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A Surprise Occurrence in Acoustic Bottom Backscatter Measurements Conducted in the Eastern Bering Sea

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Bottom Backscatter Measurements Conducted in the eastern Bering Sea

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ABSTRACT

Acoustic backscatter measurements at different frequencies were made in the eastern Bering Sea in August 2006 from the *NOAA Ship Fairweather*. The measurements consisted of approximately 2,250 nm of trackline acoustic backscatter data from a 100 kHz RESON model 8111; 2,250 nm of trackline acoustic backscatter data from a 40 kHz Reson model 8160; 750 nm of trackline acoustic backscatter data from a 455 kHz Klein model 5410; and 750 nm of trackline acoustic backscatter data from a 180 kHz pre-production Klein model 7180. The two Klein systems were each towed SW-NE once along the same specified 750 nm of tracklines. The two RESON systems were each operated twice SW-NE and once NE-SW along the same tracklines as the Klein systems. The acoustic backscatter was typically what might be expected from a flat, featureless expanse of fine grained sediments. However, there was a chance encounter with an embedded community of gastropods that was documented both with bottom grab samples and video footage of the seabed. The presence of the embedded community of gastropods drastically changed the level and angle dependence of the backscatter. This paper presents a comparative analysis of the backscatter properties of the gastropod community that were observed at 40 kHz, 100 kHz, 180 kHz and 455 kHz.

INTRODUCTION

An acoustic survey was conducted in the eastern Bering Sea, from 31 July thru 20 August, 2006. The survey, which was organized by the NOAA Alaska Fishery Science Center, was conducted on the *NOAA Ship Fairweather*. The primary objective of the survey was to evaluate the utility of different sources of radiometrically adjusted acoustic backscatter data for the characterization of essential fish habitat (EFH) in the eastern Bering Sea. The sources of acoustic data discussed in this paper were Multibeam Bathymetric Echo Sonar (MBES), and Towed Side Scan Sonar (TSSS). There was two of each type of acoustic data source. The MBES were the Reson models 8160 and 8111 installed on the Fairweather which operate at 40 and 100 kHz, respectively. The two TSSS included a pre-production L3 Klein model 7180 and a L3 Klein model 5410 operating at 180 and 455 kHz, respectively.

DISCUSSION

The survey scheme used in the FISHPAC experiment is shown in Figure 1 with a NOAA Ship acquiring MBES data and

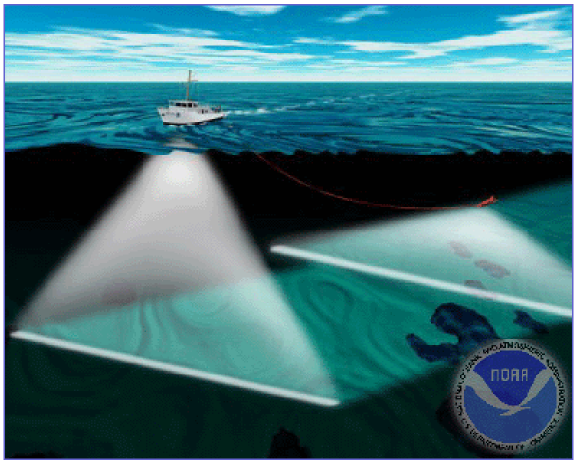

Figure 1 The survey scheme used in the FISHPAC EFH experiment.

TSSS data along a track line. The 8111 and the 8160 were actually operated simultaneously and the different TSSS were operated in sequence. The model 5410 was initially towed toward the NE along a given survey line. That operation was followed by the ship returning down the same survey line while acquiring ground truth data at sights that had been selected based on a rapid on-board review of the side scan data from the model 5410. A third pass was made along the same trackline while towing the pre-production model 7180 toward the NE, as the previous towing of the model 5410. The totality of the FISHPAC tracklines which were traversed three times is shown in Figure 2, along with the location of the chance encounter with the community of gastropods. X08 and X09 indicate locations of two closely spaced sites that were investigated to provide ground truth for the EFH experiment. The ground truth investigations included use of a SEABed Observation and Sampling System [1] to acquire grab samples of the bottom; use of a Towed Auto-Compensating Optical System (TACOS) [2] to acquire video footage of the seabed; and use of a BOT Free Fall Cone Penetrometer [3] to characterize the sediment properties.

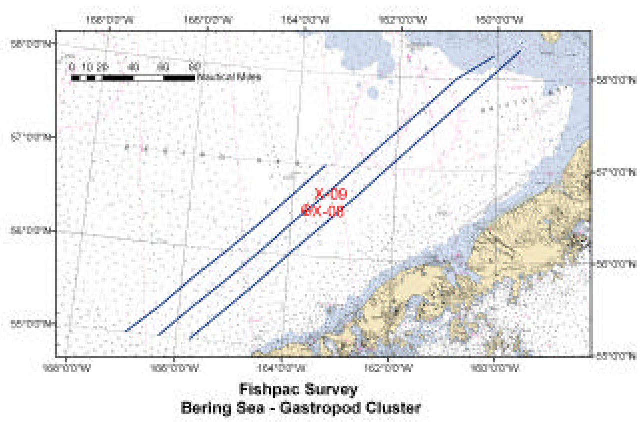

Figure 2 Completed survey tracklines of the FISHPAC EFH experiment with X08, X09 marking the location of the gastropod cluster.

Figure 3 shows a surprise occurrence in acoustic backscatter acquired with the 5410, which upon taken ground truth measurements proved to be a cluster of gastropods. The image is overprinted with two boxes to designate areas of background next to the gastropod cluster, which is marked with its own surrounding box.

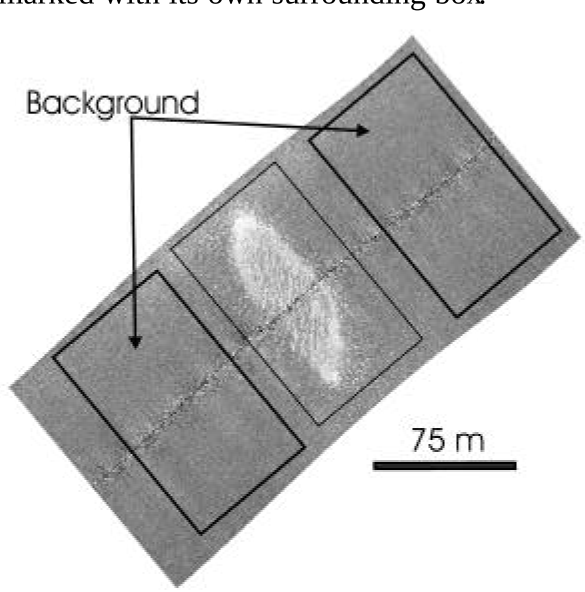

Figure 3 Backscatter image of gastropod cluster acquired with L3 Klein 5410 along with demarcation of areas designated as background.

The cluster has a distinctly elevated backscatter when compared to the backscatter of the surrounding area. Figure 4, which was moasicked from video footage acquired with TACOS, clearly shows a number of individual gastropods.

Figure 4 Mosaic of TACOS Video showing internal structure of the gastropod cluster

Musing as to how sediment properties influence backscatter will most likely lead to information of the sort that is presented in Figure 5, which illustrates the impact of incidence angles and material type on backscatter from the sea bed at 100 kHz.

Note that there is no explicit indication of interface roughness in Figure 5, nor is there a specific graph for "gastropod cluster". That led the authors into an attempt to leverage this surprise occurrence of backscatter in the eastern Bering Sea into a graph that could hereafter be included in renditions of the information shown in Figure 5. That effort fell short of the goal because not all of the metadata required to make radiometric adjustments to the

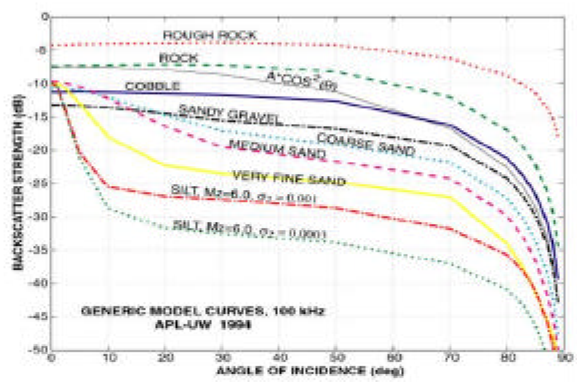

Figure 5 Relationships between acoustic backscatter and incidence angles for different sea bed materials at 100 kHz.

backscatter were available. An alternate approach to using the data from the gastropod cluster to promote better understanding of acoustic backscatter was more successful. The radiometric adjustments to the backscatter imagery from the MBES and TSSS would have been performed within GEOCODER [4], if all of the metadata required for such adjustments were available. Despite the lacking metadata, GEOCODER is sufficiently flexible to make a precise determination of the difference in backscatter as a function of incidence angle between the background and the area of the gastropod cluster.

The backscatter record in Figure 3 was reduced to a three small sections of equal along track length a, one SW of the cluster, the cluster and one NE of the cluster. A faux angular response was computed for three sections of backscatter imagery for each of the four acoustic systems. The faux angular response curves surely were fraught with embedded effects due to source level, transmit beam pattern, receive sensitivity, receive beam pattern, pulse length, height of the sonar above the seabed, local sea floor roughness, sea floor hardness, and the sonar frequency. However in moving between the three sections of imagery, the acoustic roughness and hardness of the seabed surely changed and it is possible, but uncertain, whether or not there was a change in subsurface in- homogeneities. Questions about the origin, development and vertical structure of these gastropod clusters, both above and below the sea bed interface, remain to be investigated, but are beyond the scope of this paper.

RESULTS

Figure 6 presents the change in backscatter between the gastropod cluster and the surrounding background sediment. The general trend seen in the measurements is for the delta backscatter for all four acoustic systems to be positive and to increase as a function of incidence angle.

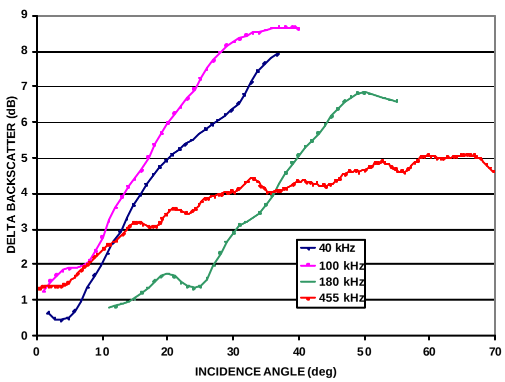

Figure 6 Change in backscatter attributable to the presence of a gastropod cluster.

The increases in backscatter at 40 kHz, 100 kHz and 180 kHz in the gastropod cluster have similar slopes with increasing incidence angle. The near nadir increase in backscatter at 455 kHz is comparable to the increase in backscatter at 100 kHz for grazing angles up to about 10 degrees. Beyond 20 degrees, the increase in backscatter in the gastropod cluster at 455 kHz is distinctively different (markedly lower) than the increase backscatter at 40 kHz and 100 kHz.

The pattern of changes in backscatter with frequency associated with the gastropod cluster warrants an explanation.

It was previously stated that Figure 5, contained no explicit indication of interface roughness. That statement needs to be expanded because the figure does contain information related to the size of particles that comprise the sediment. However there is no information as to how different assemblages of those particles may relate to the RMS deviation from a nominal plane through any assemblage in particular, yet the RMS is a common descriptor of surfaces. Regardless of the RMS roughness of an interface, it is the acoustic roughness of the interface that determines the pattern in which an acoustic wave impinging onto the sea bed will be scattered. The acoustic roughness is dictated not by the linear (physical) dimension of deviations about a nominal plane through the local interface between the water and the sea bed, but is dictated by the deviations about that plane when expressed in terms of the acoustic wavelength. Consequently, any particular assemblage of sea bed materials varies from being acoustically smooth at long acoustic wavelengths to being acoustically rough at short acoustic wavelength.

If the seabed is acoustically rough at a particular frequency, then the variability of backscatter may be a weaker function of incidence angle for small angles than it would be for a lower frequency. Once the acoustic frequency is high enough for a given physical roughness (RMS) of the seabed to be acoustically rough, the surface is also acoustically rough for all higher frequencies. For a given circumstance of frequency where the surface is acoustically rough, an increase in impedance contrast (hardness) of the interface should result in an increase in backscatter at all incidence angles.

In the case of the gastropods in the eastern Bering Sea, the authors suggest that while the background sediment surrounding the cluster is acoustically rough at 455 kHz, it is acoustically smooth at 40 kHz and 100 kHz. The background sediment is probably tending toward being acoustically rough at 180 kHz, such that there is a weak change (reduction) in backscatter with incidence angle, at low incidence angles. It is further suggested that within the gastropod cluster the sea bed is acoustically rough at all four frequencies. That could explain the pattern of changes in backscatter with frequency associated with the gastropod cluster. At 455 kHz, the sea bed was acoustically rough both inside and outside the cluster, however the increase impedance contrast due to the presence of the shells caused an overall increase in the 455 kHz backscatter but did significantly change the angular response with incidence angles. Inside the gastropod cluster the physical RMS roughness of the sea bed increased to the point that it was also acoustically rough at 40 kHz, 100 kHz and 180 kHz. The different changes in the backscatter as a function of incidence angle at the three lower frequencies are different manifestations of both the increase in acoustic roughness and impedance contrast.

In support of the contention that the sediment background is tending toward being acoustically rough at 180 kHz is that at incidence angles less than 20 degrees the behavior at 180 kHz is similar to that at 455 kHz, a frequency where the sediment is no doubt acoustically rough. At grazing angles greater than 20 degrees, the behavior at 180 kHz is similar to that at 40 and 100 kHz, where supposedly the seabed changed from being acoustically smooth at those frequencies outside the gastropod cluster to being acoustically rough at those frequencies inside the cluster.

CONCLUSIONS

This investigation has lead to probable explanations of why a cluster of gastropod shells has distinctively different backscatter characteristics at different frequencies and incidence angles when compared to the backscatter of the surrounding area.

Faced with the inability to radiometrically adjust the backscatter due to the lack of critical metadata for all four of the acoustic systems used in the FISHPAC experiment, the authors have resorted to a careful examination of the change in the backscatter for different incidence angles and different frequencies. The result serves as another reminder that in acoustic backscatter, it is the acoustical roughness of an interface, which depends on the acoustic wavelength, rather than the actual physical dimensions of the interface roughness that dictate the results.

ACKNOWLEDGEMENTS

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