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QUANTITATIVE GROUND-TRUTHING OF HABITAT CHARACTERISTICS USING VIDEO MOSAIC IMAGES

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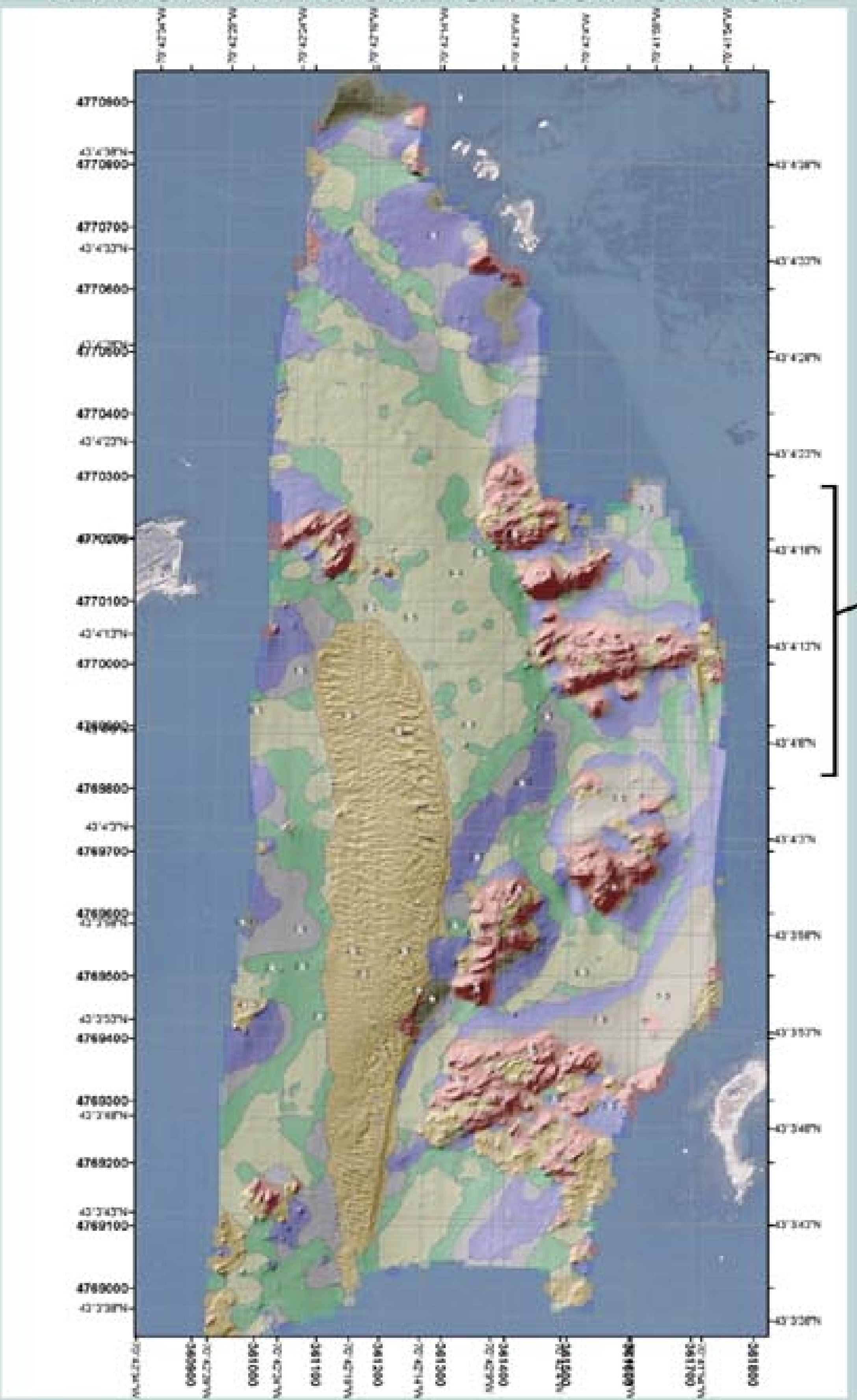
SEAFLOOR DELINEATED USING LOCAL FOURIER HISTOGRAM (LFH) TEXTURE FEATURE CLASSIFICATION



Introduction

Seafloor regions were delineated for a study area in the Piscataqua River, NH/ME [1] by applying a modified texture feature classification technique [2] to bathymetry data. Those results suggested correspondence to previous delineations of the seafloor according to sedimentological properties [3].

We suggest that the map delineated by texture feature classification represents a physical habitat model (PHM) of the seafloor, or effectively a map representing testable hypotheses about seafloor characteristics. We also suggest that a PHM could, and likely should, include additional data such as acoustic backscatter, substrate composition, configuration, energy regime, and primary solute concentrations. The variabilities of those factors, and their spatial and temporal recurrence intervals (periodicities) should also be considered, especially in estuarine environments. The better the key environmental factors can be described, the more likely the PHM will be an accurate representation of biological habitats.

However, even with limited data sources, a PHM can be developed to provide hypothetical habitat spatial distributions and characteristics that can be tested by ground-truthing techniques. Segmentation of 1 meter gridded multibeam bathymetric data alone provides delineations of seafloor features configurations that relate to substrate type and sediment transport dynamics that therefore also serve as influential factors to biological constituents.

References

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2. Zhou, F., Feng, J., Shi, Q. 2001. Texture feature based on local Fourier transform. ICIP conference proceedings. IEEE 0-7803-6725-1/01.
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4. Rzhanov, Y., L. Linnett, R. Forbes, 2000. Underwater video mosaicing for seabed mapping. 2000 IEEE International Conference on Image Processing, 10-13 September, 2000, Vancouver, Canada.
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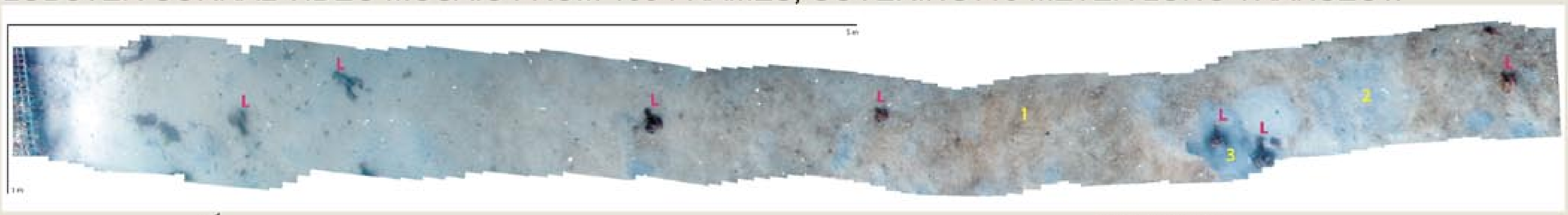
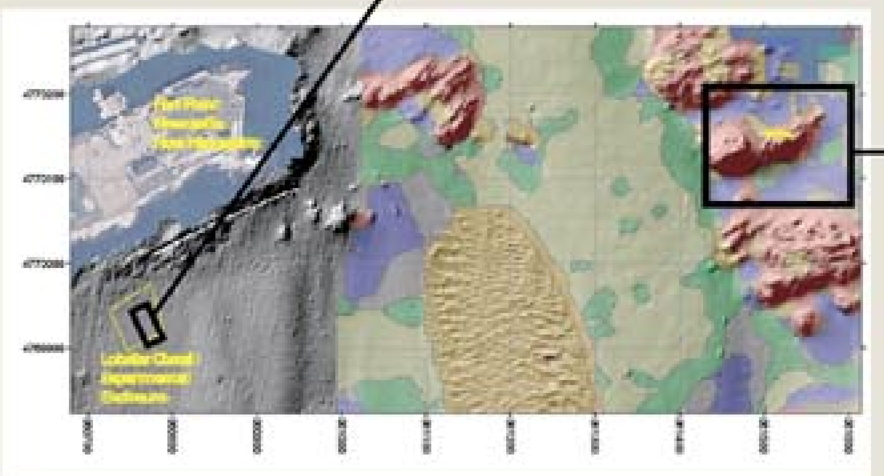
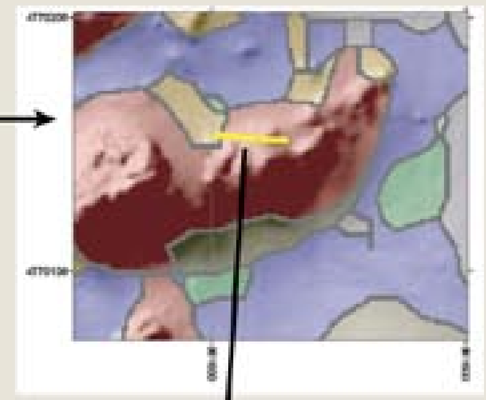
VIDEO MOSAIC IMAGERY.

LOBSTER CORRAL VIDEO MOSAIC FROM 100 FRAMES, COVERING A 9 METER LONG TRANSECT.







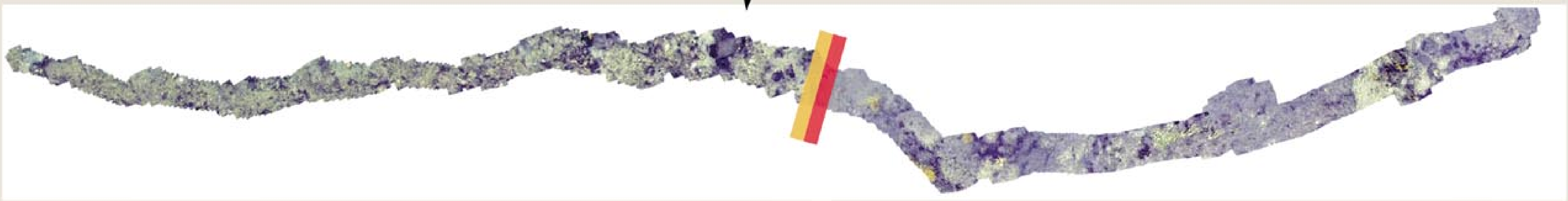
Video Mosaic Imagery

Mosaics were generated using a featureless coregistration method using frequency domain differences between the images to solve automatically for affine motion parameters, translation, rotation and zoom [4]. Colors of both mosaics were manually adjusted after mosaic assembly.

The mosaic from the lobster corral reveals fine sediment (silty fine sand) region occupied by benthic megafaunal lobsters (*Homarus americanus*) and crabs (*Cancer borealis* and/or *C. irroratus*), and large infaunal clams (*Ensis directus* and possibly others), evident from their siphons and empty shells. Note that the bathymetry in the region of the lobster corral has not yet been classified by texture feature analysis. Examples of the three types of apparent sediment surface condition are labeled: 1 (Algal/microbial covered), 2 (Bare or shallow bioturbated), and 3 (Bio-excavated deep). Lobsters (>50% in image) are labeled with L.

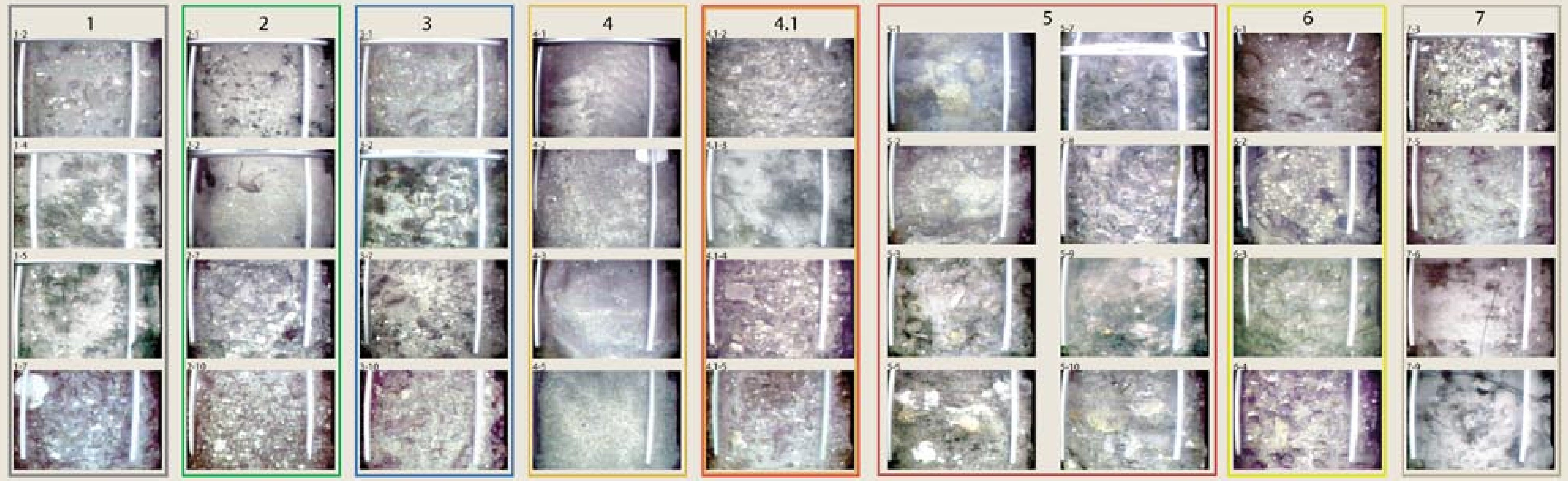
The mosaic from the rocky region reveals a transition from shelly gravel sediments to boulders and bedrock. The transition observed in the mosic is marked using colors corresponding to the nearest texture feature class regions from the segmented bathymetry map. On the rocks several species of sponges, bryozoans, and tunicates are evident.

ROCKY REGION VIDEO MOSAIC CONSTRUCTED FROM 875 FRAMES, COVERING A 20 METER LONG BOTTOM TRANSECT.



POINT SAMPLE IMAGERY.

STILL IMAGES CAPTURED FROM VIDEO ACQUIRED IN THE STUDY AREA IN EACH SEAFLOOR LFH TEXTURE CLASS REGION.



Point Sample Imagery

Images collected during sediment grab sampling
The images shown are individual frames from a video deployment accompanying grab sampling for sediment and infaunal community analysis. The images are grouped according to the seafloor texture classes from which they were acquired. The video had only ambient light illumination, and colors were adjusted manually. Each frame represents an area of about 0.125 m^2. Some of these images will be used as part of a standard set for analysis of video transect and mosaics. The standard set of images will be investigator-classified, and analysis will consist of comparisons between video and mosaic images and the standard images as in [5]. Manual and automated comparison and classification is planned.

VIDEO MOSAIC ANALYSIS.

Analysis of Mosaic Images

The two primary goals of the analysis of lobster corral mosaic were to (A) Detect and enumerate occurrences of specific fauna, in this case, lobsters (*Homarus americanus*), and (B) Delineate substrate surface conditions apparent according to three apparent classes: (1) Sediment with a micro-algal or microbial layer coverage; (2) Bare sediment, without algal coverage, although perhaps shallow bioturbated; and (3) Deep bioturbated excavations (bio-excavations). In general, for the region from which the mosaic imagery was acquired, the sediment surface conditions were easily distinguishable by coloration, such that (1) bare sediment was olive to olive-gray, (2) sediment with algal cover was reddish-brown, and (3) bioturbated sediment was bluish to bluish-gray due to digging and burrowing of crabs (*Cancer irroratus* or *C. borealis*) and lobsters that exposed the anoxic subsurface sediments. The leftmost part of the image was not included in analysis because of uneven illumination. That excluded portion represented approximately 70 centimeters along the long-axis of the mosaic.

Manual analysis of mosaic imagery

Abundance of megafauna in lobster corral video mosaic
Simple visual analysis of the mosaic accomplishes our first goal (A), to detect and enumerate lobsters. In the mosaic, seven lobsters were present with more than 50 % of the body in the image. Partial lobsters crossing edges were not counted.

Density of megafauna in lobster corral video mosaic
Since all images were adjusted to the same zoom level during automated co-registration, and since the beginning of the transect contains a physical target for which dimensions are known (fence with 3.8 cm mesh), coverage area could be estimated. For the portion of the mosaic analyzed, the coverage area was 5.87 m^2. That allowed estimation of lobster density, 1.2 m^{-2}. That high estimate reflected the higher frequency of occurrence of lobsters in that part of the enclosure. Subsequent parts of the video sequence suggest a much reduced density.
To accomplish a density estimate by analysis of a video sequence would require knowledge of precise distances traveled between any frame as well as height from target surface. Such information could be provided by a surface positioning system but is unlikely to produce accurate estimates. Accurate estimates of bottom area imaged requires either co-registration of the image series to reproduce the entire tract, or detailed instantaneous data from precise motion and position sensors incorporated with the camera. The latter option requires much more sophistication and expense than available to many studies.

Sediment surface condition in lobster corral video mosaic
Even by eye, sediment surface condition was difficult to delineate accurately . To aid visual determination of condition, the histogram from each color channel of the image (RGB) was range-adjusted, eliminating the highest and lowest 1 % of values, approximately. Seldom was a particular area of the seafloor totally covered by one class. Some generalizations were made, and therefore surely some errors in the estimates exist. The coverage areas with the pre-specified conditions were determined to be:

1. Algal/microbial covered	3.46 m^2
2. Bare or shallow bioturbated	2.27 m^2
3. Bio-excavated deep	0.14 m^2

Mosaic image measurements can be made at specific intervals of distance or area covered to provide substrate conditions and organism density estimates for any part of the seafloor imaged.

Substrate transitions in Piscataqua River rocky region mosaic
Substrate transitions are visible and delineations easily drawn for the mosaic from a rocky region on the eastern side of the river mouth channel. Despite that the mosaic was acquired from what appeared to be a rocky outcrop in the bathymetry image, various substrates exist. Patches of gravel, shell hash, shell valves, and boulders exist in addition to bedrock. It appears that a variety of sediments with a wide grain size distribution cover portions of the outcrops. Texture feature classification similarly suggests that at least two seafloor textures exist there, at that scale of analysis. The positioning data accompanying the video used to construct the rocky region mosaic was not precise enough to determine whether the transitions delineated in the mosaic corresponded to bathymetric features apparent in the bathymetry map. Our goal for future deployments is to collect positioning data suitable to accurately georeference the video imagery and mosaics. Using video from several transects in the delineated study area, we are constructing mosaics that will allow us to describe substrates and biology for each region, and assess the accuracy of the texture feature classification technique. We can then use that accuracy assessment for adjusting and understanding the impact of the texture feature classification parameters.

Automated analysis of biological features in seafloor video mosaics

The video image mosaic below is of exceptionally high quality and has relatively homogeneous backgrounds with respect to the biological features, therefore automated analysis was relatively simple. The figure shows the original mosaic image.

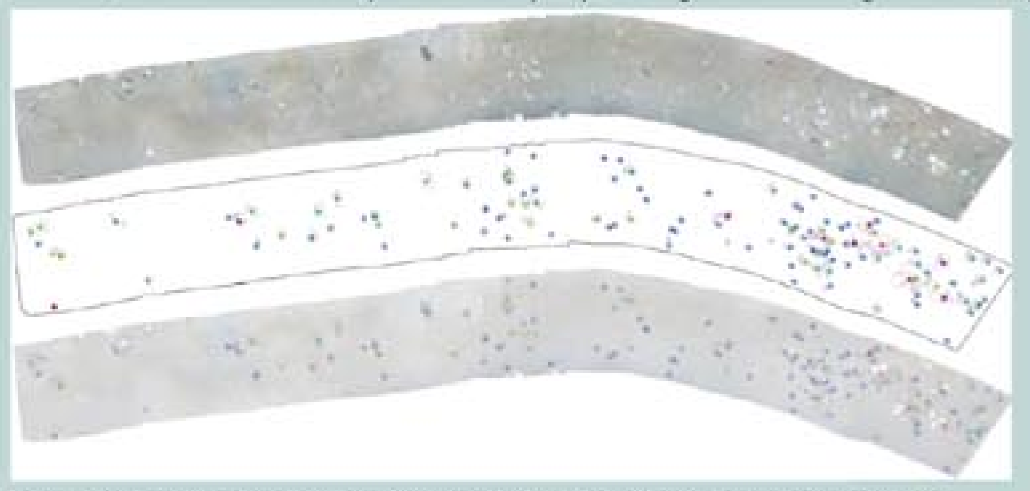


Figure. (a) Original mosaic image. (b) Results of edge-detection (using Frei&Chen filter), thresholding, and particle analysis for features > 100 pixels, excluding features touching edges. Color codes represent 5 cluster groups generated using shape and size indices from the features. (c) Overlay of segmented feature outlines on original mosaic image.

Deployment considerations
In the lobster corral mosaic, other biogenic features are apparent, specifically clam siphon openings. Diver collections confirm the presence of the razor clam Ensis directus, and most of the spent shell valves on the sediment surface appear to be from Ensis as well. Their siphons are just large enough to resolve in the mosaic. To assess infauna or small epifauna, the deployment requirements differ. Images must be collected close to the bottom, and lighting must be good and uniform. The results of such a deployment is shown in the mosaic. One disadvantage with that type of deployment is that coverage is reduced. Given a fixed camera field of view, the smaller the range to the target, the smaller the imaged area. However, close-range imaging allows smaller features to be resolved, and larger features to be seen with more clarity.