APPROVED
6/16/08

Final Report

NOAA award number: NA06NMF4540264

Scallop Research Set Aside number: 06-SCA-010

Project Award period: 1 June 2006 to 30 June 2007

Adaptive Characterization of Scallop Populations Using High Resolution Optical Imaging

Arnie's Fisheries, Inc.
113 MacArthur Drive
New Bedford, Mass 02740

Scott M. Gallager, Jonathan Howland, Amber D. York
Woods Hole Oceanographic Institution

Norman H. Vine, Richard Taylor
Advanced Habitat Imaging Consortium

27 February 2008

Original requested funding:	**Federal $0**	**Match $352,836**	**Total $352,836**
Actual funding generated:	**Federal $0**	**Match $292,240**	**Total $292,240**

Table of Contents

1. Abstract

2. Description of the problem addressed

2.1 Description of camera and vehicle including previous development

2.2 Goals and objectives of this project

3. Description of approach, methods, and work accomplished

3.1 Data collection – Imaging cruises

3.2 Biological sampling

3.3 Comparative transects with R/V Albatross IV

3.4 Image processing: lightfield removal, color correction, and mosaicing

3.5 Image segmentation and target extraction

3.6 Providing internet access to imagery and data products

4. Results

4.1 Discussion

4.2 Contribution to management

5. Participating organizations

6. Project data and data products

7. References

8. Acknowledgements

9. Presentations and posters

10. Selected images

11. Project accounting

Figures and Tables

1. Overview map of imaging transect locations
2. HABCAM vehicle coming back in
3. Map of NLSCLA transects (thumbnail of area imaged)
4. Map of NLSCLA Habitat Research Area transects (thumbnail)
5. Map of Southeast Part CLA2 transects (thumbnail)
6. Map of HAPC CLA2 transects (thumbnail)
7. Map of CLA1 transects (thumbnail)
8. Mosaic from Trip 1, Asia Rip, NLSCLA
9. Plot of NOAA R/V Albatross tow 47-19 and optical transects, Trip 2
10. Plot of NOAA R/V Albatross tow 47-2 and optical transects, Trip 2
11. Plot of optical scallop counts in 100 meter bins, Trip 2, tows 47-19 and 47-2

Table 1: Comparison of scallop counts from R/V Albatross and HABCAM system

12. Plot comparing shell heights derived from Albatross and HABCAM system
13. Mosaic from Trip 3, Southeast Part
14. Scallops on deck while setting camera, Southeast Part, Trip 3
15. Examples of automated segmentation of scallop "targets"
16. Example of conversion from raster to vector images
17. Comparison of shell height from Albatross dredge and optical transects
18. Comparative plots by taxa from Trip 2, NLSCLA Habitat area, Trip 2
19. Linear plot and CV of scallop numbers from Elephant Trunk transect, February 2006
20. Plots of random samples needed to bring Coefficient of Variation to 10

Table 2: Number of images collected during this project by area

21. Power spectrum of scallop distribution along 9.5 kilometer transect
22. Sample images illustrating variability of water quality and color
23. Sample image of Barndoor skate, stationary
24. Sample mosaics from Trips 2, 4, and 5

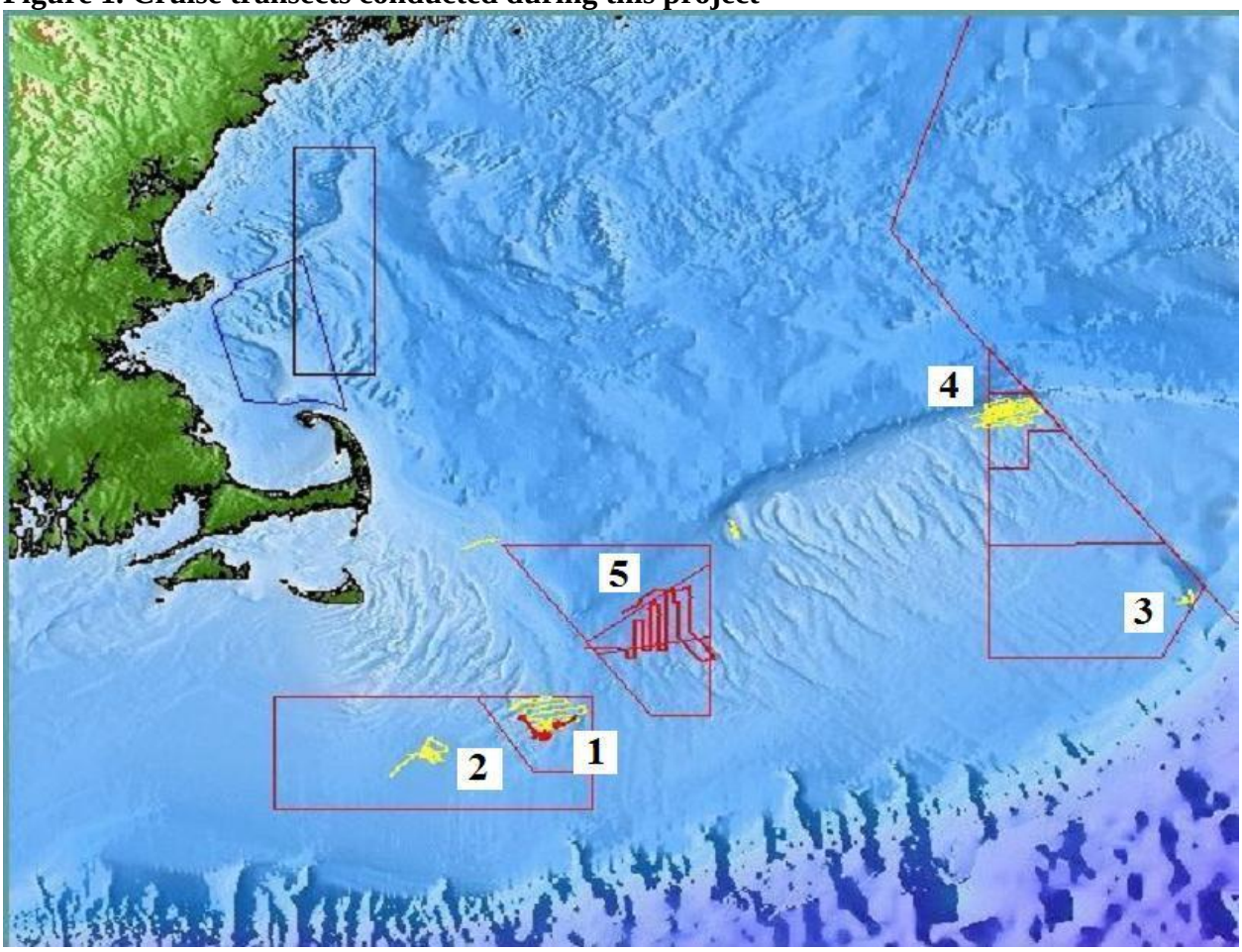
Table 3. Final financial accounting

Adaptive Characterization of Scallop Populations Using High Resolution Optical Imaging

1. Abstract

Over 2 million high resolution digital images (1280x1024 pixels) were collected during five cruises conducted from June through October 2006 using the WHOI habitat mapping camera system, HABCAM, aboard the commercial scallop vessel F/V Kathy Marie. Areas imaged included two portions of the Nantucket Lightship Closed Area, the Southeast Part of Closed Area 2, the Habitat of Particular Concern (HAPC) along the Northern Edge of Georges Bank, and Closed Area 1. Short reconnaissance mode transects were also conducted on the Cultivator Shoals, near the entrance to Nantucket Sound, and along the southern part of the Stellwagen Bank National Marine Sanctuary. Primary technical accomplishments include refinement of shipboard procedures for data collection and processing methods. Significant progress was made in developing algorithms for lightfield removal and color correction (Vine), automated segmentation and extraction algorithms of targets (Gallager), and in documenting the spatial variability of the scallop population in the Elephant Trunk area. Precise counts of all scallops in 5 areas (~150,000 images) were made in order to develop "test sets" in order to compare results derived from automated segmentation algorithms. Additional progress was made in the development of a web-based application to identify, measure, and count each individual of all taxa imaged. All data are available via http://habcam.whoi.edu.

Figure 1. Cruise transects conducted during this project



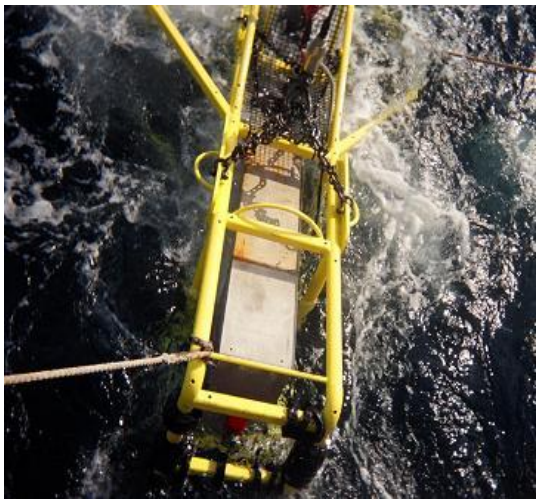
2. Description of the problem addressed

Accurate and timely biomass estimates of the Atlantic sea scallop resource are of increasing importance to scallop management scientists, and to the sea scallop industry, particularly within access areas scheduled to open in the following year. In these areas biomass is exceeding high, routinely measured in tens of millions of pounds, thus a small error in estimation equates to a large dollar amount. Underestimation results in unnecessary fleetwide losses for the year, while overestimation results in unsustainable short term gains followed by longer term reductions and instability in catch rates, as we saw in the initial opening of the Hudson Canyon area where in the third year of access fishing rates fell below costs. While there are procedural issues that need to be addressed within the Council system, they are primarily related to timing issues that determine process scheduling and thus continuity. The most important management need has been and will continue to be that of having accurate data to monitor scallop density and growth rates, in order to set the Total Allowable Catch (TAC) especially within the scallop Access Areas. The technologies described here are designed to assist in that process by improving accuracy of the data available while minimizing survey time.

2.1 Background on previous instrument development

In 2002 the Northeast Consortium funded initial development of the camera and vehicle culminating in a four hour transect in the western Great South Channel conducted from WHOI R/V Oceanus in March 2003. Basic components of the instrument package, consisting of a networked high dynamic range digital camera, two machine vision strobes for lighting, a CTD, altimeter, compass, ADCP, and an Imagenix 881a sonar, performed as designed, however light levels were below those necessary for first quality imagery. ~11,000 images were obtained.

In 2005 funding from the NEFMC Scallop RSA program (NOAA NA05NMF4540009) allowed our group to make major modifications to the existing towed vehicle frame, double the strobed lighting to 4 40w units, and outfit the New Bedford scallop F/V Kathy Marie with data acquisition computers and drives, an A-Frame and a refurbished WHOI NOMAD winch with 3 fiber, 1 conductor 120V, 0.68" armored cable suitable for conducting independent camera transects on the scallop grounds. Approximately 750,000 images were obtained during three data collection trips conducted November 2005 to February 2006. Significant progress was made in image processing algorithms including lightfield removal and color correction (Vine). Additional progress was made in development of segmentation algorithms to extract targets (scallops and other taxa) from the color processed imagery (Gallager).



Operationally the camera system is towed at 4-5 knots (~2m / sec) and acquires images at the rate of 5 frames per second. The resulting imagery may then be combined into a continuous ribbon of overlapping images or mosaics at the rate of about 100 nautical miles per 24 hour day.

2.2 Goals and objectives of this project

The primary goal of this project was to move the HABCAM instrument from development status into an operational mode.

Our approach included six central elements:

1. Conduct imaging cruises. Transects were made to areas of importance to the scallop fishery: NLSCLA, Southeast Part, the Northern Edge HAPC, and Closed Area I. Cruises to these areas were preceded by examination of previous NOAA Fisheries scallop surveys and VMS plots from earlier years in order to plan our transects in order to concentrate on areas of known high scallop biomass. Particular effort was made to understand scallop patch variability in order to better plan transect placement.

2. Conduct biological sampling. Exact measurements of shell height were taken in specific locations for the purpose of verifying the size measurements calculated using the vehicle altitude and coefficients calculated from the initial calibration of the distortion introduced by the camera lens. The associated meat weights, known to vary by area and time, moved us toward greater precision in fishable biomass estimates.

3. Conduct joint ship operations with the NOAA R/V Albatross IV. Transects were conducted in parallel with the R/V Albatross IV to allow side by side comparison of sampling methods and the effect on population statistics. Dredge efficiency, that is the percentage of scallop retained by a dredge when towed over a scallop population, is known to have significant variability, particularly with regard to vessel towing speed, wire scope, substrate type, tow direction relative to bathymetry, and tow direction relative to tide and/or current. Although this variability is assumed to balance out over many tows, direct comparison of methods (dredge and camera) allowed for a better understanding of the dredge variability involved and is intended to move us in the direction of greater precision.

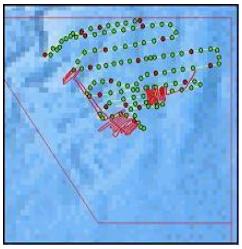
4. Image processing, color correction and balancing. Improvements to the algorithms that flatten and level the lightfield, a necessary first step toward accurate and uniform color correction, were made. Color correction algorithms were expanded to include a "whitepoint" method useful in stretching the camera CCD response across the fullest range of color values.

5. Image segmentation, feature extraction, and characterization of substrate and habitat. Efforts continued to refine and accelerate the segmentation algorithms in order achieve higher throughput and greater accuracy of target classification. Several new segmentation approaches have been implemented and tested with varying results for speed and accuracy. "Test Sets" from a variety of regions were developed to represent different sea floor conditions. These Test Sets consist of about 40,000 images each and have been manually processed with all targets and substrates classified as a training set for the automated classification process. The objective is to characterize benthic habitat by segmenting targets (e.g., scallops, fish, clams, sponges, seaweed, etc.) from background physical characteristics (e.g., sand, cobble, shell, etc.) and make statistical associations between organisms and their environment.

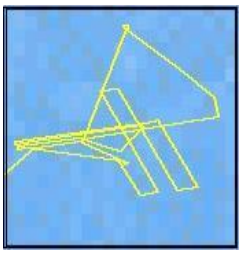
6. Provide access to data via the internet. All imagery and associated data (latitude / longitude, depth, conductivity, temperature) may be accessed via http://habcam.whoi.edu, with locations plotted at 10 minute intervals on the project MapServer at http://habcam.whoi.edu/Maps.

3. Description of approach, methods, and work accomplished

3.1 Task 1 - Data collection More than two million images were collected during five cruises conducted June to October 2006.

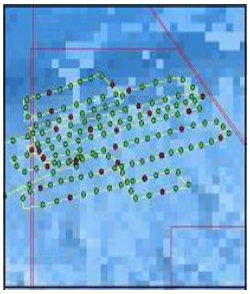


1. 12-14 June 2006. 125 nm. Participants: T Chute (NMFS), N Vine, R Taylor. Transects were conducted in NLSCLA before the scallop fishing season opened on 15 June 2006. This survey was designed to describe baseline conditions in the smaller area most likely to be heavily fished after the area opened (Fig. 3), including the area south of Asia Rip shoal (Fig. 8).

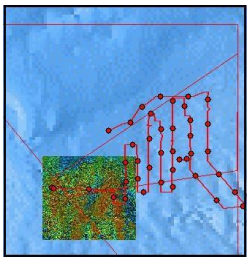


2. 24-27 July 2006. 86nm. Participants: S Gallager (WHOI), N Vine, R Taylor. F/V Kathy Marie sailed to an area south and west of the scallop fishing area within the NLSCLA, near the Andrea Doria, in order to meet the NOAA R/V Albatross IV. This area, ~1 x 6 nm, had been identified as having a dense set of scallop by previous Albatross scallop survey tows, and was specifically selected as it was not open to scallop or groundfish vessels with bottom tending gears, thus not subjected to the scientifically confounding effects of unknown amounts of fishing. (Fig. 4)

3. 27 August to 1 Sept 2006. 100nm. N Vine and R Taylor accompanied F/V Kathy Marie on a fishing trip to the Southeast Part of Georges Bank within Closed Area 2. With the help of vessels fishing nearby, a small area with a dense starfish concentration was located and photographed. Contiguous areas exhibited either dense scallop populations or entirely empty scallop shells. (Fig. 5)



4. 26 - 29 September 2006. 162 nm. Participants: V Nordahl and T Rowe (NMFS), A York, J Howland (WHOI), N Vine, and R Taylor. Parallel transects were conducted in the northern portion of the HAPC in Closed Area 2, an area closed to bottom tending mobile gear for 12 years. Shorter exploratory transects were also made on the Cultivator Shoals, and near the entrance to Nantucket Sound. (Fig. 6)



5. 15 – 18 October 2006. 200nm. Participants: A York, K Bolles, N Vine, R Taylor. Parallel transects were conducted in Closed Area I, both within and outside the area currently to be opened to the scallop fishery in 2007 (figure 7). Short exploratory transects were made in an area off Pollock Rip, and in the southern end of Stellwagen Bank National Marine Sanctuary. Note area of USGS multibeam coverage (Valentine, 1998).

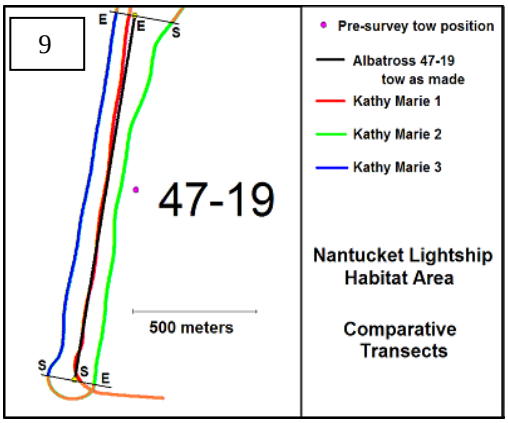
Figure 8

3.2. Task 2. Biological sampling

A Letter of Acknowledgement (LOA) for Scientific Research Activity was obtained from NOAA Fisheries Northeast Regional Office to conduct short sampling tows in the areas to be imaged for comparison with the optically derived sizes of the scallops. This was an important element in the areas not open to fishing, and in areas where the Albatross survey tows were not conducted.

3.3. Task 3. Conduct comparative tows with NOAA Fisheries R/V Albatross IV

Initially, long crossing transects were conducted to map the bounds of the scallop settlement streak located southwest of the scallop fishing area in the NLSCLA while on station before arrival of NOAA R/V Albatross (see 2 in Fig 1). After meeting up three comparative tows were conducted. During the first Albatross tow we followed several hundred meters astern but it was rapidly evident that the tow direction was directly into the tide with the silt plume from the dredge optically opaque. During the next two Albatross tows several miles away F/V Kathy Marie waited 10 minutes for the plume to clear before attempting to pass over the exact tow.



For tows 2 and 3 multiple camera transects were conducted at each Albatross tow position. For Albatross tow 47-19 (Fig. 9), the first pass went as close as possible to the known survey track, with subsequent transects conducted to each side at a planned distance of 25 to 75 meters. In the second location, Albatross tow 47-2 (Fig. 10), the first pass attempted to follow directly between the known set and haul positions, with the subsequent photographic tows repeatedly crossing the first with the intent of identifying the dredge path in order to document short term dredge effects. Despite these repeated attempts, we were not able to visually identify the Albatross dredge tow path in the imagery with any certainty, perhaps due to the strong tide at the time and the flow characteristics of the silty substrate.

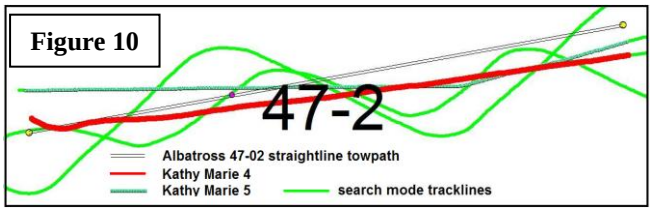
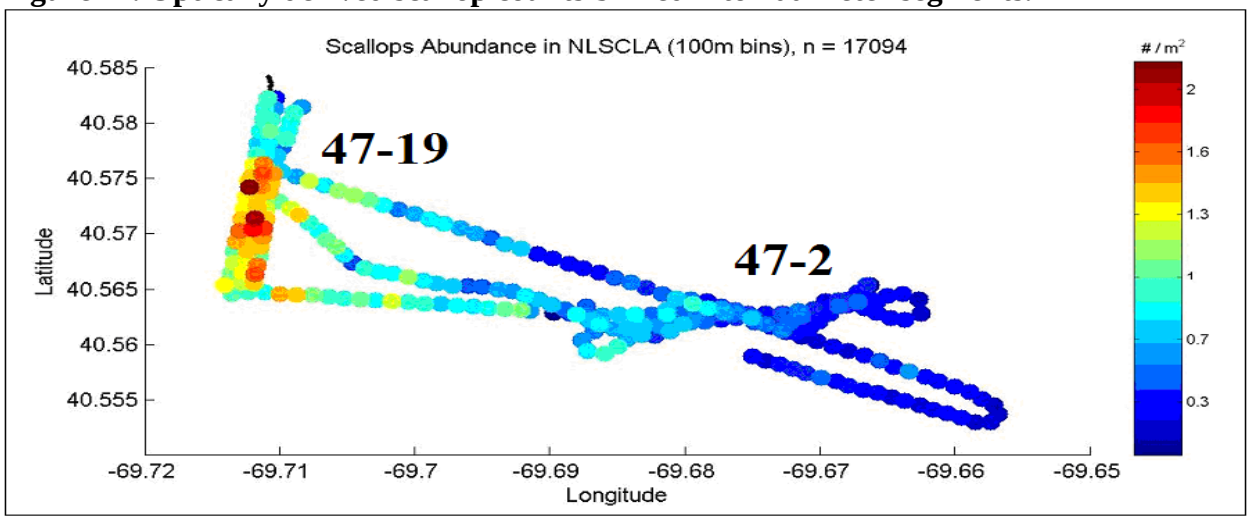


Figure 11. Optically derived scallop counts binned into 100 meter segments.



Discussion of comparative tows

Each image of the comparative transects was individually examined, with scallop counts and sizes entered into a MATLAB application developed by HABCAM group member York. This application allowed rapid entry of data concerning all identified taxa in order to develop presence/absence, size and other associative statistics for the areas imaged. Using the data from the altimeter a footprint or Field of View (FOV) was computed giving number of animals per square meter. Images were then binned in the along track direction into groups representing 100 meter segments of the total trackline, then plotted (Fig. 11). The resultant plot clearly indicates that scallop densities were considerably different between the two locations of the comparative tows, yet dredge based survey results were similar to each other, i.e. 950 vs. 980 animals total. The implication is that the dredge efficiency was considerably different though the tows were in close proximity in space and time (about 1 nm and 1 hour), of similar depth, and with a visually similar substrate in both, a fine grained sandy silt. The primary difference was in tow direction with tow 47-19 conducted cross tide or 90 degrees to the tidal flow, and 47-2 conducted fair tide or in the direction of the tide. Calculated dredge efficiencies for the two tow sites, including expansion for the liner effects on the larger scallop, were 14 to 17% for the 3 optical transects for tow 47-19, and 31% for tow 47-2. While considerably different and implying significantly different biomass, both are well within the range of expected dredge efficiencies as currently estimated. Shell size distributions measured both on deck of the Albatross and by the HabCam imaging vehicle are very similar with a difference in mean values of only a few mm (Fig. 12).

Table 1. Comparison of dredge and optical tows in Habitat Area, NLSCLA

ALBATROSS TOWS 2006					DREDGE		nominal		OPTICAL				IMPLIED
	STATION	STRATA	TOW	AREA	scal_ct_raw	scal_ct_exp	swept_area	scall/m2	track	scal_count	imaged_area	scall/m2	efficiency
ALBA06_47-19	253	6470	19	NLSCLA_HAB	950	1,330	4,500	0.30	red	3403	1875	1.81	0.16
									green	4045	1875	2.16	0.14
									blue	3332	1875	1.78	0.17
ALBA06_47-2	252	6470	2	NLSCLA_HAB	980	1,372	4,500	0.30	red	1772	1800	0.98	0.31
									lt. blue	1765	1800	0.98	0.31

3.4. Task 4. Image processing, color correction and balancing

Color correction algorithm development continued with the emphasis being on expanding the range of usable altitudes, and dealing with different light attenuation properties in different water masses (Vine). These are significant challenges as variable altitude is an inherent characteristic of the towed vehicle system employed, and water quality characteristics vary considerably by area, by season, and over short distances especially near the frontal convergence zones in northern waters. As new algorithms have been developed over time, many raw image data files were processed and converted multiple times for comparison purposes. This iterative process is time consuming but necessary. The critical issue is that the lighting is truly ideal only within a fairly narrow altitude range and the more advanced algorithms significantly widen the range that yields acceptable imagery by individually boosting the color bands based on altitude. Having more uniform color correction greatly improves the follow-on tasks of segmentation and mosaicing, however because each image is processed individually the light intensity and overall color balance alongtrack must continue to vary using these techniques.

The current processing algorithms take 3 to 4 seconds per image on a 3 GHz PC. At this output rate the implication is that it will take at least 15 separate processing operations being conducted simultaneously to have the system approach “real time” at our current rate of image generation, about 5 images/sec. To address this situation our approach has been to have multiple

networked machines with each processing the contents of one ten minute directory, sequentially requesting a new image each time one is completed.

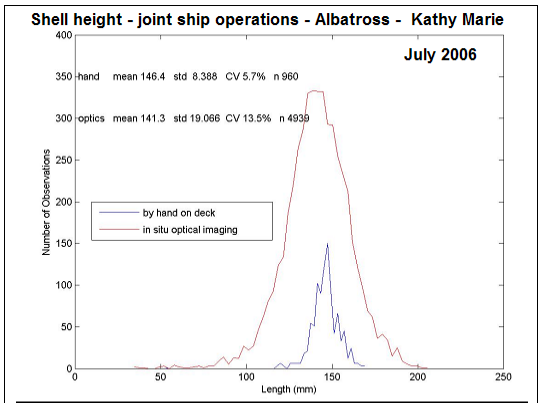


Figure 12. Shell height distributions for scallops measured by hand on deck of the Albatross (blue) and optically and automatically by HabCam (red). Note that the means of the distributions are within several mm.

3.5. Task 5. Image segmentation and target extraction

Automating the extraction of accurate useful information from the large volume of data collected is our greatest challenge at this time. In conjunction with a separately funded effort, a subset of the imaging transects from several areas with distinctly differing substrate and water clarity characteristics has been manually classified frame by frame. Each identifiable individual of each observed taxa has been counted (York), and had size calculated using the original lens calibration and vehicle altitude. Results were entered into a spreadsheet and plotted, and are being used to gauge the accuracy of automated image segmentation and target extraction software used to derive scallop counts and substrate characteristics, the primary longer term goal of this effort. At the time of this report the segmentation (target identification and extraction) operations require a similar amount of time per image, and similarly must be sequentially distributed to multiple networked processors.

3.6. Task 6. Providing internet access to imagery and data products

At this time over 2 million images from this project's transects are online at the project website along with imagery from previous efforts. These and all other related data products are accessible via http://habcam.whoi.edu.

4. Results

Image mosaicing

The automated mosaic strip (Fig 13, right, Y. Rhzanov, CCOM, UNH) illustrates both the progress and the difficulties in registering images to each other, and balancing the color obtained from the camera CCD. The original images were obtained during a fishing trip to the Southeast Part of Georges Bank, southern Closed Area 2 (Fig 14).

Figure 14. Southeast Part of GB

Sea conditions were calm with a slight swell evident. Note both the changes in width of the strip and the changes in luminence as the camera altitude off bottom varied along the tow path. Where the camera and strobes are nearer bottom, the lighting is brighter and the field of view (FOV) somewhat narrower. Conversely as the vehicle is

Figure 13

raised with the swell the image darkens slightly and the FOV widens. The automated co-registration process removes most all of the disparity between the size of the same object in adjacent frames caused by motion and differing altitudes between frames but does not attempt to produce uniform color. Final calibration of the lens distortion will complete the rectification process for these images, where the bottom is near flat, the tide relatively weak, and the roll, pitch, and yaw near zero.

Image segmentation

Automating the segmentation of targets remains the largest challenge to our efforts to move toward "real-time" processing, though significant progress has been made in refining, and increasing the speed and accuracy of the existing algorithms. Figure 15 contains examples of scallops automatically segmented from the background of the images.

Figure 15. Extracted "targets"

An additional approach has been explored using techniques developed by researchers from the Los Alamos National Laboratory, Space and Remote Sensing Sciences Group. The application shows great promise in speeding up the identification of "targets" such as scallops based on techniques that render the rectangular pixel arrays into "trixels", that is triangular areas of similar color. While the approach degrades the resolution of the original format somewhat, it greatly increases the speed of rendering and target segmentation, the primary goal. A more formal partnership with the Los Alamos group is being sought to further collaboration on the use of these techniques, as the algorithms in use were not developed to solve for our specific application.

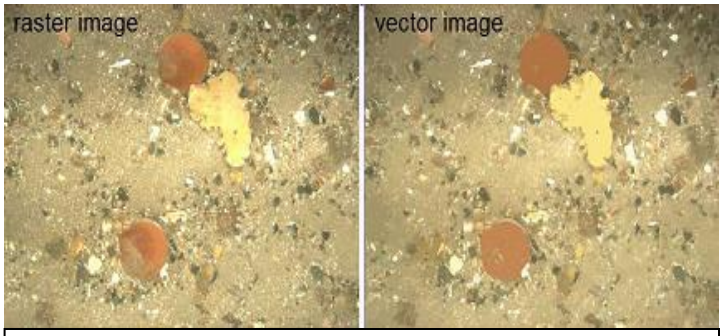


Figure 16. Raster to vector image conversion

Development of "Test Sets"

In order to facilitate development and verify the accuracy of automated target extraction algorithms, over 150,000 images from 5 different areas were individually examined by A. York. Individuals from every identifiable taxa in each image were counted and measured to the nearest mm with the results tabulated in a flat file. Over the course of the effort, A. York developed a "point and click" program to more efficiently identify and measure organisms within the images, with all data then recorded to the nearest mm in a tabulated flat file. S. Lerner later developed a version of this program that can be used over the internet. Image groups and the application may be downloaded via http://habcam.whoi.edu.

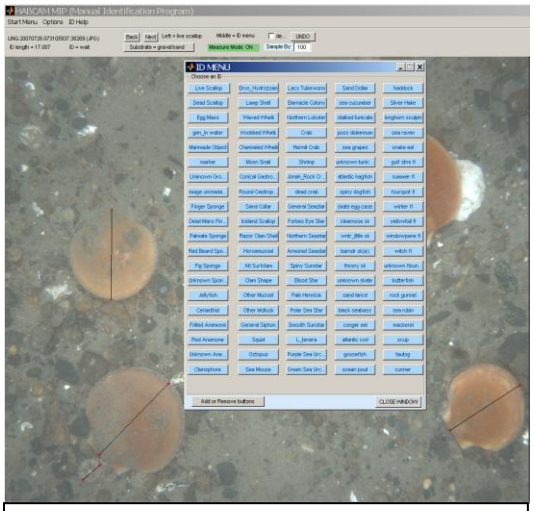
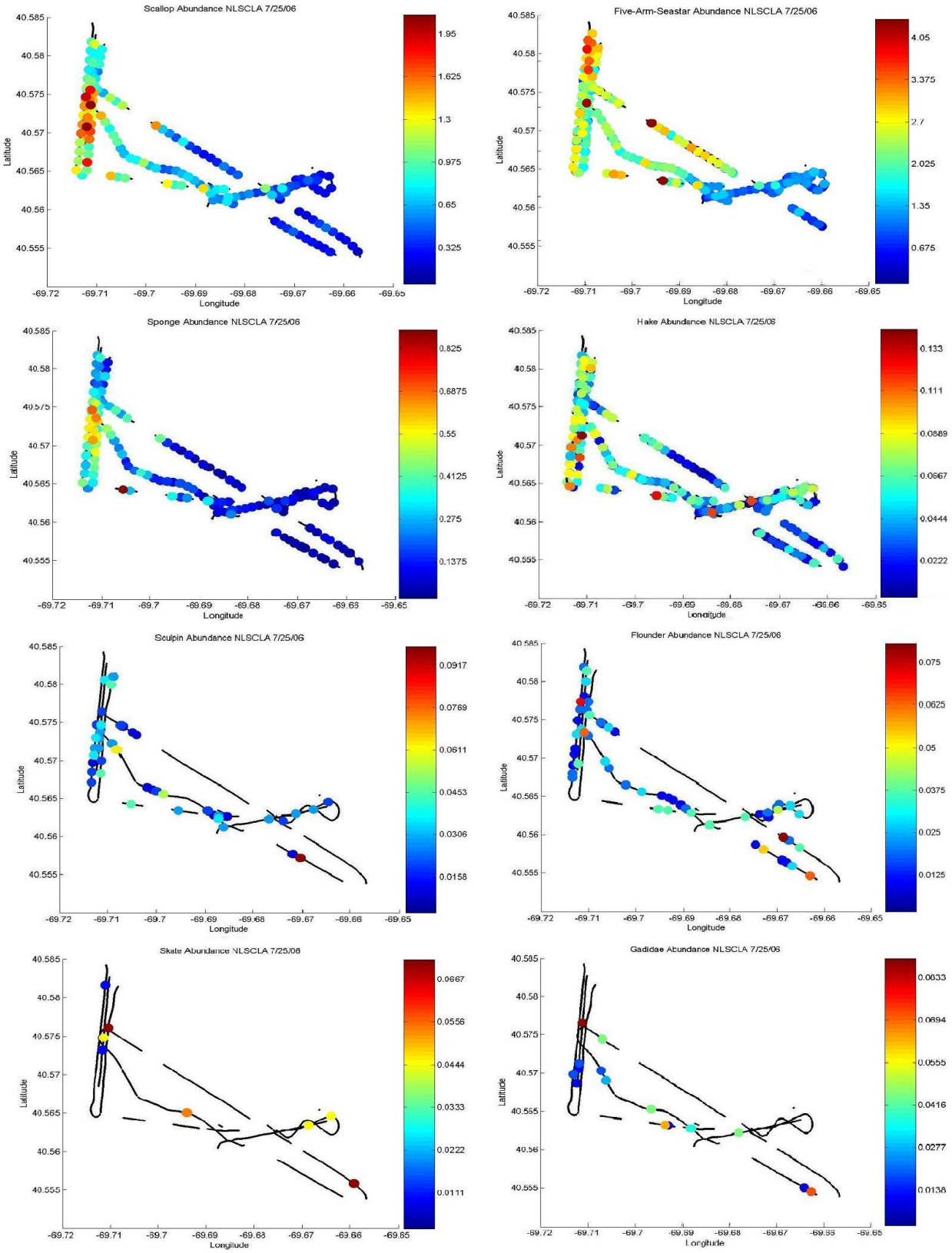


Figure 17. "Test Set" application window

Figure 18. Comparison of density and location of various taxa, NLSCLA Habitat Area. Note that density color scale varies between plots.



Additional efforts

Photographic transects were conducted in the Elephant Trunk scallop access area during the data collection portion of the previous project (NA05NMF4540009), however data analysis was not completed at the time of final reporting in Dec 2006. A thorough frame by frame examination of data from a 9.5 kilometer strip was carried out by team member A. York during this project time period and with results reported here.

Figure 19. Along track distribution and abundance of scallops in Elephant Trunk.

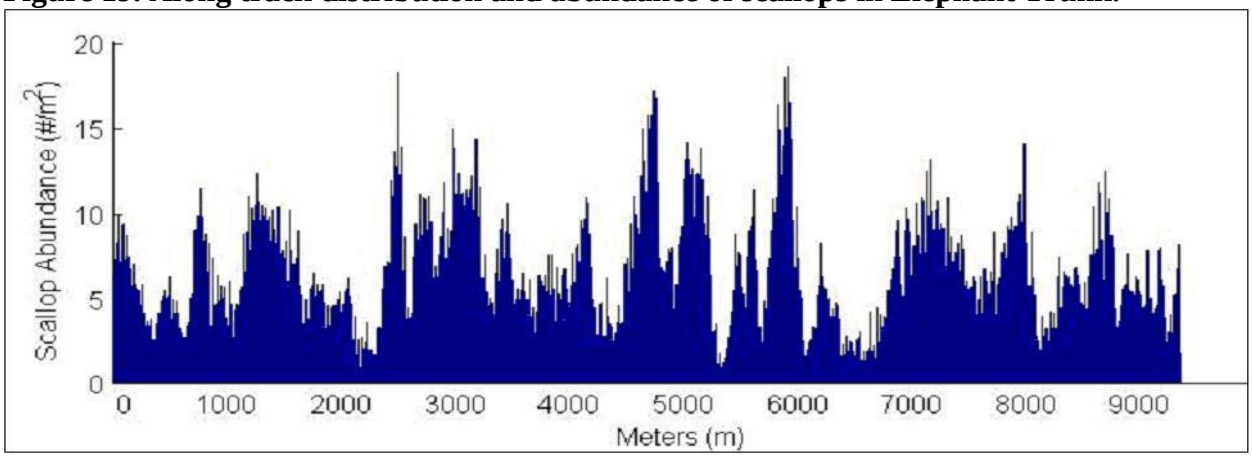


Figure 20. Number of simulated samples taken from this population required to achieve a stable mean and a CV less than 10.

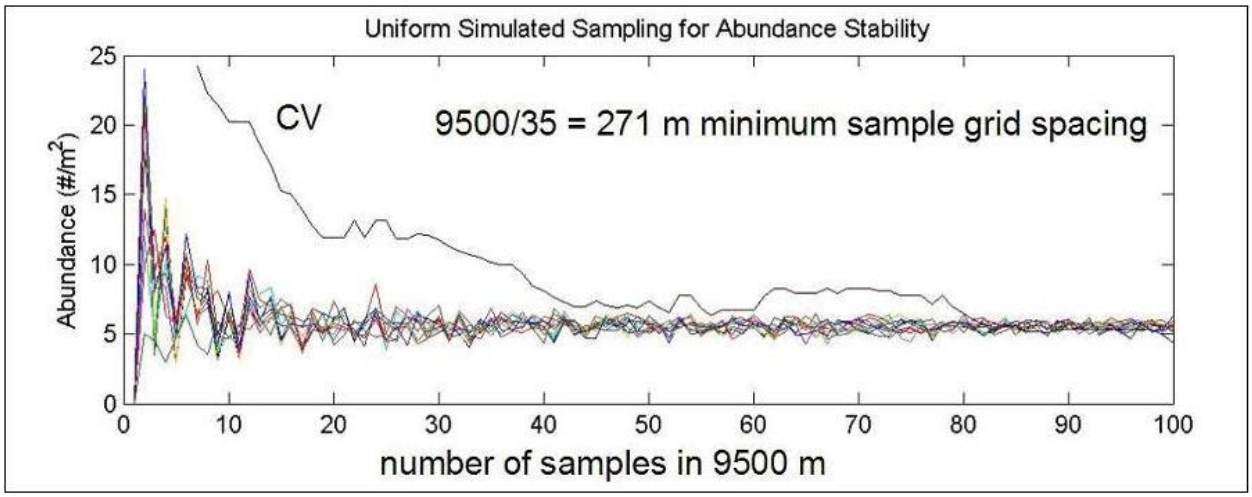


Table 2. Summary table of bottom imagery collected during this project

Cruise Area	date	~hours	~n_nmiles	~n_images	notes	~area
5. NLSCLA	20060612	31	125	437,500	fishing area	175
6. NLSCLA_ALBA	20060725	22	86	301,000	habitat area/Albatross	30
7. Southeast Part	20060828	20	100	200,000	fishing	12
8. Closed Area2_HAPC	20060927	34	136	476,000	long transect	88
a. Cultivator Shoals		4	15	52,500	quick look	6
b. entrance to Sound		3	11	38,500	quick look	5.5
9. Closed Area1	20061017	46	185	647,500	long transect	500
a. Pollock Rip		1	5	17,500	quick look	3
b. SBNMS	20061018	2	8.5	28,000	quick look	4
~Total RSA year 2		163	672	2,198,500		824

4.1. Discussion

Results show that when operating 24/7, the HabCam vehicle can image more than 2.5 times the area swept per day than a standard scallop dredge. Scallop dredges appear to be operating at an efficiency of about 14 to 31% depending on current and tow direction. Continuous image data stitched into mosaics allow absolute counts of organisms and the nearest neighbor distance to be calculated. This provides information on patchiness at multiple spatial scales. Size distributions measured by optics non-invasively are comparable to those measured by hand on board a survey vessel. Progress is being made on automated segmentation, feature extraction and classification of targets and substrate. These tasks will need to be conducted in real-time on the ship if we are to keep up with the high volume data stream from HabCam.

4.2. Contribution to management

Close examination of data collected along a 9.5 kilometer transect in Elephant Trunk access area revealed both the wide variability in scallop densities and the existence of a patch size just over 300 meters that are not readily explainable by bathymetric or other obvious bottom features (Fig. 21) Another strong patch frequency signal occurred around 1100 meters. The implication is that sampling at any distance greater than the patch size will lead to reduced accuracy in estimating the population. Moreover, information obtained in real-time on patchiness scales will allow for adaptive sampling of populations thereby minimizing vessel time while maximizing statistical accuracy of the survey. Shell height comparison of image data with dredge survey results conducted by NOAA R/V Albatross IV are presented in Figure 12.

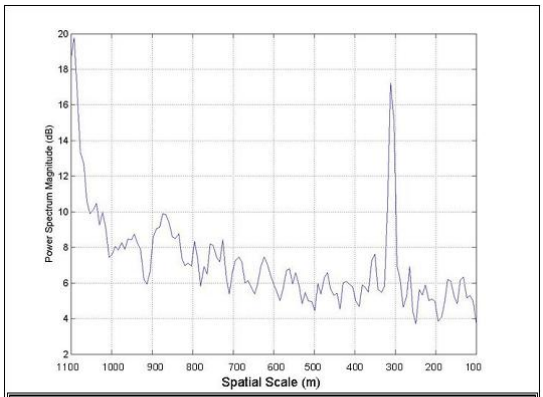


Figure 21. Power spectrum of scallop abundance along a 9.5 km long continuous transect in Elephant Trunk. Note a large spike at 320m and a second at about 1100m. These indicate that the population is highly patchy at those spatial scales.

4.3 Opportunities for further work

Many images of the invasive tunicate *Didemnum* sp. have been identified in areas where it was not previously known to be present. *Didemnum* sp. is a colonial ascidian whose mats have been found to overgrow gravel, pebble, cobble, and boulder substrates as well as sessile organisms including mussels, sponges, bryozoa, hydrozoa, and other ascidians. *Didemnum* growth has also been found on dead *Placopecten magellanicus* (sea scallop) shells. While the impacts of *Didemnum* growth on Georges Bank are currently unclear, efforts are underway to document it's spread, predators, effects on biodiversity, possible shellfish mortality, and responses to repeated substrate disturbance. HabCam transects have revealed three areas of *Didemnum* growth on Georges Bank: the Northern Edge, Nantucket Shoals and Eastern Great South Channel, the latter two of which were unknown previous to this study. The population along the Northern Edge spans from outside to inside of an area closed to groundfish and scallop fishing thereby providing a site to study the differences in *Didemnum* growth under disturbed and undisturbed conditions. HabCam images provide an opportunity to study the association between percent cover of *Didemnum*, bottom substrate type, and oceanographic features, including benthic shear stress which can assist modeling efforts to predict areas at risk to *Didemnum* spread. We have recently submitted a proposal to Sea Grant to use HabCam images to characterize Didemnum distributions along the northeast continental shelf.

5. Participating organizations

Woods Hole Oceanographic Institution
Scott M. Gallager, Jonathan Howland, Amber D. York

Advanced Habitat Imaging Consortium
Norman H. Vine, Richard Taylor

F/V Kathy Marie, Arnie's Fisheries, Inc., New Bedford. Owner Arnold DeMello. Captain Paul Rosonina, Mate Jarry Schervo, Engineer Tony Melo, Joe Santos, Donald Rosonina.

Los Alamos National Laboratory
Lakshman Prasad, Sriram Swaminarayan
ISR-2, Space and Remote Sensing Sciences Group
International, Space and Response Division

6. Access to project data and data products

All processed images and associated navigation and oceanographic data collected during this project reside on a server provided by NMFS under the terms of additional funding from the Advanced Technology Working Group. The server is physically located in the WHOI laboratory of Scott Gallager, Marine Research Facility, MRF 107, and may be accessed via the URL http://habcam.whoi.edu

7. References

Agenda (2006), Design of Scallop Surveys: 2007 and Beyond, Coonamessett Farm.

Ahlen, J (2005) Colour Correction of Underwater Images using Spectral Data, PhD Dissertation, center for Image Analysis, Uppsala University, Uppsala, Sweden, 66pp.

Applegate, A (2005) Maps of spatial usage of scallop fleet using VMS, Scallop PDT.

Barker, BAJ, I Helmond, NJ Bax, A Williams, S Davenport, VA Wadley (1999) A vessel-towed camera platform for surveying seafloor habitats of the continental shelf, Continental Shelf Research, Pergamon, 19:9 1161-1170.

Coffin, D (2006) Decoding raw digital photos in Linux,
URL: http://wwwcybercom.net/~dcoffin/dcraw

Draft Scallop Survey Discussion Documents (2006), Scallop Survey Advisory Panel, 23pp.

Du Fresne, S, D Fletcher, S Dawson (2006) The effect of line-transect placement in a coastal distance sampling survey, Journal of Cetacean Research and Management, 8:1 79-85.

Fishermen's Reports (1982-2006) Annual scallop survey results, NEFSC, NMFS.

Jensen, A L (1996) Subsampling with line transects for estimation of animal abundance, Environmetrics, John Wiley& Sons, Ltd., 7:3 283-289.

Kalikhman, I and I Ostrovsky (1997) Patchy distribution fields: survey design and adequacy of reconstruction, ICES Journal of Marine Science, 54:809-818.
URL: http://icesjms.oxfordjournals.org/cgi/reprint/54/5/809.pdf

Kendall, M S, M E Monaco, K R Buja, J D Christensen, C R Kruer, M Finkbeiner, and R A Warner (2001) Visual Characterization of Benthic Habitats in the USVI, ROV Methods Used to Map the Benthic Habitats of Puerto Rico and the U.S. Virgin Islands, NOAA Silver Spring, MD.
URL: http://biogeo.nos.noaa.gov/projects/mapping/caribbean/startup.htm

Lai, S R and L B Christensen, The 'Fish at Depth' Viewer,
URL: http://fishbase.se/manual/English/FishBaseFishAtDepthViewer.htm

Lindbloom, B (2001-8) Chromatic Adaptation Algorithms,
URL: http:// www.brucelindbloom.com/index.hml?Eqn_ChromAdapt.html

Quinn, T J and V F Galucci (1980) Parametric Models for Line-Transect Estimators of Abundance, Ecology, 61:2 293-302, Ecol. Soc. of Amer., URL: http://www.esajournals.org.

Stokesbury, KDE (2005) Comparison of habitats supporting high and low sea scallop, *Placopecten Magellanicus*, densities on George Bank, Final Report, NOAA NA03MNF4540260, 15p.

Strong, A. S., M. Service, A. Mitchell (2006) Application of the Visual Fast Count for the quantification of temperature epibenthic communities from video footage, Journal of the Marine Biological Association of the U.K., 86, 5189.1-.7.

Sutton, G and E O'Keefe (2006) Annex II, Seabed Mapping: Multibeam Bathymetry, Backscatter and Video Imaging of the Seabed in the South East Coast Scallop Grounds, Final Report of Project 01.SM.T1.07, 21pp. URL: http://cmrc.ucc.ie/publications/reports/AnnexII.pdf.

Valentine, Page C (Editor), Middleton, Tammie J, Malczyk, Jeremy T., Fuller, Sarah J. (2002) Maps Showing Sea Floor Topography, Sun-Illuminated Sea Floor Topography, and Backscatter Intensity of Quadrangles 1 and 2 in the Great South Channel Region, Western Georges Bank, USGS IMAP 2698. URL: http://pubs.er.usgs.gov/usgspubs/i/i26988.

Acknowledgements
Northeast Consortium provided funding for initial camera and vehicle development in 2002. Particular recognition is due for the efforts of Jonathan Howland, Lane Abrams, and Andy Girard of the Woods Hole Oceanographic Institution for their contributions.

NEFMC/NMFS Scallop RSA program grant (NOAA NA05NMF4540009) for funding further camera system development in 2005. This funding allowed the system to become fully functional including winch, A-Frame and vehicle modifications.

NMFS Advanced Technology Working Group, Deborah Hart P.I., for providing additional funding for software development, data processing and serving, with the software specifically focused on color correction and segmentation of targets.

Owner Arnold DeMello, Captain Paul Rosonina and crew for allowing us to use and modify his fine vessel Kathy Marie, adding considerably to their workload and scheduling problems over the course of the project.

Participating vessels: In addition to the F/V Kathy Marie eleven other commercial scallop fishing vessels participated in this project by generating the funding for conducting the work:

Kayla Rose, New Bedford, Mass, Captain Joseph Corriea
Christian and Alexa, NYC, New York, Captains Art and Ken Ochse
Kathy and Jackie, New Bedford, Mass, Captain Abel Arujo
Westport, New Bedford, Mass, Captain Edward Welch
Atlantic, New Bedford, Mass, Captain Peter Barcz
Santa Barbara, New Bedford, Mass, Captain Joseph Viera
Elizabeth and Niki, New Bedford, Mass, Captain Joseph Fernandes
Cool Change, New Bedford, Mass, Captain Earl Chor
Act IV, New Bedford, Mass, Captain Magnus Aadland
Addy J, New Bedford, Mass, Captain Michael Edwards
Baystar II, Newport News, Virginia, Captain Charles Morse

9. Manuscripts, Presentations and Posters

Gallager, SM, Sensors and Sensor Networks to Observe Ecological Processes in Aquatic Systems, American Academy for the Advancement of Science, St. Louis, January 2006.

Gallager, SM, New Methods for Surveying Sea Scallops, Benthic Organisms and Habitat. Symposium on Optics and Acoustics in Applied Fisheries Oceanography, Bedford Institute of Oceanography, February 2006

Gallager, SM, J Howland, AD York, R Taylor, N Vine, L Prasad, S Swaminarayan, R Gupta P Rago, D Hart, G Rosenkranz, Development of Imaging Hardware and an Optical Image Database and Processing Tools for Automated Classification of Benthic Habitat and Enumeration of Commercially Important Scallop Stocks, 16th International Pectinid Workshop, May 2007.

Howland, J. SM. Gallager, H Singh, A Girard, L Abrams, C Griner. N Vine and R Taylor, Development of a Towed, Ocean Bottom Survey Camera System for Deployment by the Fishing Industry, Oceans ’06, Boston September 2006.

York, AD, R Taylor, N Vine, S Lerner, D Hart, L Prashad, and SM Gallager. Development of an Optical Image Database and Processing Tools for Automated Classification of Benthic Habitat and Enumeration of Scallop Stocks, Ocean Biodiversity Symposium, Halifax, NS, Sept 2007.

Gallager, SM, L Mayer, P Auster, R Taylor, N Vine, M Fogarty, and D Hart, The US Northeast Bentho-pelagic Observatory (NEBO) to Support Fisheries and Ecosystem Management, Ocean Biodiversity Symposium, Halifax, NS, Sept 2007.

10. Selected images. Figure 22. Water clarity, color, brightness, and contrast in different areas of operation all have direct affect on the automated color processing and segmentation.

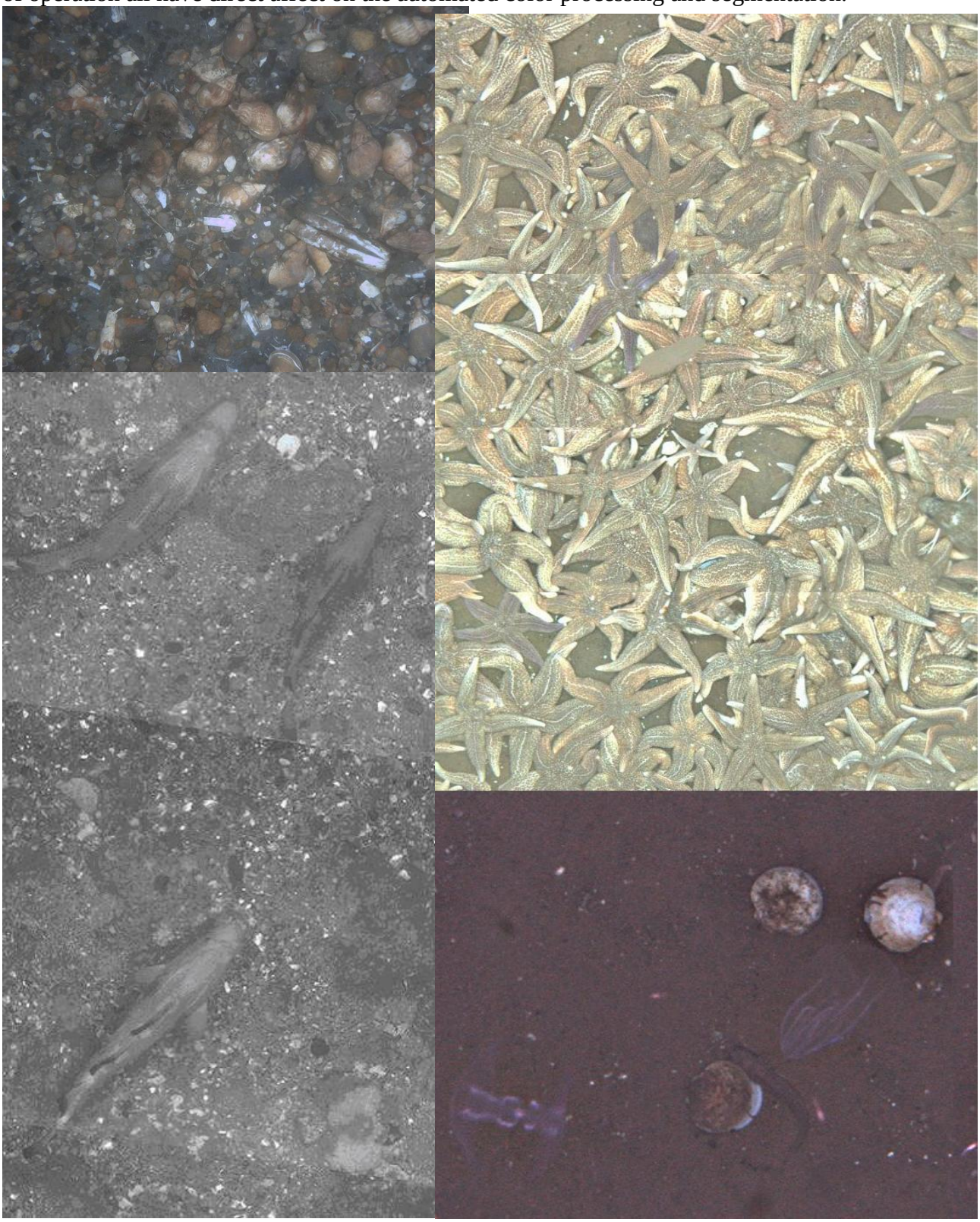


Figure 23. Barndoor skate,
Closed Area 1, unusual in that the individual is stationary across frames. Width 1.2 m.

Figure 24. Mosaics from transect areas (see also Figure 8 Trip 1, and Figure 14 Trip 3)

A. Trip 2 - 20060725 **NLSCLA** **Habitat Research Area** **entire area is silty sand**	**B. Trip 4 - 20060829** **Northern Edge HAPC** **rare area with boulders**	**C. Trip 4 - 20060830** **Great South Channel** **shoal area near entrance to Nantucket Sound**	**D. Trip 5 - 20061018** **East of Closed Area 1** **edge of Little Georges, razors and moonsnails**

11. Project accounting

Due to equipment issues and the scheduling necessity of meeting the NOAA R/V Albatross, the portion of this project that included data collection with the AUV was removed, with the changes documented in the amended workplan submitted through NOAA GrantsOnline.

Table 3. Final project accounting

Scallop RSA NA06NMF4540010					Catalog number NA 11-454			subtotals	ORIGINAL	FEDERAL	INDUSTRY	REVISED	ACTUAL
FINAL FINANCIAL STATEMENT					25 February 2008				Research	Share	Research	Research	Research
424B Form item					no.	rate			estimate		Share	estimate	budget
6	a.	Personnel	Salaries		0	0		0	0	0	0	0	0
	b.	Fringe benefits						0	0		0	0	0
	c.	Travel			4400	0.44		1,936	1,936	--------->	1,936	1,936	1,936
	d.	Equipment											
			250GB harddrives		40	120		4,800					
			Harddrive cases		10	500		5,000					
					Subtotal equipment ---------->				9,800	--------->	9,800	9,800	27,350
	e.	Supplies	cables			100		100	100		100	100	393
	f.	Contractual			no.	rate	subt						
		Industry	CLA TRIPS	2	18,000	4.95	178,200	178,200					
			OPEN AREA DAS	120	1,900	4.95	1,128,600	1,128,600					
			Fishing Vessels			73%		953,964	---------->		953,964	953,964	876,720
		Research				27%		352,836					
			WHOI contract	see attached ----->			178,859						107,315
			Norman Vine		45	500	22,500						36,350
			Richard Taylor		50	400	20,000						28,900
			Vessel charter		21	5500	115,500						83,455
			Science crew		12	200	0						2,400
			Subtotal research contractual items ------>					336,859	336,859	--------->	336,859	282,315	258,420
	g.	Construction						0	0	0	0	0	0
	h.	Other			rate	days	months						
			Additional Insurance		100	21		2,100					
			Communications										
				website	50		12	600					
				telephone	100		12	1,200					
			Printing					241					
						Subtotal Other --------->			4,141	--------->	4,141	4,141	4,141
				Subtotal noncontract research items ---->					15,977	--------->	15,977	15,977	33,820
				Subtotal contractual research items ---->					336,859	--------->	336,859	282,315	258,420
					Total research related budget-->				352,836	--------->	352,836	298,292	292,240
	i.	Total direct charges									1,306,800	1,252,256	1,168,960
	j.	Indirect charges									0	0	0
	k.	TOTAL PROJECT BUDGET ---------->								0	1,306,800	1,252,256	1,168,960
7		Program income									0	0	0