Project Completion Report
Subaward #Z532701
Grant # 2008-38500-19301

PROJECT CODE: 09-06

PROJECT TITLE: Assessment of Environmental Impacts of Oyster Aquaculture in New England Waters

DATES OF WORK: 1/11/2010 to 4/30/2012

PARTICIPANTS:
Christopher V. Davis, Ph.D., Executive Director
Maine Aquaculture Innovation Center
5717 Corbett Hall, Room 436
Orono, ME 04469-5717
207-581-2263
cdavis@midcoast.com

Carter Newell, Ph.D.
Pemaquid Oyster Company, Inc.
7 Creek Lane
Damariscotta, ME 04543
207-557-3887
musselsandoysters@gmail.com

John Richardson, Ph.D.
Blue Hill Hydraulics
447 Falling Bridge Road
Blue Hill, ME 04614
207-374-3294
jrichardson@bluehillhydraulics.com

Daniel Cheney, Ph.D. Executive Director
Pacific Shellfish Institute
120 State Ave NE #142
Olympia, WA 98501
360-754-2741
cheney@pacshell.org

Anthony Hawkens, Ph.D.
Plymouth Marine Laboratory
Prospect Place
The Hoe
Plymouth PL 13DH
United Kingdom
0044-0-1752633100
aish@pml.ac.uk

Tessa Getchis
Sea Grant Cooperative Extension Program
University of Connecticut
1080 Shennocossett Road
Groton, CT 06340-6048
860-405-9104
tessa.getchis@uconn.edu

Cooperating, Non-funded Participants:

Jeffrey McKeen
Pemaquid Oyster Company, Inc.
PO Box 302
Waldoboro, ME 04572-0302
207-446-8923
jmckeen@earthlink.net

Stewart Hutchings
Dragon Oysters, LLC
33 Front Street
New Haven, CT 06513
203-785-8854
stewart.hutchings@snet.net

REASON FOR TERMINATION: Objectives completed

PROJECT OBJECTIVES:

- Develop Hydrodynamic Flow Models of two oyster farms and put results into a GIS framework.
- Develop a Seston Depletion Model based on field data and oyster feeding rates. This tool will help to assess, at any site, how oyster biomass on a given farm will affect food availability for the other oysters, and determine a hydraulic zone of influence between different farms or important wild habitats.
- Assess benthic infaunal, epifauna and meiofaunal impacts and communicate them through the GIS. We expect to find that oyster cultivation will increase biodiversity and the biomass of invertebrates at the study sites, lending credence to the concept that oyster aquaculture is good for the environment.
- Create an American oyster growth model using ShellSIM, calibrated at field sites. This tool will be coupled with the seston depletion model to predict growth of a single oyster, or a large population of oysters at different densities.
- Develop the GIS framework into an interactive tool incorporating all of the above data into a user-friendly application for oyster farmers, managers and regulators. A user of the final product will, for example, be able to query any location within the study domain and retrieve information describing local hydrodynamics (*e.g.*, flow speeds, volume flux, current direction, and water depth), biodiversity information, and predictions of oyster growth.

ANTICIPATED BENEFITS: With a focus on shellfish (oyster) aquaculture in New England, specifically ecosystem research, this project will describe interactions of aquatic shellfish farms with phytoplankton, marine invertebrates and fish, and lead to the development of guidelines for farm siting issues and carrying capacity. Utilizing an aquaculture GIS format (STEM-GIS) to disseminate results, we will contrast the Maine and Connecticut sites' bathymetry, water velocities and directions, phytoplankton depletion by the shellfish and provide ecological information about the farms, aquaculture activities and BMP recommendations. Furthermore, we will develop an oyster growth module which may be used to optimize shellfish production.

PRINCIPAL ACCOMPLISHMENTS: Summarize in a concise form the findings for each objective for the duration of the project. Measurement data are to be given in SI units. However, to minimize confusion, a dual system of measurement may be used to express results.

- **Objective 1. Develop Hydrodynamic Flow Models of two oyster farms and put results into a GIS framework**.

In year 1, we utilized MIKE-21 to develop a 25 meter grid 2 dimensional flow model for the upper Damariscotta River, Maine. The 25 m grid cell area and results for the flow model are presented in Figure 1. In addition, high resolution bathymetry was developed for the model in the vicinity of the Pemaquid Oyster Company farm site.

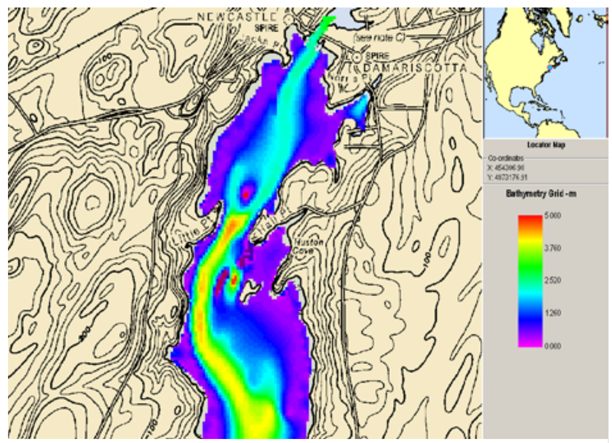


Figure 1. 25 m mesh bathymetry of the upper Damariscotta River Estuary.

The GIS was populated with time varying and spatially varying water column characteristics developed from field data and historical data. These water column characteristics were temperature, salinity, chl *a*, dissolved oxygen, total particulate matter (POM), particulate organic matter (POM), particulate organic carbon (POC) and ammonium. This data was used in the GIS, to predict oyster growth rates of an individual oyster, and combined with daily mean water velocity, the growth rate of a benthic culture of oysters at varying densities at each grid cell in the GIS.

- **Objective 2. Develop a Seston Depletion Model based on field data and oyster feeding rates.**

The purpose of this aspect of the project was to allow for a GIS functionality in which one can control oyster density at a particular grid cell and generate site specific oyster growth as a function of bottom seeding density. There were three components to this aspect of the project:

a. Flow-3D model. We developed a seston depletion model which incorporates benthic boundary layer physics, water depth, site specific water velocities, a defined upstream seston concentration, and a density dependent filtration rate based on oyster biomass. This "patch modeling" was completed by June of 2012, using algorithms based on a mussel seston depletion model. .

b. Integration into GIS. The output of this model (developed using Flow-3d) reduces seston by a percentage, and that reduced food supply is then fed into SHELLSIM to predict a (reduced) growth rate of the planted oysters. This functionality of the GIS was integrated by July, 2012
c. Field data is used to calibrate the model developed in (a) above. Drs. Newell and Davis successfully obtained seston depletion information at the Pemaquid Oyster Company lease site in July (Figure 4) and September, 2010 using moored seabird CTD's

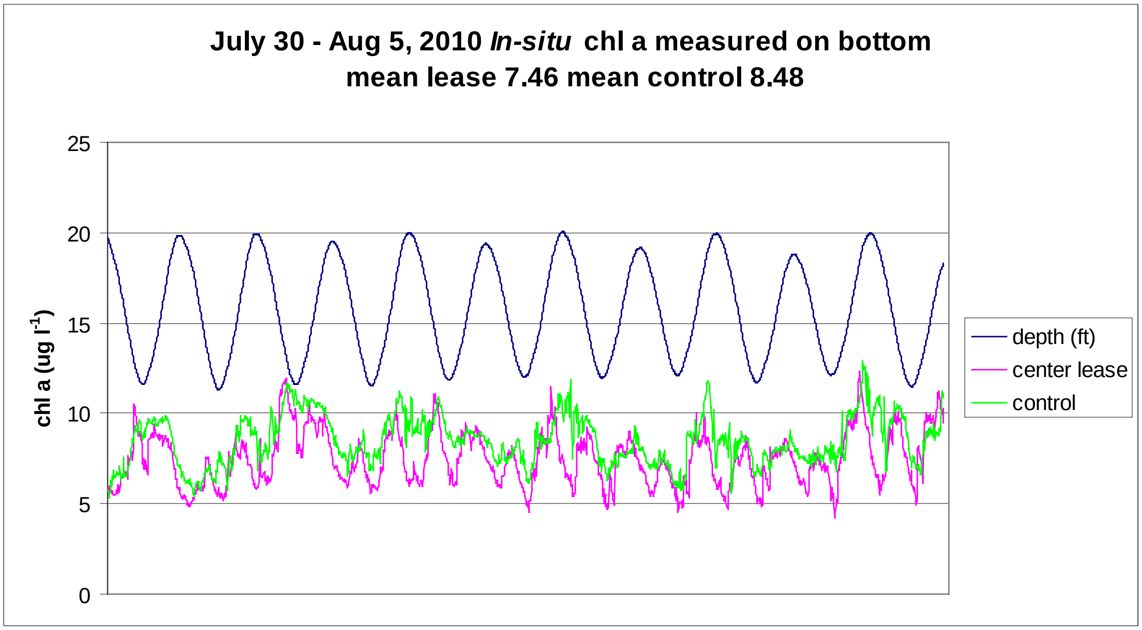


Figure 2. Seston depletion data at the POC lease site in July-August, 2010.

- **Objective 3. Assess benthic infaunal, epifauna and meiofaunal impacts**.

Bottom sediments were sampled, using a Smith-MacIntyre grab sampler, on the oyster farm and off the site in control stations on May 10 and September 10, 2011. The data showed greater abundance and taxa richness at the oyster lease sites, and just slightly lower diversity. This result is common in slightly organically enriched environments. There also was an absence of *Capitella*, which is an indicator organism of overly enriched sediments at aquaculture sites. Mobile epifauna, were sampled using underwater video and photography on bottom and around floating nursery trays. Diverse and abundant epifauna at the oyster cultivation sites was found at all sites.

- **Objective 4. Create an American oyster growth model using ShellSIM, calibrated at field sites.**
  - Field sampling of water column characteristics occurred bi-weekly from May to November, 2010 and 2011 at the vicinity of the oyster farm. CTD profiles were also taken at those sites.
  - Tagged oysters were reared in either bottom cages or surface floating bags for two field seasons to determine changes in growth parameters (shell length, live weight, dry weights, etc.) to validate the growth model.

- Oyster biometrics were developed for oysters of a wide range in size (from seed to over 100 mm long) for SHELLSIM calibrations. This was done to compared actual growth to that predicted with SHELLSIM using the growth drivers.
- Oyster biodeposition study. In order to calibrate the oyster physiology and growth model SHELLSIM, investigators undertook *in-situ* measurements of oyster biodeposition in flow-through feeding. (Figure 3). A flow-through chamber was assembled on an oyster nursery raft, and monthly 24 hour experiments were performed from May – November, 2010 and 2011. At the end of a feeding run, cumulative biodeposits (feces and pseudofeces) were collected for 10 individual oysters (along with 2 control chambers) relative to Chl a, POM, SPM and PIM in composite water samples taken hourly over the 24 hour period using an ISCO water sampler.

Figure 3. Flow-through feeding manifold with 10 oysters and 2 control chambers.

- A preliminary analysis of the chambers using dye studies and 3-d flow modelling resulted in recommended minimum flow rates through the chambers of 400 ml per minute (Figure 4). Simulations were run with a "virtual oyster" in the chamber to recommend possible changes in the chamber dimensions and baffle locations (Figure 4).

  The growth driver data (temperature, salinity, POC, PON, chl a, SPM, PIM, POM) was used by Dr. Hawkins, along with the *in-situ* feeding and absorption data, to simulate oyster growth in Maine and Connecticut (Figure 5).

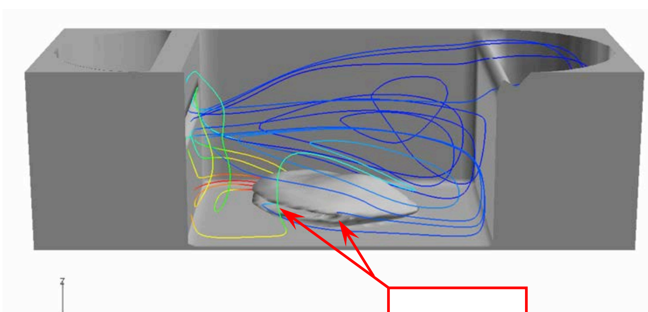
- 

Figure 4. Exhalent Flow Streamlines within a feeding chamber– Side View (colored by mixing - red is unmixed, blue is well-mixed).

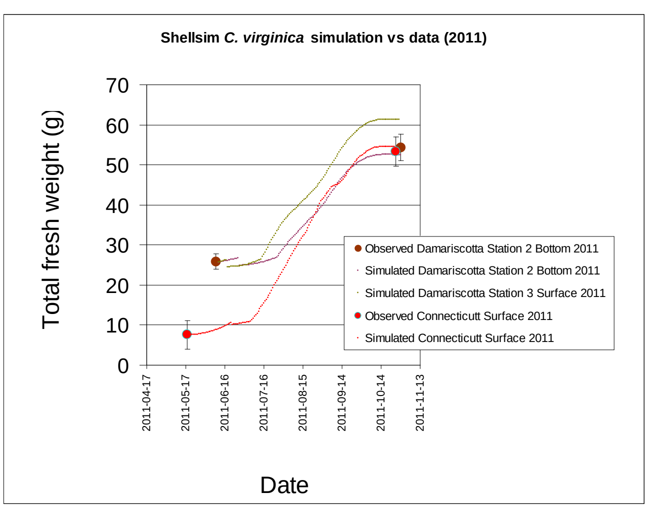


Figure 5. Predicted versus actual growth of oysters based on the ShellSIM growth model.

Objective 5. Develop the GIS framework into an interactive tool incorporating all of the above data into a user-friendly application for oyster farmers, managers and regulators.

In 2011, investigators conducted several surveys in order to learn how to improve the interactive nature of the GIS framework. We gave presentation and focus group surveys in Maine and Connecticut:

most understood it, but found it hard to use. Suggested training extension agents for outreach.
From these surveys, we determined that the primary audience, shellfish growers, wanted a more simplified user interface. From this we began development of new pages with FAQ's: growth (length, meat, weight) at different locations in the domain, growth as a function of density, growth as a function of seed size, time of year. These changes became part of the follow on NRAC funding. The surveys also determined other elements wanted: growth in surface vs bottom culture, contrast good vs bad year, reduce cost in data collection for growth drivers (flow model, water temp. and salinity, food (chl a , SPM, PIM, POM, POC, PON). These issues are being addressed in the current NRAC-funded project

IMPACTS:
The NRAC-funded project "*Assessment of Environmental Impacts of Oyster Aquaculture in New England Waters*" led to an ongoing follow-on NRAC funded project *("Shellfish STEM-GIS (ShellGIS) Development for Improved Siting and Farm Management"* that is refining the oyster growth model adapted for "Oyster-Gro" surface/bottom growing growing cages as the project described in this report focused on bottom culture methods. Although the STEM-GIS package has been demonstrated to shellfish farmers at four presentations in the past two years, the PI's want to complete the software to before showcasing the product more extensively.

The University of Maine and the University of New England in collaboration with the MAIC have successfully submitted an application to the FY2014 National Science Foundation EPSCoR (**E**xperimental **P**rogram to **S**timulate **Co**mpetitive **R**esearch) Research Infrastructure Improvement Track 1 program with a $20M proposal entitled "*Maine EPSCoR: The Nexus of Coastal Social-Environmental Systems and Sustainable Ecological Aquaculture*". Given that the internal University competition winnowed the applicants from eleven down to this proposal was a major accomplishment. A significant scientific component of the proposed research within this EPSCoR proposal is to expand the STEM-GIS platform from the Damariscotta River demonstration site to six bays along the coast of Maine. This would not have been possible without the support of NRAC funding this initial research.

RECOMMENDED FOLLOW-UP ACTIVITIES:
Follow up studies are currently underway as part of an NRAC-funded project: *(Shellfish STEM-GIS (ShellGIS) Development for Improved Siting and Farm Management*

SUPPORT:

YEAR	NRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	MAIC	TOTAL	
2010	$115,731				$64,338	$64,338	$180,069
2011	$ 84,263				$39,338		$123,601
TOTAL	$199,994				$103,676	$103,676	$303,670

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED:

Newell, Carter R., Anthony J. S. Hawkins, Kevin Morris, John Richardson, Chris Davis and Tessa Getchis. 2013. ShellGIS: a Dynamic Tool for Shellfish Farm Site Selection. *World Aquaculture* 44(3):50-53.

Carter Newell, Anthony Hawkins, Kevin Morris, John Richardson, Chris Davis, Tessa Getchis. 2012. ShellGIS: A GIS software tool for predicting growth and environmental effects of bivalve shellfish according to site selection and culture practice. Presented at the Northeast Aquaculture Conference & Exposition, December 2012 in Groton, CT.

Carter Newell, Anthony Hawkins, Kevin Morris, John Richardson, Chris Davis, Tessa Getchis. 2013. ShellGIS: A GIS software tool for predicting growth and environmental effects of bivalve shellfish according to site selection and culture practice. Presented at the World Aquaculture Society Conference, February 2013 in Nashville, TN