per school, N, is nominally 10 000 and the separation between sardines in school, s, is nominally 1 fish length, $L \cdot s$ is much smaller than the wavelength at f (the resonance frequency of individuals), which suggests that schools may exhibit acoustic properties of bubble clouds. Long-term, broadband transmission loss measurements at a shallow-water site in the Gulf of Lion revealed absorption lines due to dispersed sardines at 1.3 kHz at 20 m at night and 2.7 kHz at 65 m at dawn. Temporal changes in observed values of f were consistent with concurrent echo sounder observations of the vertical migration of sardines, and theoretical computations based on laboratory measurements of swim bladder dimensions. The measured resonance frequency of sardines in schools during daytime, 1.7 kHz at 65 m, was 0.6f at the same depth at dawn. The observed frequency shift is consistent with a hybrid model of the fundamental resonance frequency of a bubble cloud, which is based on theories developed by Feuillade, Nero, and Love (1996) and dAgostino and Brennan (1988), and $s = 0.8\ L$ and $N = 5000$ fish per school. [Work supported by ONR.]

11:05

3aAO8. Backscattering and extinction cross sections of two swimbladdered fishes at the lowest resonance, as modeled by the boundary-element method.
Kenneth G. Foote (Woods Hole Oceanogr. Inst., Woods Hole, MA 02543) and David T. I. Francis (Univ. of Birmingham, Birmingham B15 2TT, UK)

The boundary-element method has been applied to backscattering and extinction of sound by swimbladdered fish at the lowest, breathing-mode resonance. Corresponding cross sections have been computed for specimens of two representative kinds of swimbladder-bearing fish, namely physostomes and physoclists, which, respectively, possess and lack an external duct. The respective fishes are herring (*Clupea harengus*) and pollack (*Pollachius pollachius*), for which swimbladder morphometric data are available. The depth dependences of the cross sections are computed over the range 0–500 m. Comparisons are made with measurements and other modeled results for a number of species. [Work supported by ONR.]

11:20

3aAO9. Target strength and density structure of Hawaiian mesopelagic boundary community patches.
Kelly Benoit-Bird and Whitlow Au (Hawaii Inst. of Marine Biol., P.O. Box 1106, Kailua, HI 96734, benoit@hawaii.edu)

A broadband sonar system and digital camera with strobe lights were mounted on a vertically profiling frame with a depth sensor. The target strengths and densities of animals within individual mesopelagic boundary community patches were investigated as a function of depth. Simultaneous echosounder surveys permitted comparison of density estimates from echo-energy integration and echo-highlight counting. Target strength values suggest nearshore boundary community animals are primarily myctophid fishes which was confirmed by preliminary photographic evidence. Target strength varied significantly as a function of distance from the shoreline and time. Echo-energy integration estimates of density made with these revised target strengths compare well with those made with echo highlight counting. These density measures show that previous density estimates were too low but do not change the conclusions of these studies. Vertical microstructure in density was apparent but animal size and compositional structure was not evident within a patch. Patch edges were abrupt, with no differences in the density or target strength from patch interiors. These edges were generally straight, with a sharp drop in density to the background density of zero. Estimates of animal size as a function of time provide information about the diel migration patterns of these mesopelagic animals.

11:35

3aAO10. Inversion of the depth, thickness, and absorption coefficient of a layer of fish (anchovies) from transmission loss measurements in the Yellow Sea.
Orest Diachok and Stephen Wales (Naval Res. Lab., Washington, DC 20375, orest@wave.nrl.navy.mil)

Estimates of bioacoustic parameters of fish (anchovies) and geoacoustic parameters of the bottom were simultaneously inverted from the TL measurements of Qiu *et al.* (1999) in the Yellow Sea. Replica fields were calculated with BIO-C-SNAP, a C-SNAP based normal mode model, which permits inclusion of bio-absorption layers. The inversion was based on minimizing the rms difference, D, between measured and calculated values of TL at multiple source and receiver depths and ranges, and involved a simultaneous search for bio-layer depth (d), bio-layer thickness, bio-alpha (a), geo-sound speed, and geo-alpha. The resultant values of D were extremely small (1.9 dB at 1.35 kHz). By contrast, inversion calculations, which assumed that all excess attenuation at this site was due to the bottom, resulted in unacceptably large values of D (9.5 dB at 1.35 kHz). The inverted value of d, 6.8 m, was consistent with laboratory measurements of the resonance frequencies of 10-cm anchovies (1.35 kHz at 6 m), the dominant species in the Yellow Sea. The inverted value of a was consistent with previously reported number densities of anchovies in the Yellow Sea. Inverted geoacoustic parameters were within previously reported bounds. [Work supported by ONR.]

11:50

3aAO11. Studies on geometrical backscattering models of marine bodies.
Anil Kumar C. Parameswaran, Sajith N. Pai, N. Soniraj, P. R. Saseendran Pillai, James Kurian, Supriya M. Hariharan, C. Madhavan, and T. K. Mani (Cochin Univ. of Sci. and Technol., Cochin 682022, India)

The target strength of marine bodies depends on two components—one of them is easy to measure and a good relationship can be established with the target strength value, while the other presents a higher variability that no method can help to reduce, which include the orientation of the fish and a range of environmental conditions and a set of biological facts. Studies on physical models and aspects are expected to provide a clear insight into the issues relating to the target strength variability. Such physical models are developed by converting the physiological shape of the fish into standard and simple geometrical shapes. Data obtained from some of the commercially important species, individually positioned at the center of the acoustic beam, 3 m from the transducer in a test facility were used for the computation of target strength. The target strength value obtained from these reference targets is an indicator of the model performance. Mathematical description of the scattering by some of the species and subsequent comparison with laboratory data have demonstrated that the scattered level by an individual due to a single ping, strongly depends upon size, shape, frequency, material properties, and orientation. Perhaps one of the most notable peculiarities of this work is the simplicity of the approximation and the close agreement between the real world value and the model solution.