Changes in Geomorphology and Backscatter Patterns in Mount Misery Shoal, Long Island Sound as Revealed through Multiple Multibeam Surveys

Laurie A. Zaleski Laurie.Zaleski@msrc.sunysb.edu, **Roger D. Flood** rflood@notes.cc.sunysb.edu
Marine Sciences Research Center
State University of New York
Stony Brook, NY 11794-5000

Abstract

High resolution swath sonar surveys provide an opportunity to investigate seafloor morphology and backscatter patterns. Bathymetric and side scan surveys may be used to define seafloor topography and interpret seafloor geomorphology. Through the comparison of multiple surveys, morphological changes and migration trends of seafloor features can be assessed.

Introduction and Methods

Mount Misery Shoal lies in Long Island Sound, north of Port Jefferson Harbor (Figure 1). The study area extends from the northern edge of Mount Misery Shoal, offshore for approximately 1 km to a depth of 28 m, and for 2 km alongshore. Multiple surveys were done and the comparison of data collected in the two surveys shows definite topographical and backscatter changes, apparently related to sediment movement.

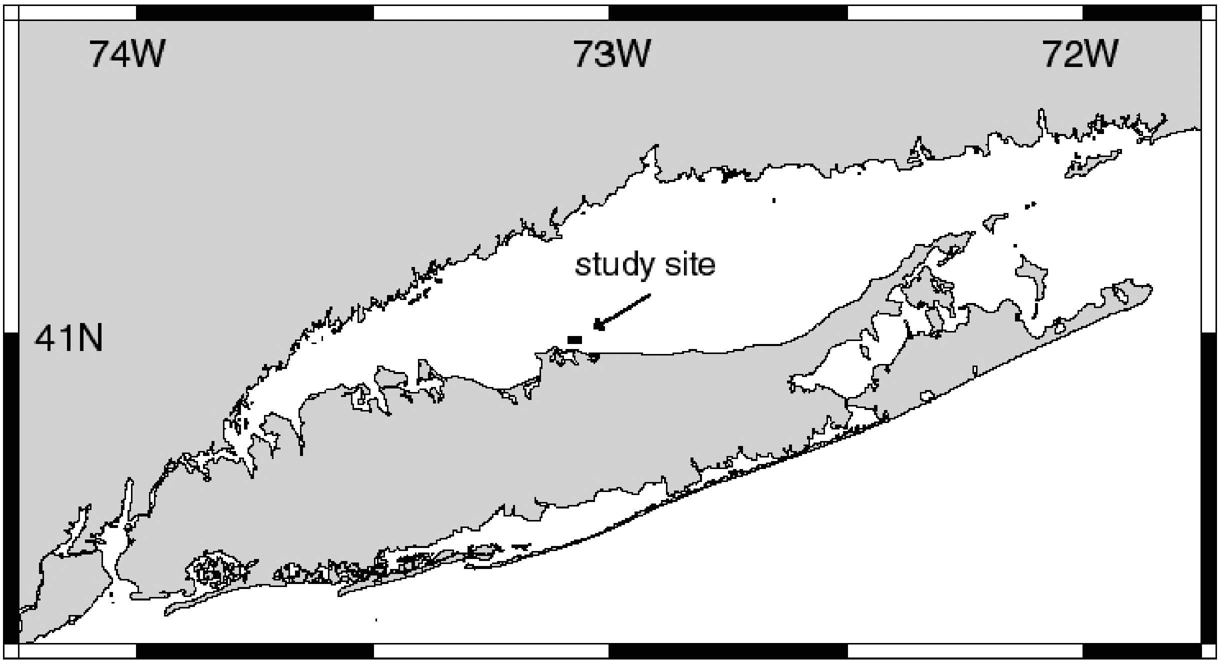


Figure 1. Study site location in Long Island Sound, north of Port Jefferson Harbor (Flood, 1998)

Two surveys were done in October 1998 and March 2000 using the Kongsberg Simrad EM3000 multibeam echo sounder. Bathymetric and backscatter maps of the study site were produced. Analysis of multibeam data demonstrates subtle changes in the seabed over the 1.5 year period, including the appearance of new sand waves and the migration of existing waves. Over the 1.5 years, changes in backscatter patterns also occurred indicating changes in sediment distribution apparently related to sediment transportation. Knowledge about sediment type and substrate was obtained through sediment samples and their associated backscatter values.

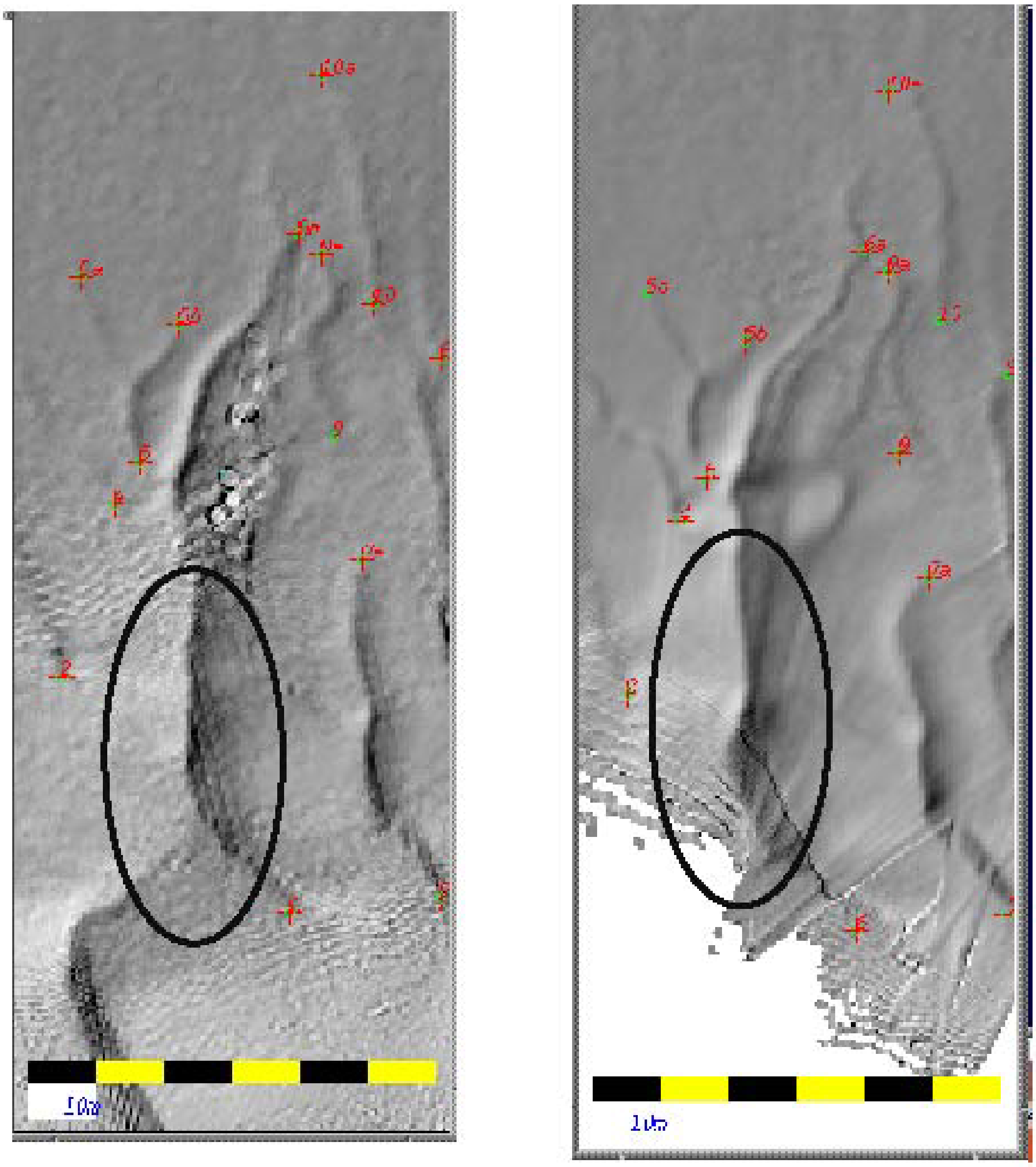
Sand wave migration, morphological changes and sediment distribution changes were ascertained by comparing the bathymetric, sun illuminated, and backscatter images of the two surveys. Both surveys were processed using identical vertical and horizontal offsets, pixel size, and resolutions. Horizontal and vertical survey offsets were calculated. Horizontal survey offset was calculated by comparing the position of assumed stationary objects. Vertical survey offset was established by averaging the vertical difference along transects in areas predominately flat in nature. Backscatter values were compared to determine any changes in sediment type or distribution. Twenty-seven sediment samples were taken during the 2000 cruise to understand the lithology of the area and to better evaluate the backscatter patterns.

Initial Results

A horizontal survey error was calculated by identifying objects in both data sets presumed to be stationary, such as the glacial boulders. The difference in position between the objects in both surveys was measured. From this difference the direction and magnitude of the offset was determined. The maximum offset was 3.1 m, and the minimum 0.6 m. The average offset, 1.5 m, is within the acceptable range considering our positions are thought to be accurate to within one meter for each survey. The average offset is greater than 1 m, but the navigation system was not performing optimally during the 1998 survey. The offsets were predominately to the southwest and southeast directions, 7 of the 24 objects offset southwest and 7 objects offset southeast and the other 10 offset in other directions. This comparison suggests that we might expect differences of up to a few meters for stationary objects. However, differences in position of more than a few meters may well suggest that seabed features have moved.

To establish the vertical offset between the 1998 and 2000 surveys transect lines ranging from 79 meters to over 900 meters long were taken across areas that appear to be flat on the sun illuminated map and had few or no obstacles. A difference map was generated by subtracting the 1998 map from the 2000 map thus giving an image of overall vertical differences between the two surveys and the average was taken of these differences. The scale of this digital terrain map was 0.5 meter grid size. The weighted average vertical offset of all lines was -5.7 cm, the median -4.1 cm with the largest average offset -23.6 cm in and the smallest offset 0.9 cm. The vertical offset between the two surveys is well within an acceptable range for a survey, being that the vertical position is thought accurate to 15 cm for each survey. This comparison suggests that we might expect differences of up to -10 to +10 centimeters for stationary objects. However, differences in height of more than 10 cm may well suggest that the heights of morphological features such as sand waves have changed.

Once it was determined that the surveys were comparable, the areas near the ridges were analyzed. The smaller western ridge and larger central ridge consist of 14 and 15 identifiable sand waves respectively. Sand waves either grew, migrated, changed shape, emerged, disappeared, or remained the same. For each sand wave a beginning and end point was marked on both surveys. The direction and magnitude of sand wave migration as well as any length change was calculated by taking the difference between the positions of the sand waves in each survey. In addition, the locations of distinctive junctions were identified on one of the images and the feature was searched for on the other image.



1998 Survey

2000 Survey

Figure 2. An example of a sand wave that has changed shape over time. The shape has transformed from a smooth curve in 1998 to one with a bump in 2000 as seen in circled area. This sand wave has not migrated during the study period. Marks indicate beginning and end points of the sand waves. Circular anomalies seen in 1998 survey are caused by bad data points.

This procedure was sufficient for determining overall direction and movement, and change in size of the sand waves, however subtle changes in shape have also occurred in certain areas over the two-year span. An example of this is sand wave 6 located on the smaller ridge (Figure 2). On the 1998 survey the ridge curves smoothly but by 2000 a bump has formed. A 12.4 m increase in length is also observed. Another aspect of the morphological change occurring in the Mount Misery Shoal area is the migration of some sand waves and appearance of one or more new sand waves.

Twenty-seven sediment samples were taken during the 2000 cruise. Sampling sites were selected in order to best represent the sediment character in the study area based on the 1998 survey (Figure 3). Sample sites were chosen according to the degree of backscatter and topographic features. Sites of high and low backscatter as well as some transitional areas were chosen. Samples were taken in and around boulders with scoured depressions, as well as in and around sand waves. Samples were also taken in areas that seem to be representative of the overall sediment type in the study site.

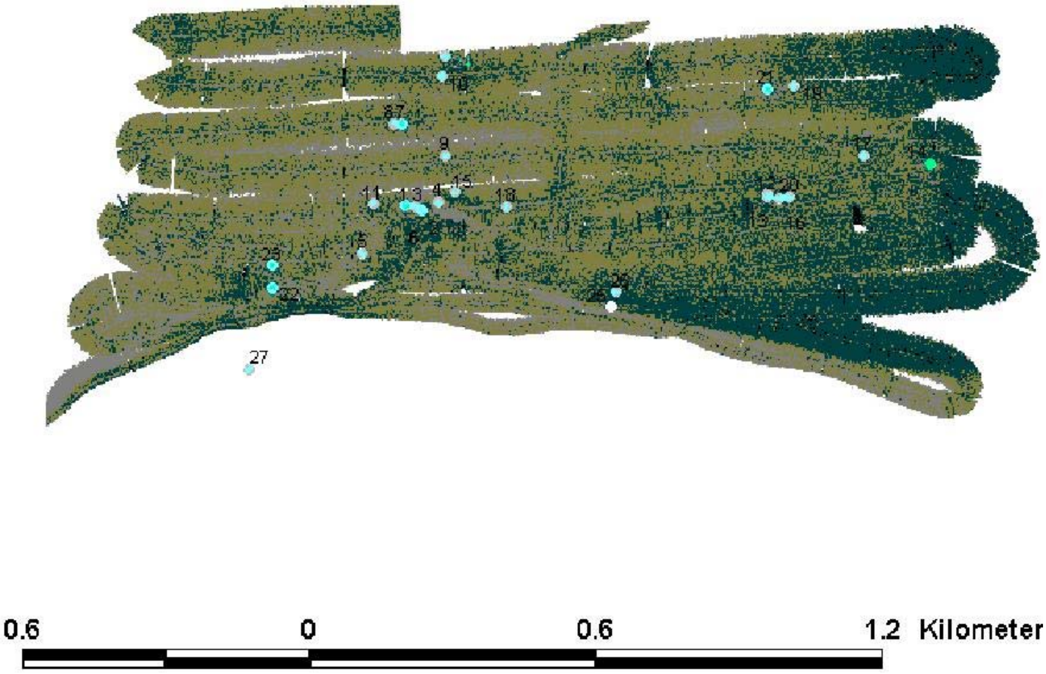


Figure 3. Sediment sampling sites as shown on 1998 backscatter image.

Most of the study area is moderately well sorted very coarse sand is the predominant sand type in the area based on samples taken. Variations of sediment type are found predominately around the central ridge. Two predominate groupings of samples can be observed. One set is coarser and better sorted and the other is finer and less sorted (Figure 4).

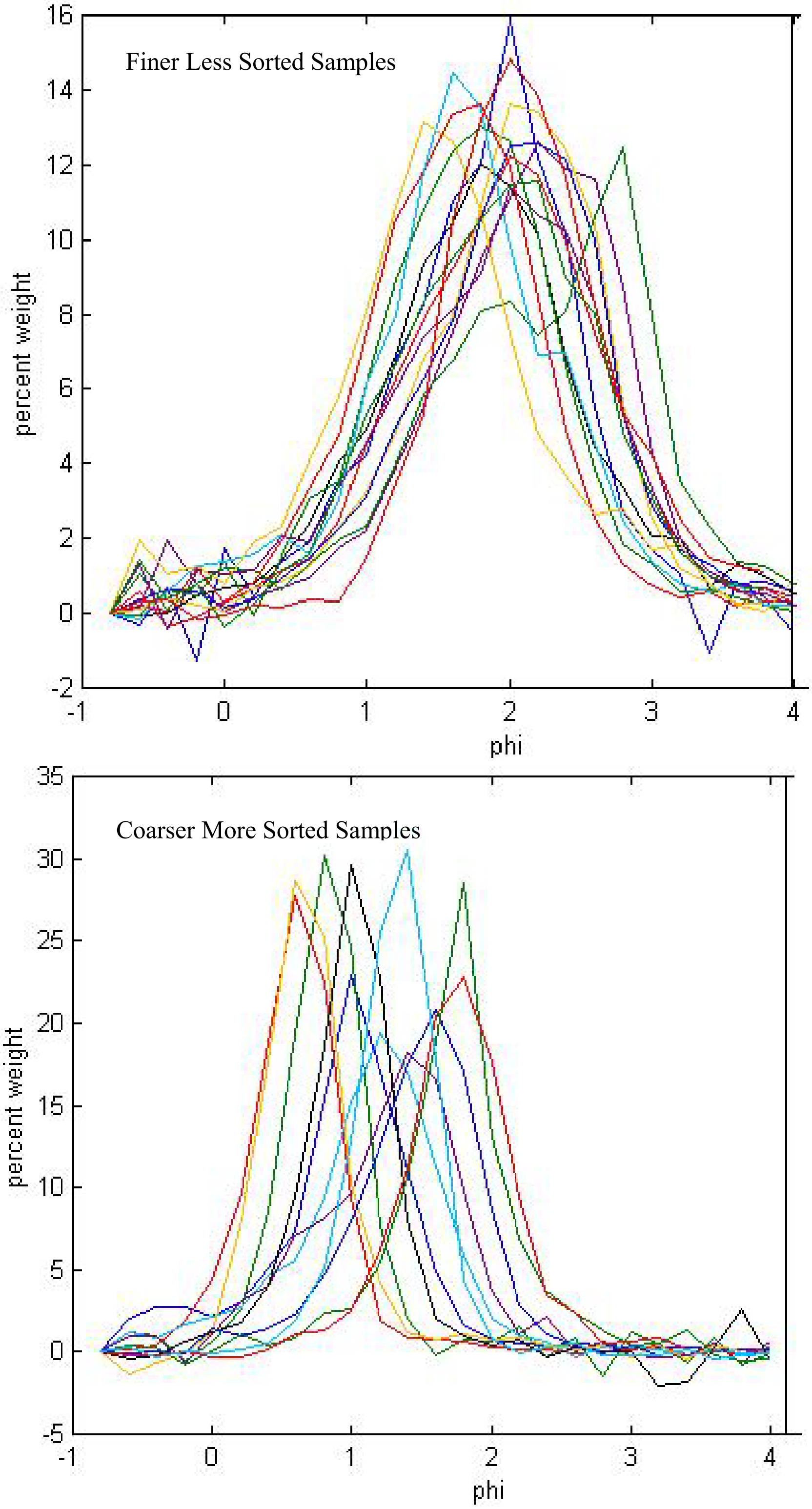


Figure 4a. Sediment analysis indicates two prominent groups of sediment types.

The backscatter values taken at the sample sites varied from -39.1 to -46.4 dB in 2000 and -37.2 to – 50.8 in 1998 with backscatter increasing with increasing grain size. When samples with a mean size of 0.5 to 1.25 phi and other samples that appear to be atypical are removed the slope of the calculated trend line is sharply increased and the R^2 value increases from 0.03 to 0.8 (Figure 6). This relationship suggests that one can get a reasonable correlation between backscatter and grain size over a limited size range, but there are other important variables.

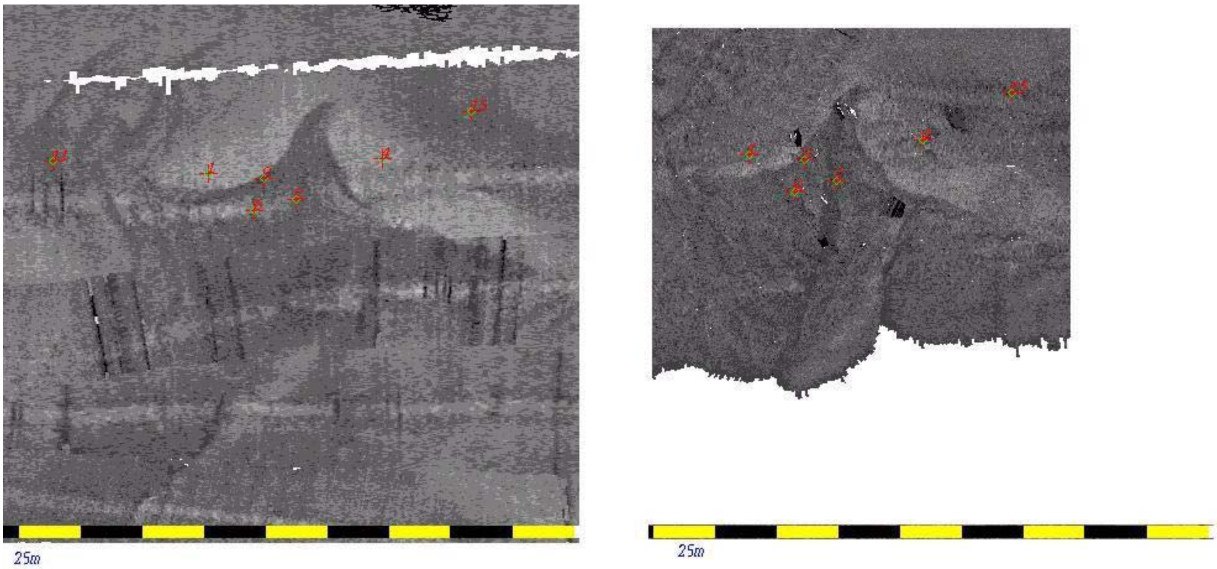
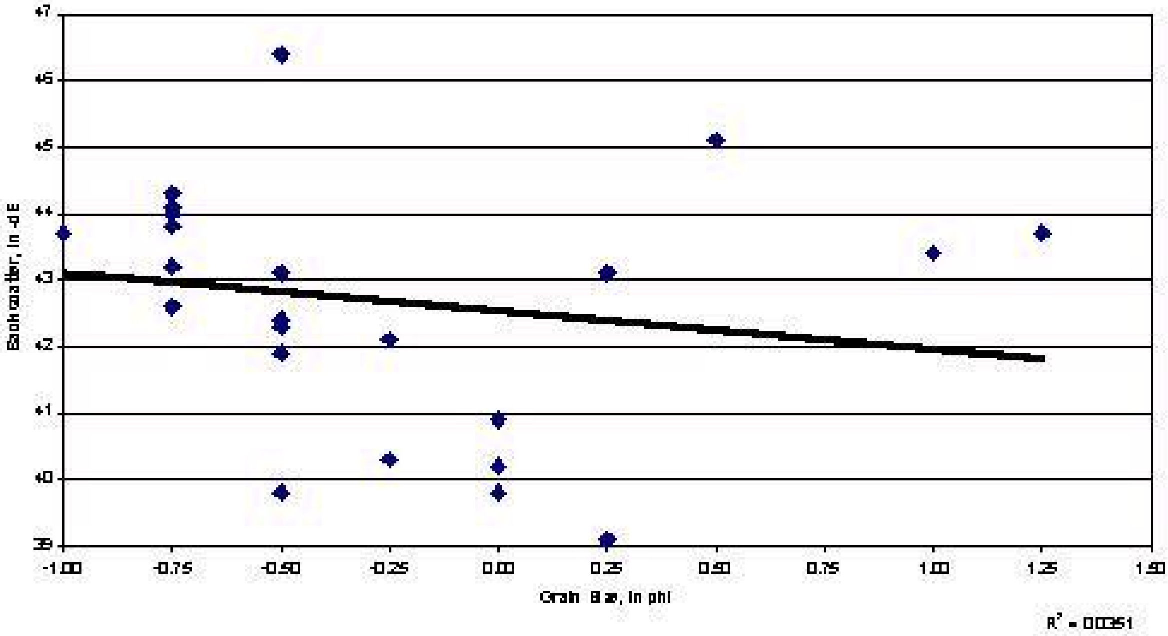


Figure 5. Changes in backscatter intensities as seen around central ridge. Sediment samples collected at positions indicated. Dark vertical marks are instrumental artifacts caused at the time of data collection.

Differences in backscatter distribution patterns between the two surveys indicate that there has also been an identifiable change in sediment distribution. The most significant backscatter changes occurred around the central shoal. The 1998 survey has a larger area of high backscatter around it, whereas in 2000 the higher backscatter area has greatly diminished (Figure 5). Higher backscatter is an indication of rougher, more irregular, or more reflective type sediment. Sediment samples taken during the 2000 cruise from areas of both high and low backscatter suggest that this sediment is coarse sand. However, samples from the lower backscatter areas were significantly smaller in volume than samples taken from higher backscatter areas. These small samples collected from the low backscatter areas may be an indication of a much harder substrate there since the sampler was unable to penetrate as far down into the sediments.


Backscatter versus Grain Size

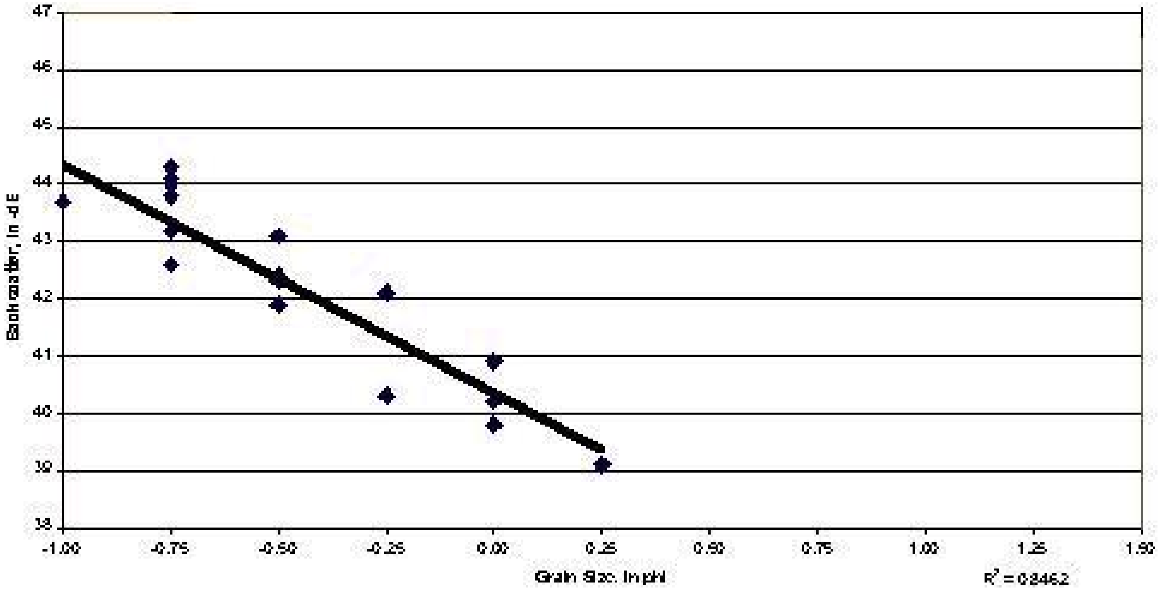

Backscatter versus Grain Size with smaller grains and atypical samples removed

Figure 6. Backscatter versus sediment grain size and Backscatter versus grain size without smaller grains.

Conclusions

Morphological changes were examined through the comparison of multiple multibeam surveys in the Mount Misery Shoal area of Long Island Sound. Analysis of multibeam data demonstrates subtle changes in the seabed over the 1.5 year period, including the appearance of new sand waves and the migration of existing waves. Knowledge about sediment type and substrate was obtained through sediment samples and their associated backscatter values. From 1998 to 2000, changes also occurred in backscatter patterns, which indicate that sediment was transported. Temporal analysis provides information that allows for the estimation of transport trends and rates and this study demonstrates that the comparison of multiple multibeam surveys can provide information about seafloor changes over time in active transport areas.

The overall movement of sediment is eastward, sediment accumulating on the lee side and eroding from stoss side of the sand waves. Sediment movement in this area is probably due to a fairly complex combination of estuarine and tidal circulation. The migration trend of the sand waves in both the western ridge and the central shoal areas appears to be rotational with the northern ends migrating to the northwest while the southern ends migrating southeast.

References

Flood, R.D. (1999). Multibeam Mapping in Long Island Coastal Waters. Geology of Long Island and Metropolitan New York, LI Geologists.