Progress Report
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Project Title:"Shellfish STEM-GIS (ShellGIS) Development for Improved Siting and Farm Management"

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Participants:
Dr. Christopher V. Davis, Maine Aquaculture Innovation Center
Carter Newell, Ph.D., shellfish biologist
Christopher Davis, Ph.D., shellfish biologist
John Richardson, Ph.D., hydraulic engineer
Kevin Morris, Ph. D., Software engineer
Anthony Hawkins, Ph.D., ecosystem modeling
Tessa Getchis, Sea Grant Cooperative Extension

The following progress has been made on the primary objectives of this NRAC study. Progress is updated from the report sent Nov. 1, 2012.

1. Add a suspension culture module (previous version was bottom culture only) using the OysterGroTM system and floating trays to allow prediction of oyster growth.
2. Add a function to allow for prediction of oyster growth as a function of density in suspension and bottom culture.

Blue Hill Hydraulics has set up CFD models to determine the % depletion in oyster grow trays to facilitate growth vs density modeling in suspension culture, similar to the patch model we developed for bottom culture. In the GIS system, this also required entering additional layers of temperature and salinity for surface waters. To calibrate these predictions, additional field work is ongoing, and some of the results are presented below. Depletion was about 10% at both sites around the oyster grow cages, and initial chl a concentrations started out lower (1.6 Mook vs 2.2 POC) in the middle of the larger Mook Farm. CFD modeling should be completed by Sept, 2013.

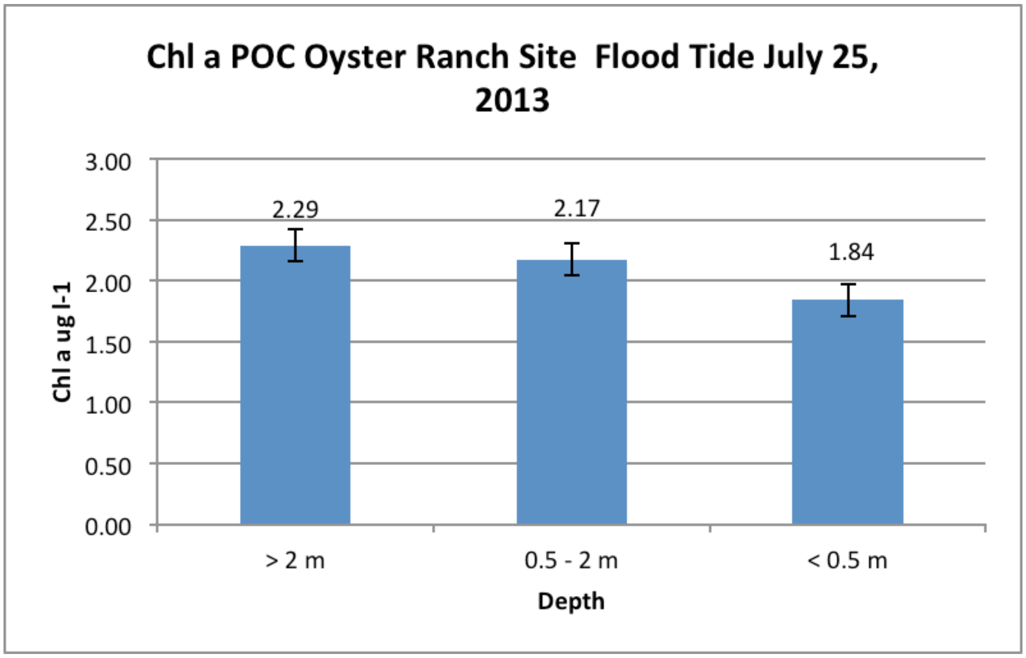

Figure 1. Depletion in the near surface water on the flood tide (POC site, Oyster Ranch)

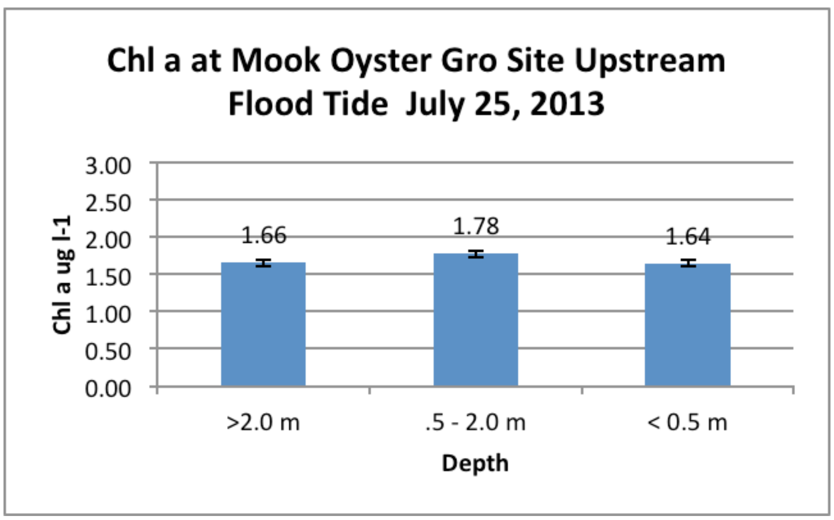

Figure 2. Upstream at Mook Site.

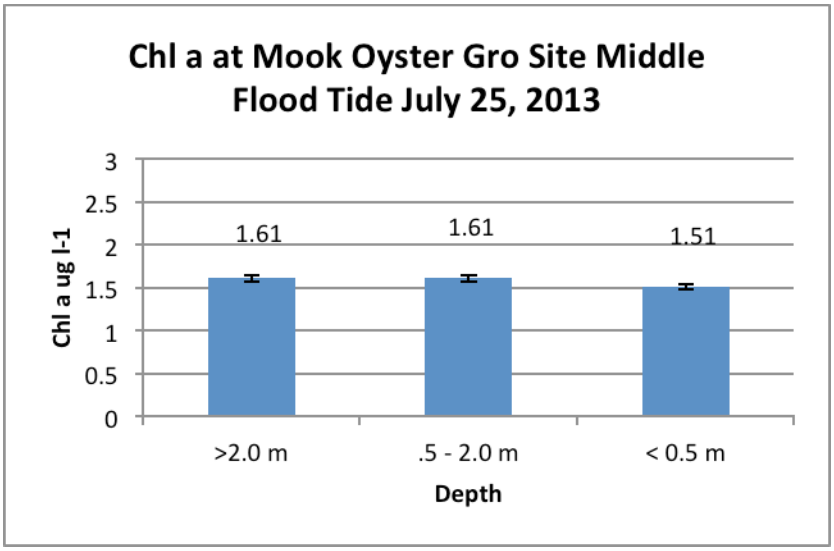

Figure 3. Middle at Mook site (20 cages down 50 cage line).

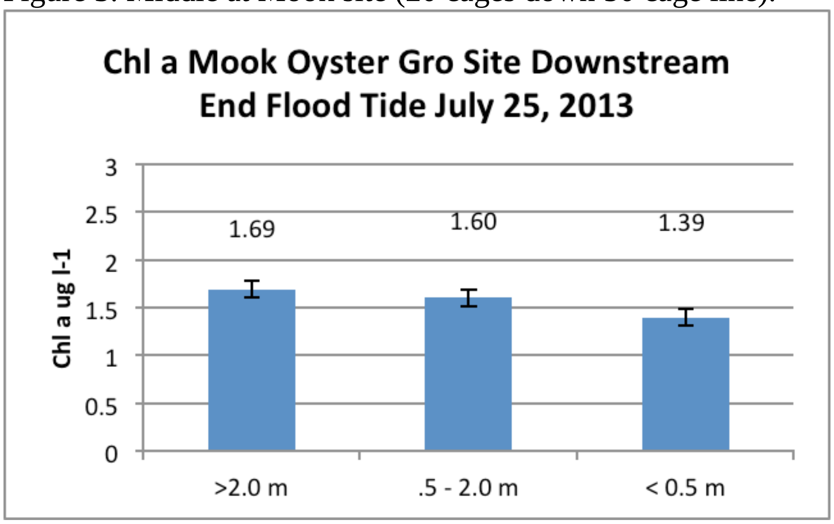

Figure 4. End at Mook site (50 cages down, north end).

These profiles, along with moored CTD's and current meter deployment will continue in August, 2013. In addition, field data on the effects of density on growth in oyster ranch trays on the POC site, and SHELLSIM model validation (oyster growth vs growth driver data collected June – Sept, 2013) is on-going.

3. Conduct a sensitivity analysis of natural inter-annual variations in weather and associated water quality parameters (temperature, salinity, food concentration and food quality) on oyster growth.. This has been performed and the sensitivity of oyster growth to variations in temperature and salinity is an expert layer of the GIS. We have also determined that Chl a, TPM and SPM can predict oyster growth adequately without POC and PON.

4. Add a function to allow prediction of oyster growth as a function of inter-annual variations. (see number 3 above). Note: due to the effect of water temperature on oyster clearance rates, their growth is especially sensitive to temperature). This has been incorporated into the GIS system.

5. Develop an economic modeling tool for oyster growers showing tradeoffs between stocking density, time to harvestable size and associated yield. At our February meeting in Nashville, we developed user screens and input and output parameters for the economic model. In addition, the output graphs are being simplified for interpretation.

6. Integrate into the software publicly available GIS layers depicting other marine-dependent uses, living marine resources and habitats, and environmental data which can be used as a decision making tool. Data from the upper Damariscotta River were supplied in GIS format and integrated into the system. The GIS specialist is providing screens which show where you can't do aquaculture (leases and pollution closures), other conflicts (navigation, intertidal zones, etc.) and overlaying them on oyster habitat where good production is possible. This portion of the project is ongoing. Dr. Kevin Morris is expected to have the layers entered by November, 2013. The approach to be used is outline here:

Using STEMgis as a decision making tool

There are two aims here. One to use decision making tools to identify the **best areas** to place new aquaculture farms given scientific data, modelling and public opinions and the second to use the tool to illustrate **how differing public or scientific opinions can affect the decision making process.** The areas in which shellfish farms are located are invariably in sites that could be used for many purposes, for example, sailing, dredging, ports etc. These different uses have different priorities for different people depending on their own personal interests. Also, it not always possible to precisely define opinions in terms of numbers that can be used in a mathematical model. We therefore propose to use a fuzzy logic (Zadeh, 1965)[1] approach for these types of data. Fuzzy logic enables you to capture and use opinions such as 'map layer X has a somewhat positive affect on public acceptability' or 'map layer Y has a very low negative affect on public acceptability'. The words somewhat, very and low are terms that can be used in fuzzy mathematics and are very useful in capturing public opinion where the hard scientific facts are not available. Two similar projects that the investigators have been involved with include SimCoast which is Fuzzy Logic Rule Based Coastal Zone Management System (www.discoverysoftware.co.uk/SimCoast.htm) and MARA-GIS which is a fuzzy logic decision making for hazard mapping related to dredging activities (http://www.cefas.co.uk/media/462109/ex5766-mara-gis%20technical%20report%20r_2-0.pdf).

There will be many map layers included in this study which will help to define public opinion including:

Existing lease/franchise/grant sites Shellfish classification areas Shoreline access points (if available) or marinas Chl a, HAB charts (if available through state or citizen monitoring efforts)

Protected/threatened habitats (states usually have something like this or a general species SAV coverage)

[1] Zadeh, L. A. 1965 Fuzzy Sets. Information and Control 8:338-353.

Other layers that will help to define the best areas for shellfish farms will be derived from the ShellSIM model in STEMgis and will include Shellfish growth, profitability and environmental factors. Even these data have a related 'fuzziness' in terms of the uncertainty that are found in all modelling techniques and of course in terms of the relevant important of each factor. For example, should the environmental benefits outweigh profitability or vice versa. Different people will have different views on this. In order to capture these differing opinions this projects will initially derive the 'fuzzy logic rules' from all investigators in the project and then gather similar rules from stakeholder meetings and to not only those involved in the aquaculture industry but also other users of river and coast.

Each map layer can have a number of associated rules or opinions. In order to produce an answer to a question such as 'where is the best place to locate an aquaculture farm' these layers and rules need to be combined. This will be done using SimCoast in conjunction with STEMgis. STEMgis will produce the unions and intersections of each map layer spatially and feed these through to SimCoast so that the rules at each intersection pass through its inference engine. This will then produce a gradational confidence map showing values from -1 (i.e. strong negative) to 1 (i.e. strong positive) in answer to the question posed, e.g. best place to locate a farm. All of this complicated procedure will of course be hidden from the user. This project will show results from a wide range of differing opinions and show how these can have great effects on the outcome of such a confidence map. It will also provide a very simple user interface so that users can quickly change their opinions relating to certain parameters (for example environment versus profitability) and see the results change on the map.

7. Develop a large-scale food depletion module to examine the interaction between oyster farms upstream or downstream (i.e. hydraulic zone of influence). At the Nashville meeting, the group developed output functions for this result, and determined how the bottom patch model and the surface tray model results3 3 will be used via a mixing program similar to Cormix by BHH. This work is ongoing and is being calibrated with the field data collected in August, 2013.

8. Investigate the relative impact of different environmental variables on oyster growth with the purpose of reducing the cost of collecting site specific hydrodynamics and water quality data for individual culture locations. See # 3 above. Work by Dr. Hawkins has also determined that in some areas, Chl a alone is sufficient for predicting oyster growth. Since POM/TPM is the most expensive water quality parameter to collect, it might be possible to measure temp, sal, chl a and oyster growth and back out the expected POM/TPM measure if monthly growth measures were made. Ultimately the development of a low coast coastal monitoring buoy for temp, sal, and Chl a would allow for good spatial coverage for the GIS system and wider application in the region. This concept has been developed in a U Maine/UNE EPSCoR proposal for $20 million submitted to NSF in August, 2013 with Newell as a co-investigator.

9. Create a user interface which answers frequently asked questions from growers.
Through the suggestions of Tessa Getchis, we totally changed the user interface and simplified it to allow for a logical and straightforward progression from choice of species, choice of culture technique, management strategies and expert options. These changes will significantly improve the utility of the system for extension agents and growers. A Powerpoint presentation given by Getchis was presented at a meeting of extension agents, and is attached.

10. Develop and deliver 20 minute outreach presentations for both scientific and trade meetings. Dr. Newell presented talks on the project at NACE (December) as well as a 1.5 hour workshop there, and a talk at NSA/WAS in Nashville (Feb 2013). In addition, posters and talks were presented at the WAS meeting in Prague (2012) and a poster at the NSA/WAS meeting on ShellGIS. A presentation will be made at the November, 2013 Aquaculture Conference in the Canary Islands.

11. Host a focus group meeting with key industry and resource management officials to conduct beta-testing of the model. Beyond the workshop at NACE, meetings are planned when the project is completed (early 2014).

12. Host a technology transfer workshop for the Northeast Aquaculture Extension Network. Next year's meeting will feature a training workshop on the GIS.

13. Develop a NRAC fact sheet on the use of ShellGIS. Being worked on by the group and led by Tessa Getchis.

14. A publication (World Aquaculture Society Magazine) of our SHELLGIS program is coming out soon (in press). The article is attached.

Expected completion of all objectives (field work and modeling and GIS final form) through December, 2013 with presentation to extension by March, 2014 in a final workshop.

Attachments:
Aquaculture conference abstract (accepted)
Powerpoint for NE Extension meeting
WAS paper submitted

Attachment 1: Aquaculture Conference Nov. 2013

Title:

Applications of SHELLGIS: the intersection between biophysical factors, shellfish production capacity, and societal priorities

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Abstract:

Whilst ecosystem modeling has been widely used to predict the carrying capacity for bivalve culture in numerous estuaries, system scale approaches do not have sufficient spatial resolution to adequately represent critical localized effects of current flow on the supply and use of food particles. Instead, Geographical Information Systems (GIS) help display, manage and communicate spatially resolved information, including outputs from integrated models, helping to optimize site selection and culture practice at the scale of the culture unit. *ShellGIS* was developed as a practical tool for bivalve mollusc farmers for selecting good sites and managing them for optimal growth rates and seed to harvest yields.

ShellGIS analyzes shellfish farming practices in space and time, accounting for the interactive effects of seeding density, culture type and hydrodynamics. Recent improvements to the GIS include detailed flow models and prediction of oyster (*Crassostera virginica*) growth in both surface cages and on the bottom as a function of location, seeding density, seed size and time of year seeded. However, while species specific and production technology specific priority areas may be identified for the aquaculture industry, in rural coastal areas, there has been a need to balance aquaculture development and other uses of the coastal zone. We utilized SIMCOAST, a fuzzy logic rule-based expert system, and interviews with stakeholders, to balance conflicting uses in a novel application to aquaculture siting and development in the U.S., and an innovation in marine spatial planning efforts.