

being well suited for solving ill-conditioned equations with inhomogeneous functions. This concept was extended to fish target strength estimation and obtained results were compared to SVD performances.

3aAOa6. Gas cavities in phytoplankton. Dmitry A. Selivanovsky, Igor N. Didenkulov (Inst. of Appl. Phys., 46 Ulyanov St., Nizhny Novgorod, 603600, Russia), and Pavel A. Stunzhas (Shirshov's Inst. of Oceanology, Moscow, 117851, Russia)

Acoustical and related properties of phytoplankton suspensions were investigated in laboratory conditions and *in situ*. A review of studies is present. It was found that cells have gas cavities which allow them to keep a neutral buoyancy. Under sharp compression gas cavities dissolve and recover only under the light exposition. Such properties can explain an anomalous migration of some sound scattering layers. The use of the compression/decompression method allowed us to find gas cavities in blood erythrocytes also. The 6.5-MHz acoustic backscattering from phytoplankton suspensions was applied for characterization of reverberation level under the natural condition and compression (up to 5 atm), which allowed us to evaluate a relative volume of gas cavities in cells. Gas cavities increase an acoustical cross section by 2–3 orders. A dispersion of sound velocity in phytoplankton suspensions with the phase and the resonance methods (from 200 Hz to 11 MHz) for six kinds of living cell suspensions was also studied. Both the increase and decrease of sound velocity dispersion with frequency was observed. The effect is different for cells of different kinds. [Work supported in part by RFBR, Russia.]

3aAOa7. Modeling considerations for acoustic scattering by fluidlike elongated zooplankton: Model intercomparisons and recommendations for euphausiids and copepods. Timothy K. Stanton and Dezhang Chu (Dept. of Appl. Ocean Phys. and Eng., Woods Hole Oceanogr. Inst., Woods Hole, MA 02543-1053)

Predictions of acoustic scattering by fluidlike elongated zooplankton are made using the deformed cylinder model and Distorted Wave Born Approximation over a wide range of animal size, shape, material property inhomogeneities, and orientation, as well as acoustic frequency. Each shape represents a digitized form of the shape of a euphausiid or copepod at low-, medium-, and high-resolution sampling of the shape (e.g., at low resolution, a straight smooth finite cylinder is used and at high resolution, a rough tapered bent finite cylinder is used). The results are analyzed in order to determine the conditions under which the various degrees of complexity in modeling the scattering are required. For example, the predictions illustrate that for modeling the scattering for animals near broadside incidence, relatively simple models can be used (smooth homogeneous bodies). However, for animals off broadside, which can be the case for downward-looking echosounders insonifying euphausiids and copepods, roughness and sometimes inhomogeneities must be used to model the scattering accurately (roughness effects dominate scattering well off broadside). Comparisons are made with laboratory data involving euphausiids, shrimp, and copepods. [Work supported by ONR.]

3aAOa8. Inference of material properties of zooplankton from acoustic and conductivity measurements. Dezhang Chu (Dept. of Appl. Ocean Phys. and Eng., Woods Hole Oceanogr. Inst., Woods Hole, MA 02543) and Peter Wiebe (Woods Hole Oceanogr. Inst., Woods Hole, MA 02543)

In order to infer correctly biological information from raw acoustic data, various acoustical models have been developed and much progress has been made both in laboratory experiments and field applications. However, the acoustic properties of biological scatterers, such as sound-speed and density, have a profound influence on the target strength estimate or volume scattering strength. A 1%–2% variation in sound speed

and density can lead to an error in target strength prediction by as much as 20 dB or a tenfold bias in biomass estimate, which could be much greater than that due to the choice of different acoustic models. There is a dearth of information about the material properties of the live zooplankton because measurement of them is difficult. An instrumented chamber was used to collect simultaneously acoustic and conductivity data with and without the presence of live zooplankton. The acoustic measurement characterizes both the back- and forward-scattering patterns, while the conductivity measurement provides an estimate of the fraction of volume the animals occupy (volume fraction). The combined information can then be used to infer the material properties of the animal. The experimental results will be presented and discussed. [Work supported by NSF.]

3aAOa9. Digital transducer, novel technology for acoustical oceanography and fisheries research. William Acker, Dan Wiggins (BioSonics, Inc., 4027 Leary Way NW, Seattle, WA 98107, bio@biosonicsinc.com), and Janusz Burczynski (BioSonics Europe, 54036 Marina di Carrara (MS), Italy)

Novel digital transducer architecture designed and produced by BioSonics Inc. offers many advantages over older analog designs. By digitizing the signal at the transducer element, the cable-coupled noise is eliminated. The signal is sampled at a high rate and accuracy (0.13%), and wide instantaneous dynamic ranges (132 dB). This allows simultaneous capture of extremely small and large echoes (single plankton specimen or bottom return) with no loss in detail or signal saturation. The data acquisition system is virtually automatic since most of the decisions are done by software. Raw data is stored on PC hard drive. Data acquisition and data analysis software packages are user friendly and operate in Windows™ environment. Many data processing tools are already developed as separate implementation of various algorithms. Digital transducers have already been successfully applied in various field projects in both marine and fresh waters: (i) monitoring and estimates of fish and plankton, (ii) fish tracking, and (iii) bottom plants estimate and seabed classification. The digital sonar is available in various packages and it can be installed on different platforms as portable systems for boats and ships, fixed platforms on dams, and in river in systems. The digital transducers are available in a wide range of frequencies (38 kHz to 1 MHz), in a single, dual, or split beam configurations.

3aAOa10. Spheres for calibrating high-frequency broadband echo sounders. Kenneth G. Foote (Inst. of Marine Res., P.O. Box 1870 Nordnes, N-5024 Bergen, Norway), David T. I. Francis (Univ. of Birmingham, Birmingham B15 2TT, UK), Hilde Furset, and Halvor Hobaek (Univ. of Bergen, N-5007 Bergen, Norway)

The notion of standard-sphere broadband calibration [Dragonette *et al.*, J. Acoust. Soc. Am. **69**, 1186 (1981)] is being realized for a new echo sounding system that spans the seven-octave range 25 kHz to 3.2 MHz. Spheres formed of tungsten carbide with 6% cobalt binder, with 10- and 20-mm diameters, have been measured in the laboratory to determine their backscattering spectra over the approximate frequency ranges 0.85–1.3 MHz and 2.9–3.6 MHz. This allows exploration of the wave number radius (ka) product over the nominal ranges 18–28, 36–56, 61–75, and 122–150. Comparison with theoretical expectation, as derived from the standard modal solution using published values for the material properties, is quite good. Confidence in the computations thus enables favorable regions of the backscattering spectra to be sought and exploited in choosing optimal diameters, as has earlier been the case with spheres for calibrating resonant transducers. In the course of checking computations, it was discovered that two independently developed numerical codes yield values

for the backscattering cross section that agree to within 1 part in 10 000 to better than one part in 1 000 000 for k_a of the order of 100. [Partial support of the EU through RTD Contract No. MAS3-CT95-0031 is acknowledged.]

3aAOa11. Shark and salmon movement measured by tracking radar-type acoustic transducers. John Hedgepeth, David Fuhrman (BioSonics, Inc., Seattle, WA), Robert Johnson, David Geist (Battelle Memorial Inst., Richland, WA), Norm Bartoo, David Holts (Natl. Marine Fisheries Service, La Jolla, CA), Tim Mulligan, and George Cronkite (Dept. of Fisheries and Oceans, Nanaimo, BC, Canada)

Studies of fish behavior have used a methodology called the tracking transducer. The principle of tracking radar, aligning the antenna beam with a target, was applied with an acoustic split-beam transducer and dual-axis rotators for tracking individual fish over long periods of time. Deviation of the target from the beam axis produces a correction to point the axis toward the target. Initial studies with active acoustics have evolved an acoustic tag tracking method that is proposed for tracking both juvenile salmon and pelagic sharks. The major advance is that active and passive radar-type tracking can be combined in the same instrument. The tracking transducer was first used at Ice Harbor Dam, Snake River, 1995, and in 1996, at The Dalles Dam, Columbia River. Two tracking systems were used to triangulate a small acoustic transmitter in salmonid fish at Lower Granite Dam on the Snake River, Washington. Recently, adult salmon, returning to the Fraser River, were tracked to measure avoidance to surveying vessels. The feasibility for tracking sharks was shown at the Tacoma, Washington Point Defiance Aquarium. A proposed method of simultaneously tracking sharks with echoes and using acoustic tags will allow behavior, abundance, and associated pelagic assemblages to be determined.

3aAOa12. Mechanoreception for food fall detection in deep sea scavengers. Michael Klages (Alfred-Wegener-Inst. for Polar- and Marineresearch Postfach 12 01 61, 27515 Bremerhaven, Germany) and Sergey I. Muyakshin (Inst. of Appl. Phys., Nizhny Novgorod, 603600, Russia)

Although knowledge about functional principles of deep-sea ecosystems is rather scarce, it is assumed that the energy supply for scavengers is restricted to large food falls of dead vertebrates. It is generally accepted that chemoreception is one of the major tools for marine organisms to detect food sources. However, another major source of information may come from hydroacoustical feeding noises produced by scavengers appearing on a cadaver reached the seafloor. The aim of the present study was to investigate whether scavenging crustaceans—pandalid shrimps *Pandalus borealis*—are able to detect such rare food fall events via mechanoreception or not. These results are based on 228 single experiments indicating that these animals possess the sensitivity to the particle dis-

placement of 0.1–10 mkm in frequency range 30–250 Hz. Therefore, acoustic feeding noises offer a possibility for animals to detect such rare events but only at distances of a few meters. At such small distances chemoreception is presumably more important. However, based on theoretical calculations on the relevance of various types of waves, originating on the water-sediment interface from any object falling on the seafloor, it is proposed that such “micro seismic events” may allow resting scavengers even some hundred meters away the detection of this event, most likely followed by chemoreceptive tracking.

3aAOa13. Echogram noise quantification with application to herring observations. Rolf J. Korneliussen (Inst. of Marine Res., P.O. Box 1070, Nordnes, N-5024 Bergen, Norway, rolf@imr.no)

Pushing the limits of scientific echo sounders involves considerations of noise, which is inherently frequency dependent. Surprisingly, perhaps, there is also a dependence on bottom depth. In this work, noise is quantified by measurement for a standard echo sounder, the EK500, at 18, 38, 120, and 200 kHz. Use of empirical relations of noise as a function of range to reduce echogram noise is described in general, and illustrated in particular for data collected on Norwegian spring-spawning herring (*Clupea harengus*) when wintering in the Vestfjord system. [Work supported by the Norwegian Research Council through Grant No. 113517/120.]

3aAOa14. Preliminary description of swimming activity and estimation of swimming speed of saithe (*Pollachius virens*) at one location in the North Sea. Jens Pedersen (Danish Inst. for Fisheries Res., North Sea Ctr., P.O. Box 101, DK-9850 Hirtshals, Denmark, jp@dfu.min.dk)

Individual saithe were tracked with a split-beam echosounder, while the vessel was drifting, in the area around Eigersundbank in the North Sea and their swimming speed estimated. The average swimming speed was approximately 4 and 1 body lengths per second for small saithe (20–30 cm) and saithe >70 cm, respectively, and a significant inverse relationship between length of the saithe and swimming speed was found. There was clear evidence of diurnal variation in swimming speed of small saithe, as the swimming speed was significantly higher during night (18–06 h) than during day (06–18 h). The number of observations on saithe >70 cm was too small to compare day and night swimming speeds. Although the results indicate higher swimming speeds of saithe in the demersal layer compared to pelagic saithe, significant differences were not found. The duration of acoustic observation time was 36–56 min per 4-h sampling interval during the 24-h cycle. A total of 278 series of saithe were selected, which, according to selection criteria, were accepted as representing tracking of single fish over two pings or more. The species identify of the targets tracked acoustically was verified by trawling in the layers investigated.