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Multi-frequency Acoustic Assessment of Fisheries and Plankton Resources

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ABSTRACT

The range of target species encountered in marine biological resource assessment and the inability to obtain a broad view of these resources by direct physical sampling techniques has lead to the utilization of various indirect measurement techniques. Among these techniques is the use of acoustics (sonar) to determine biomass distribution through echo integration and target strength measurements. WHOI is using a multifrequency acoustic system to obtain more accurate measurements of target species on the Georges Bank. The system uses advanced acoustic techniques (FM slide-encoded pulses) to enhance detectability at the lower trophic levels. An advanced towing technique enables sampling the water column to depths in excess of 200 m.

U.S. GLOBEC GEORGES BANK PROGRAM

Woods Hole Oceanographic Instituition (WHOI) is a major participant in the U.S. GLOBEC Georges Bank Program. One goal of the program is to understand the population dyamics of key species on Georges Bank including the larval phase of cod and haddock and several species of zooplankton. This requires a broad-scale field survey of the target species. Direct methods, such as physical sampling, while providing an accurate picture of the physical distribution and abundance of the population, are time-consuming, costly, and limited in coverage. To increase the area surveyed, WHOI has been using indirect sampling techniques, including both optical and acoustic solutions. These techniques when combined with limited direct sampling provide an accurate, broad-scale view of populations on Georges Bank.

Surveys of Georges Bank are undertaken at regular intervals throughout the year following a predetermined sampling path. The survey protocol combines physical sampling at a number of fixed station locations with indirect sampling while en route between stations. Data from the physical samples are used to ground-truth indirect measurements and to aid in determining population composition. (1)

The sonar system initially used by WHOI was based on conventional sine-wave pulse single-beam and dual-beam shallow-water 120 kHz and 420 kHz sonar systems that were converted to towfish operation. The system was towed just below the surface, severely limiting its sampling range. To improve their capabilities, WHOI defined a new system that would operate at greater depths. The initial BIOMAPER (Bio-Optical Multifrequency Acoustic and Physical Environmental Recorder) was a proof-of-concept system and lead to a comprehensive specification for a new system. (2)

ACOUSTIC SAMPLING

Acoustic sampling of marine organisms has been used for many years for fish stock assessment. The use of these tools for the assessment of lower trophic levels has been a relatively recent application, which has revealed a new set of measurement problems. The acoustic backscattering cross section (s_s) varies with the size of the target and the wavelength of the measuring frequency. Many studies have been undertaken to determine the relationship between target size and wavelength. For small targets where the circumference (p d) is on the order of the acoustic wavelength (l), the dependence of backscattering cross section is:

$$s_s \cong (\pi d/\lambda)^4$$

While this equation doesn't completely predict s_s for all targets, it is representative of the general target size/wavelength relationship. Because s_s is a function of the fourth power, it is apparent that different size targets will exhibit greatly different characteristics. This can be exploited to aid in target identification. It also implies that a single frequency is not appropriate for all targets.

The target species on the Georges Bank can be considered to be in one of three classes: prey, which are generally less than 1 mm; target species, which range in size from 1 mm to 10 mm; and predators, which are larger than 10 mm. Prey generally are too small to be detected acoustically. The order-of-magnitude size variation or the target species results in four orders of magnitude variation in s_s. To accurately assess these targets requires that more than one acoustic sampling frequency be used.

BIOMAPPER II

The BIOMAPER II system (Figure 1) is an advanced version of BIOMAPER, which incorporates improvements from experience with the initial system. Transducers are mounted in both up-looking and down-looking positions. A total of 12 transducers can be deployed on BIOMAPER II. Ten transducers were installed for the initial deployment, including up-looking and down-looking transducers at 43 kHz, 120 kHz, 200 kHz, 420 kHz, and 1 MHz. All transducers were split-beam except for the 1 MHz units, which are single-beam.

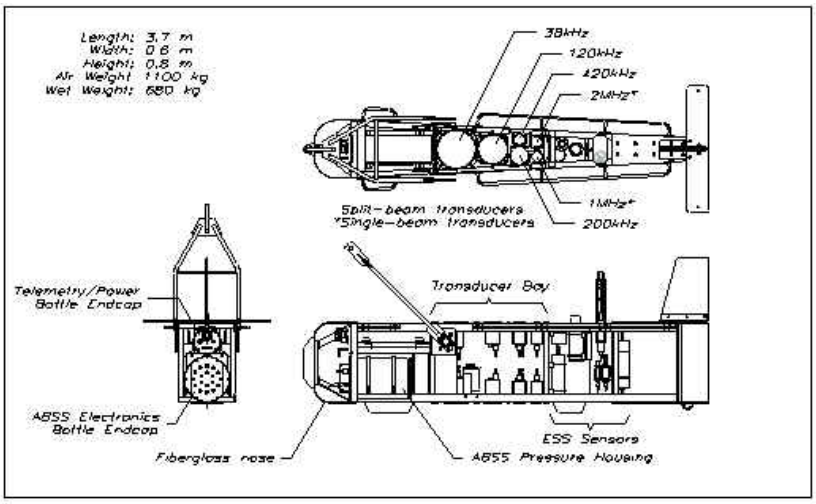

FIGURE 1. BIOMAPER II System Configuration

The physical size of the target species makes them difficult to detect at great ranges. The BIOMAPER II system maximizes detection range by using FM slide encoded transmit pulses along with matched filters to increase signal-to-noise in excess of 15 dB without decreasing system resolution. Multi-frequency fast-multiplexed operation allows successive sampling of any of the installed transducers on a ping-by-ping basis. Each transducer operates as a virtual-echo sounder, with all its operating parameters selectable on a ping-by-ping basis. In addition, the BIOMAPER II system is designed for operation to depths of 500 m, allowing a new towing technique in which the tow depth is regularly varied from near-surface to near-bottom, allowing the entire water column to be sampled.

The improvements incorporated in the BIOMAPER II system enable the comprehensive broad-scale investigation of previously inaccessible features of the Georges Bank.

Georges Bank, North Atlantic

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