

**A New Role for the Commercial Fishing Fleet in Monitoring,
Predicting and Managing Sea Scallop Resources**

FINAL REPORT

**Northeast Consortium
Contract # 00-540**

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11. Description of prior Results

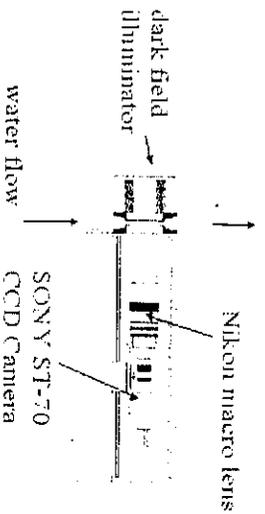
First Year Project Objectives and Results: Phase 1.

Objective 1) To implement LIHDAT: The Larval Identification and Hydrographic Data Telemetry package. <http://4dgeo.whoi.edu/lihdad> The LIHDAT instrument package was provided to a commercial fishing vessel F/V Kathy Marie where it continuously collects data in the surface waters during the entire course of their fishing trips, including steaming to and from fishing grounds. The LIHDAT web site displays raw data files and processed data in the form of time series and geo-located plots. Here is how LIHDAT works: Water under pressure from the ship's sea chest flows into a flow control valve (not shown), the Seabird SBE 45 salinometer and thermometer, the Seatech fluorometer, and then splits into two streams. A

high speed stream flows into the large flow cell (1) which images all plankton between 0.1 and 10 mm. The low flow speed stream flows into the polarized light flow cell (2) which images all birefringent material including bivalve larvae and other particles with crystalline structures.

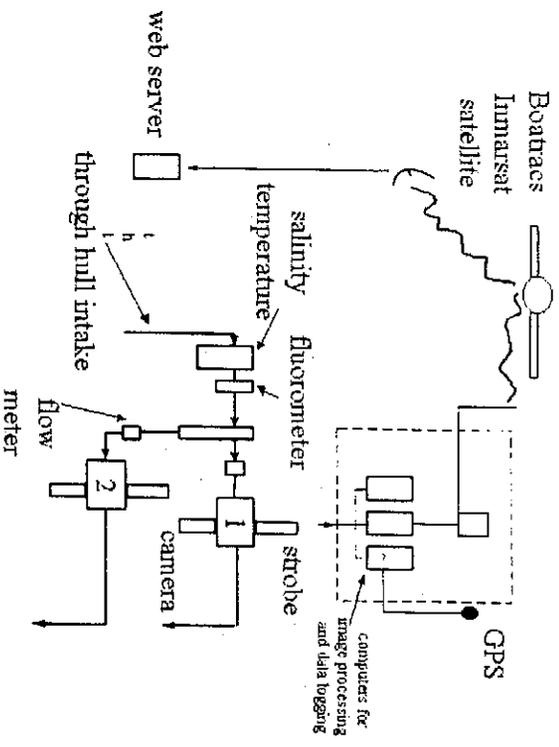
Hydrographic data collected at 1 Hz are combined with GPS time and position and recorded in a file. Plankton images are captured using dual frame grabbers, and processed by standard VPR software (Seascan, Inc) for focus

detection and plankton identification providing counts and sizes of plankton in real time. Data from images and hydrographic files are combined at 1 min intervals and written to a temporary file in zipped binary format. Once an hour the Boatracs unit grabs the

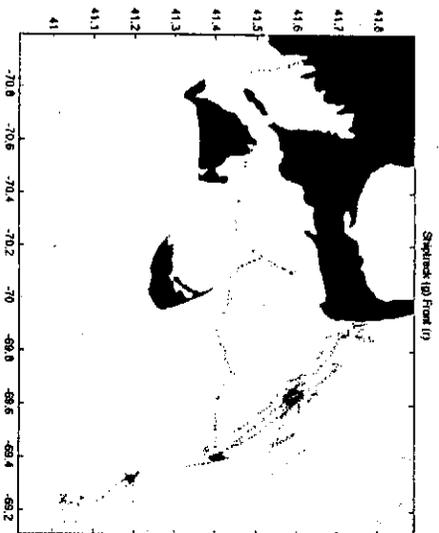


displays a new series of plots every 10 minutes.

Below are plots of the ship track generated in real time and displayed on the web site with data telemetered from the F/V Kathy Marie between 25 February and 10 March 2002. Both green and red dots indicate the ship track while red indicates where the seawater density (a combination of temperature and salinity) is two standard deviations



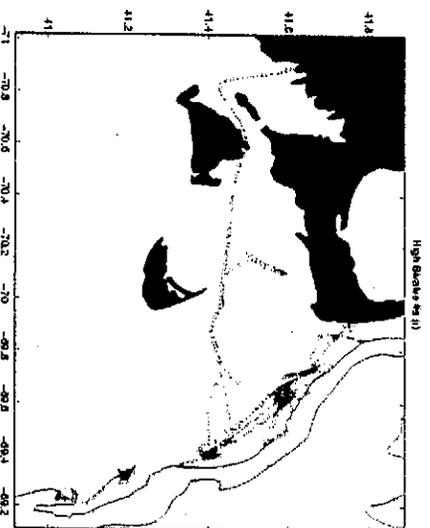
temporary file (< 1Kb in size) with 1 min averaged data and transmits it to shore via Inmarsat satellite. On shore, an automated server at the Boatracs company FTPs each file to a server in Gallagher's lab. An automated Matlab process grabs each file, concatenates it into a single file and creates plots of the various parameters. The web server



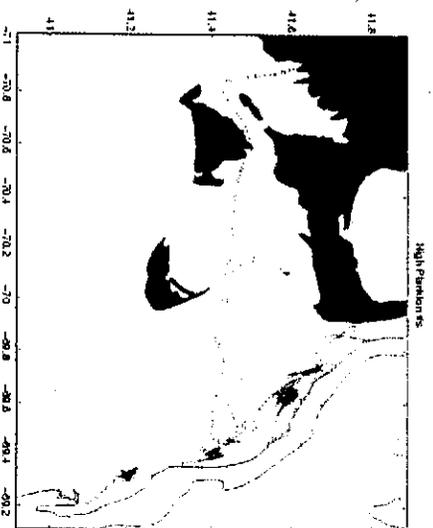
above the mean of the entire data set to date. Therefore, red dots indicate where there are sharp density gradients or fronts between two or more water masses. Note that much of the track along the edge of the Great South Channel indicates a relatively strong front.

Also, figures show where bivalve larvae and total plankton were elevated two standard deviations above the mean of each data set (i.e., red dots are regions of high abundance compared to the green dots),

respectively. At first view the plots appear very similar, which is what you might expect given that bivalve larvae will be concentrated by the same physical mechanisms as all



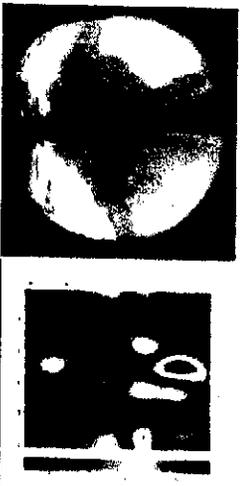
plankton. Upon close inspection, however, subtle differences reveal regions where plankton may be high, as to the south, but bivalves are not. The appearance of bivalve larvae in the water column, in general, and scallop larvae, in particular, is seasonal by species. Quite possibly the blue mussel was spawning early in the year and many of the larvae identified as such were *Mytilus edulis*. We have not been running the bivalve identification software in real time for the fishing trips this year simply because they have not been optimally coded for speed, which is an objective of the present proposal. Further processing of this season's data in the laboratory will allow discrimination between species (see next section on image processing).



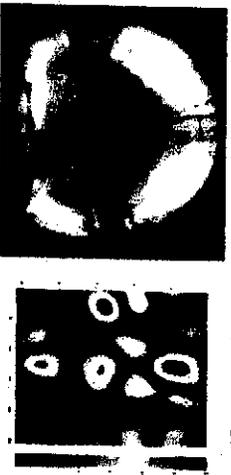
Progress Toward Automated Image Processing

With funding obtained from the Northeast Consortium and a private foundation through WHOI, we have developed novel approaches for optically identifying bivalve larvae, and

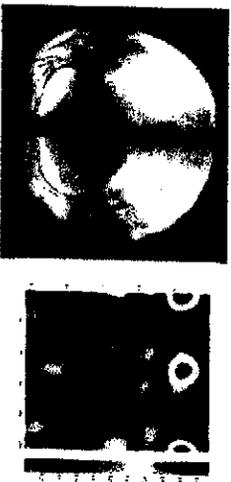
Argopecten irradians (bay scallop)



Placopecten magellanicus (sea scallop)



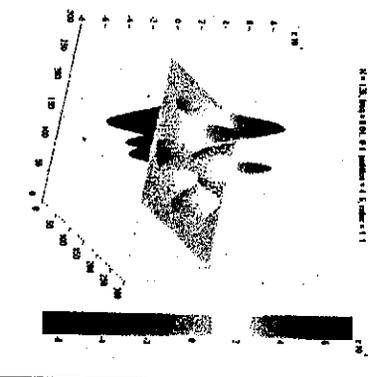
Spisula solidissima (surf clam)



particularly sea scallop larvae. Using polarized light images of bivalve larvae from LIHDAT, we are now able to use mathematical pattern recognition techniques to distinguish five species: *Argopecten irradians* (Bay Scallop), *Placopecten Magellanicus* (Sea Scallop), *Spisula solidissima* (Surf Clam), *Mya arenaria* (Softshell Clam), and *Mercenaria mercenaria* (Quahog). The classification of these color images can be thought of as being similar to identifying humans from fingerprints or the iris since each bivalve species has a specific pattern related to orientation of the crystalline shell structure. Our method involves transforming a polarized image into a number of "space-frequency" representations. These representations decompose the geometry of an image into its basic building blocks and do this at different scales. The building blocks we use, called Gabor wavelets, were originally described by Dennis Gabor, a Hungarian physicist who was later awarded the Nobel prize for his discovery of holography. We use a total

of 24 Gabor representations to describe the geometry of the gray scale image alone. Next, we calculate color invariants of the image. These invariants capture the relations between the red, green, and blue components of both the image and its building blocks. The Gabor representations and the color invariants yield a total of 150 "features" of the image.

We have calculated these features for sets of 60 images of each of the five species, and determined average values of these features for each species. We use a nearest neighbor classifier to classify each new image. This involves calculating the features for that image and determining their respective distances from the average species values. In our preliminary testing, we obtained classification accuracy of over 80%. In the figure above, images of three species: *Argopecten irradians*, *Placopecten magellanicus*, and *Spisula solidissima*, are displayed along with a Gabor representation. As can be seen, the



Gabor representations emphasize certain geometric and spectral features of the image. These differences are then quantified and used in the task of pattern discrimination.

Our research plan over the next few months includes addition of a variety of bivalve species to our digital polarized light library: *Amygdalum papyrium*, *Anadara ovalis*, *Anomia simplex*, *Arca noae*, *Arctica islandica*, *Argopecten irradians concentricus*, *Asarte borealis*, *Asarte castanea*, *Asarte undata*, *Atrina senata*, *Bankia gouldi*, *Barnea truncata*, *Brachidontes exustus*, *Chione cancellata*, *Chlamys islandica*, *Corbicula fluminea*, *Crassostrea gigas*, *Crassostrea virginica*, *Cylocardia borealis*, *Cyrtopleura costata*, *Dinocardium robustum*, *Diplothyra smithii*, *Donax*, *Dosinia discus*, *Dreissena bugensis*, *Dreissena polymorpha*, *Ensis directus*, *Gemma gemma*, *Geukensia demissa*, *Glycymeris undata*, *Ischadium recurvum*, *Laevocardium mortoni*, *Lithophaga bisulcata*, *Lucina filosa*, *Lysonia hyalina*, *Macoma baltica*, *Macoma mitchelli*, *Mercenaria mercenaria*, *Mercenaria mercenaria texana*, *Mesodesma arctatum*, *Modiolus americanus*, *Mulinia lateralis*, *Mya arenaria*, *Mya truncata*, *Mytilopsis leucophaeta*, *Mytilus edulis*, *Noctia ponderosa*, *Nucula annulata*, *Ostrea edulis*, *Ostrea equestris*, *Pecten maximus*, *Pecten ravenelli*, *Periploma leanum*, *Petricola pholadiformis*, *Pitar northuana*, *Placopecten magellanicus*, *Rangia cuneata*, *Ruditapes philippinarum*, *Solenya borealis*, *Solemya velum*, *Spisula polymyza*, *Spisula solidissima*, *Tagelus plebeius*, *Tellina agilis*, *Teredo navalis*, and *Yoldia limatula*.

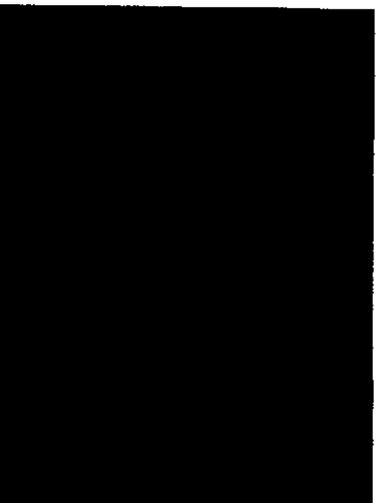
Development of the polarized light image library for bivalve larvae could not be taking place without the collaboration and interest of Dr. Richard Lutz, Rutgers University. Dr. Lutz is making available his entire collection of larval bivalves for the purpose of developing this imaging library.

Phase I Objective 2) To cross validate the identification of scallop larvae using LIHDAT and molecular techniques, and produce RAPD primers for analysis of population structure of juvenile and adult scallops in the three study areas.

RAPD primers suitable for population analysis of *Placopecten* have been identified in a primary screening by amplification of genomic DNA from about 30-40 animals representative of all the GSI collection sites. We have obtained RAPD primer sets from the University of British Columbia RAPD project. Each set consists of 100 decanucleotide primers, some of which were tested to determine the most polymorphic primers. A subset of primers has been used for genetic analysis, based on: (a) whether consistent amplification products are obtained, and (b) the number of polymorphisms detected by each primer. We have also had custom primers made (Sigma) based upon

sequence analyses and comparisons of published genomic libraries.

Figure on the left shows data from four representative adult sea scallops amplified using RAPD primer 101. PCR products were separated on a 1.2% agarose gel and stained with ethidium bromide. Lane on extreme right is a 100 bp DNA ladder. The banding patterns are very similar for all scallops sampled from all areas in the Georges Bank/GOM region. Thus the preliminary evidence from this and many other gels suggests a

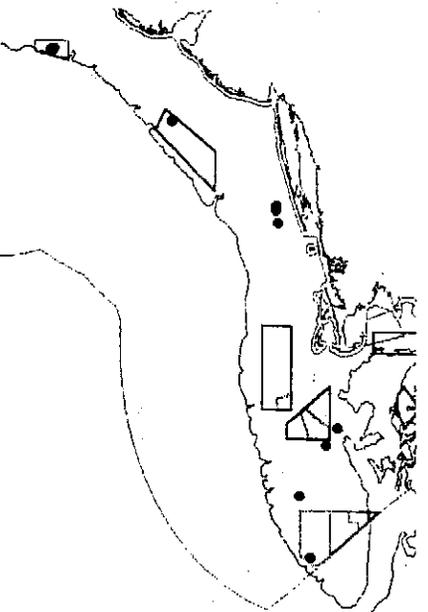


homogeneous population.

To verify the selectivity of the primers and to check for cross-reactivity, additional bivalves species were sampled and the DNA extracted and purified. These included the bay scallop, *Argopecten irradians*, surfclam, *Spisula solidissima*, hard and soft shelled clams, *Mercenaria mercenaria* and *Mya arenaria* respectively, and as a out-group species, the mesogastropod, *Euspira* (= *Lunatia*) *heros*. PCR gels are now ready to be run and banding frequencies compared with the sea scallop results.

Phase I Objective 3) The gonadal/somatic index (GSI): Field sampling and modeling.

Adult sea scallops have been collected on NOAA survey cruises and by commercial fishing vessels during the spring, summer and autumn months and processed as input into the GSI database. A spatially-explicit size-structured model for the adult populations has



been developed and will be implemented based on data from the first year of our study.

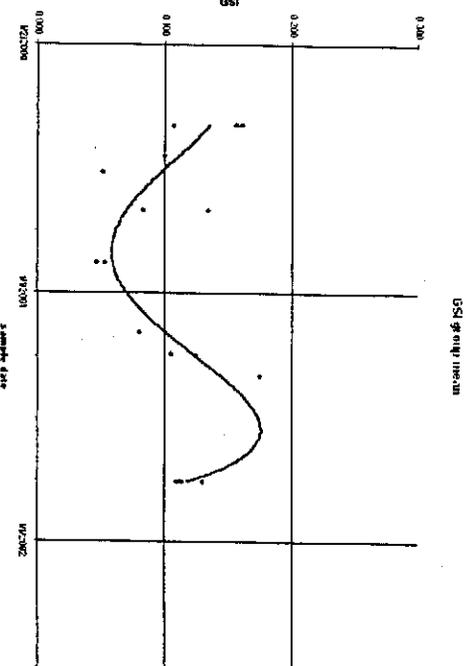
Two New Bedford scallop vessels F/V Westport and F/V Kathy Marie were contracted to collect and bring in sample scallops from each regular fishing trip taken through the year. Additional samples were contributed by NOAA/NMFS R/V Albatross from their annual scallop survey cruises. Skippers were asked to collect scallops of about the same size

in groups of 20 from various locations during normal fishing operations. Samples were placed in bags, marked with location, date, and depth, and frozen whole for preservation and transport. Processing proceeded follows: samples were thawed, the top shell removed to make a video record of the

whole animal, muscle and gonad were removed from remaining viscera, and weights of individual parts were recorded.

The primary rationale for developing a GSI is that a comprehensive timeseries would provide valuable information for management of the scallop resource over the entire range of the fishery. The upcoming task of the New England Fishery Management Council (NEFMC)

is Amendment 10 to the Scallop Fishery Management Plan (FMP), Rotational Area Management. This amendment is expected to take nearly two years of effort from NEFMC staff, the Scallop Plan Development Team (PDT), Scallop Advisory Panel, and the Scallop Committee. Particular focus is on increasing the economic value of the



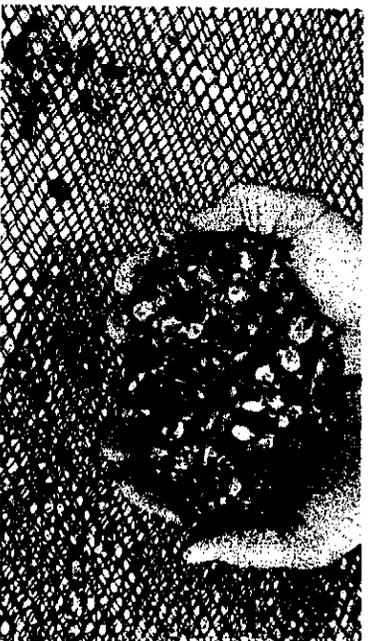
fishery, developing the rationale and methods to open and close areas in a timely manner, understanding the effects of timing options on economic return to the fleet and increasing the reproductive potential of the spawning biomass. It is this last component that relates directly to measurement of larval abundance in the water column, spat collection, and enhancement activities.

The large spatial extent of the fishery and the very few areas where samples for this study have been obtained is clear from examination of plot above. The existing literature on GSI studies are not comprehensive either spatially or temporally and most are unpublished (Lai, DuPaul). Our objectives include compiling available information into a searchable database.

A spatially and temporally comprehensive program would provide detailed information including shell height, meat weight, and gonad fraction over the entire shelf. Repetitive sampling is a necessity, however access is currently limited to the annual NMFS/NEFSC R/V Albatross IV scallop survey cruises (annually in July-August) and these last two years during specific fishing openings during the course of the year. Thus monthly data from these areas that would be valuable to management is not available. It is unlikely that it will be obtained through this project, given the difficulties of obtaining repeated access for obtaining samples within these Closed Areas.

Phase I Objective 4) Coordination with commercial vessels for deployment, monitoring and retrieval of spat collectors in regions where larvae are concentrated. Pilot programs in spat collection have indicated that four week deployments are optimal. Retrieved spat have been relocated to areas closed to fishing where traffic is minimal, thereby maximizing the chances for gear survival.

Two offshore lobster vessels captains, John Doran, F/V Amy Philbrick, Newington, N.H., and Grant Moore, F/V Direction, Fairhaven, Mass. have participated in the spat



collection portion of this project. Both vessels conduct normal operations year round in three areas of particular interest to this project, the Great South Channel (Closed Area I), the closed portion of the Northern Edge of Georges Bank (HAPC, Closed Area II), and the Southeast Part (Closed Area II)(fig 3). All are areas with strong frontal boundaries and known for repeated recolonization of scallop.

Spat collector materials were purchased, rigged and set in October and early November of 2000.

