Integrating Models, Measures, and Visualizations of Acoustic Backscatter

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LONG-TERM GOAL

The long-term goal of this program is to quantify, understand, and visualize acoustic backscatter from fish. Our strategy integrates numeric backscatter models with computer visualizations and compares model predictions to laboratory and field measurements.

OBJECTIVES

Objectives of this project include: modeling acoustic backscatter from individual and aggregations of fish; integrating fish anatomy, behavior, ontogeny, and physiology in predictions of acoustic backscatter; comparing acoustic technologies used to quantify fish distributions and abundance; and visualizing acoustic backscatter from individual and aggregations of fish.

APPROACH

Kirchhoff-ray mode backscatter models, based on digitized x-ray images of fish bodies and swimbladders, are used to predict species-specific backscatter amplitudes as a function of acoustic wavelength, fish length, and fish orientation (i.e. aspect and roll). Model predictions of backscatter from individuals are also scaled to estimate population backscatter, abundance, and are compared to laboratory and in situ field measurements.

WORK COMPLETED

Biological and physical factors influencing fish target strength were identified at an ICES Fisheries Technology Committee study group on target strength estimation in the Baltic Sea. A sampling and backscatter modeling program was designed for Baltic Sea herring and sprat. A fish anesthesia and radiographing protocol was compiled during this meeting to standardize data collection for backscatter modeling.
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Four papers and one report were published this year with an additional three papers submitted or in review. A total of 17 presentations were made individually, jointly, or in collaboration with colleagues at regional, national, and international meetings.

East coast

Comparisons of acoustic backscatter measurements of live, individual alewife (Alosa pseudoharengus) to predictions from a Kirchhoff Ray-Mode (KRM) model, a conformal mapping technique, and a modal-series-based deformed cylinder model continue in collaboration with researchers at the Woods Hole Oceanographic Institution. Backscatter measurements were obtained over 360° in the dorsal/ventral and lateral planes using a broadband (40-95 kHz) source. Model results were obtained using digital representations of swimbladder and fish body radiograph images.

A two-week cruise was conducted during Sept. 4-14, 2001 in the Gulf of Maine and Georges Bank regions in collaboration with the Northeast Fisheries Science Center. Dr. Redwood Nero and Charles Thompson (Naval Research Laboratory, Stennis Space Center, MS) conducted low-frequency (0.5-10 kHz) backscatter measurements, and Mr. Gerald Denny (Scientific Fisheries, Inc.) conducted broadband backscatter measurements (100-200 kHz) in conjunction with three downward looking echosounders (12, 38, and 120 kHz).

West coast:

Additional radiographs were obtained and KRM backscatter modeling of juvenile walleye pollock (Theragra chalcogramma) was completed to compare ontogenetic changes in acoustic backscatter. Young-of-the-year, juvenile, and adult walleye pollock radiographs were used to quantify the influence of material properties (i.e. sound speeds and density contrasts) on predicted backscatter from fish bodies and swimbladders. A computer-controlled system has been designed and tested to change tilt angles and depths of tethered individual fish. This system will be used to measure backscatter amplitudes and variability of walleye pollock.

Third generation backscatter visualizations were written using object-oriented graphics and the number of features in the viewer was expanded (Figure 1).
Backscatter amplitudes can now be displayed using a logarithmic decibel scale. Visualizations of individual fish backscatter within aggregations were enhanced to include a variety of fish sizes, orientation and backscatter outputs from any fish, and real time color fluctuations to indicate backscatter amplitudes (Figure 2). Defined path or freehand ‘fly-by’ animations can be exported as ‘movie’ files. The Fisheries Acoustics Research website has been updated to include animations (www.acoustics.washington.edu/animations).

Figure 1. Screen capture of Fish3d viewer showing walleye pollock backscatter ambit in decibel scale at 38 kHz (left panel) and 120 kHz (right panel) with graphic user interface

Figure 2. Screen capture of fish schooling animation showing a walleye pollock school in the Bering Sea. Fish bodies are color coded for backscatter amplitude at 38 kHz.
RESULTS

The study group on target strength (TS) estimation in the Baltic Sea defined a general equation that combines the influence of physical (i.e. frequency, temperature, salinity) and biological (i.e. anatomy, behavior, physiology) factors on target strength:

$$\text{TS} = f(\text{frequency}) + f(\text{length}) + f(\text{pressure}) + f(\text{temperature, salinity}) + f(\text{orientation}) +$$
$$f(\text{activity}) + f(\text{lipid}) + f(\text{gut fullness}) + f(\text{gonad})$$

Having identified individual variables, the next step is to quantify the function and relative importance of each factor using a common currency. Current conversions of target strength to fish length include length, frequency, and limited tilt angle ranges. Quantifying the relative importance will indicate if additional variables should be included in regression models and highlight research areas that will increase accuracy of acoustic-based abundance estimates.

East Coast

Comparisons of acoustic backscatter measurements to KRM model results suggest that KRM model predictions are robust and accurate within 30-40 degrees off dorsal-ventral (Figure 3), and lateral aspects (i.e. broadside incidence) and within the frequency range of the broadband measurements. At aspect angles within 40-50 degrees of head and tail-on orientation, the KRM model tends to predict backscatter amplitudes less than the measured amplitude.

![Figure 3. Alewife (length =256 mm) KRM predicted (black) and measured (red) backscatter amplitudes (Reduced Scattering Length) at 50 kHz plotted as a function of dorsal/ventral orientation.](image-url)
West Coast

Examination of walleye pollock backscatter models, in situ target strengths, and a TS-length regression (Figure 4) enabled comparison of numeric and statistical model predictions to empirical measurements.

![Graph showing target strength vs. length](image)

**Figure 4. Walleye pollock KRM predicted mean (solid) and one standard deviation (dotted), measured (solid dots), and NMFS TS-length regression (red line) at 38 kHz.**

KRM backscatter models of all radiographed fish (n = 35) were used to compile TS – length curves at 38 kHz. The curve is comprised of three overlapping length sections based on young-of-the-year (100 mm – 250 mm), juvenile (200 mm – 400 mm), and adult (350 – 600 mm) life history stages. All but one of the 38 kHz in situ average TS values fall within one standard deviation of the KRM predicted TS curve. The fit of the KRM predicted values were also compared to the fit of the National Marine Fisheries Service: $TS=20\log(L_{cm})-66$ regression model. The regression curve, empirical points, and KRM curve are in close agreement at fish lengths greater than 380 mm. The greatest disparity among the three data sources occurs at fish lengths below 200 mm suggesting that additional modeling and measuring of juvenile and young-of-the-year walleye pollock target strength is warranted.

**IMPACT/APPLICATIONS**

Comparisons of broadband backscatter data to model predictions at a wide variety of insonification angles provide insight to the potential, and the limitations, of obtaining quantitative abundance, length, and biomass estimates from non-traditional acoustic instrumentation such as multi-beam or sector scanning sonar.

Quantifying and ranking the relative importance of biological factors on backscatter amplitude and variability contributes to the discrimination and identification of acoustic targets. Incorporating
anatomical, behavioral, ontogenetic, and physiological variables in target strength models will improve accuracy of fish population abundance estimates.

TRANSITIONS

Researchers in Australia (R. Kloser) and New Zealand (S. McClatchie) are initiating collaborations to compare model predictions to acoustic backscatter measurements of meso- and bathypelagic fish species on commercial fishing grounds off the coasts of the two countries.

RELATED PROJECTS

We are participating in an international study group (Baltic Sea Herring TS) formed by the ICES FAST Working Group to investigate relationships of acoustic backscatter to Atlantic herring and sprat in the Baltic Sea. This study group is using a combination of in situ acoustic measurements, biological and morphological measurements, and KRM model predictions to quantify factors that affect target strength in an effort to improve fisheries abundance estimates of these species. The Baltic Sea project provides a base to examine all biological and physical factors influencing acoustic backscatter from teleost fish.

PUBLICATIONS


PRESENTATIONS


