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Marine Matters

ShellGIS™: a GIS software tool for predicting growth and environmental effects of bivalve shellfish according to site selection and culture practice

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Introduction

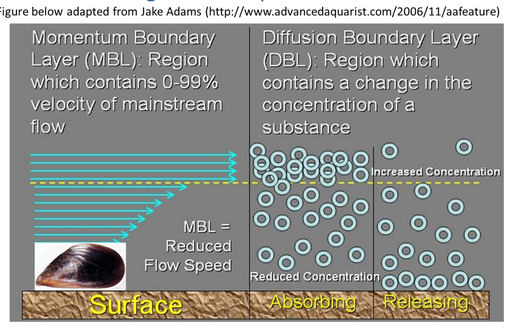
Hydrodynamic flow models and shellfish growth models are important elements of integrated applications helping to manage aquaculture production, including internalisation of wastes within multi-trophic systems and effects of aquaculture on wider ecosystem services, each according to the European Union Water Framework Directive and Food and Agriculture Organisation's guidelines for ecosystem approach. However, many of these models lack a detailed representation of the hydrodynamics in and around aquaculture, whether suspended or on the bottom, thus without sufficient spatial resolution to be useful on an individual farm scale. In addition, inadequate representation of the drivers of shellfish growth, especially the detrital component of suspended particulate matter, limits the predictability of such models. ShellGIS™ is being developed as a transferable software tool which redresses previous shortcomings by integrating state-of-the-art models of flow and shellfish biology within geographic information system (GIS) that handles additional dimensions of time and depth, thereby enabling dynamic three-dimensional predictions of growth and environmental effects in bivalve shellfish at both fine (farm) and course (system) scales according to both site selection and culture practice.

Methods

ShellGIS™ is a custom application of STEMgis, the geographic information system that handles all common requirements of mapping software plus additional dimensions of time and depth, enabling exploration of spatial data throughout four dimensions of space and time (http://www.discoverysoftware.co.uk/STEMgis.htm). Within ShellGIS, two-dimensional flow is simulated using MIKE 21 (Danish Hydraulic Institute), and three-dimensional flow using FLOW 3D (http://www.flow3d.com). Shellfish biology is simulated using ShellSIM™ (http://shellsim.com), which successfully predicts population growth and environmental effects in 13 species to date, helping account for contrasting environments by modelling the differential processing of both chlorophyll-rich and remaining organics, whilst with options that help establish the minimal set of environmental data required to simulate effectively at different locations.

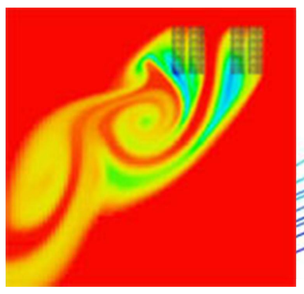
1. For bottom culture, ShellGIS™ integrates outputs from MIKE 21 and ShellSIM™ to predict how boundary layer dynamics influence shellfish growth and environmental effects according to culture practice at chosen sites

Figure below adapted from Jake Adams (http://www.advancedaquarist.com/2006/11/aafeature)

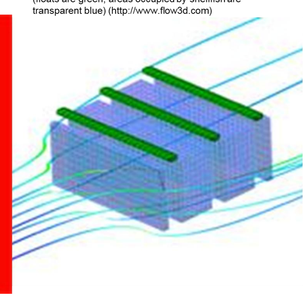


2. For suspended culture, ShellSIM™ is being embedded in FLOW 3D for ShellGIS™ to predict effects of culture structure on shellfish growth and environmental effects according to culture practise at chosen sites

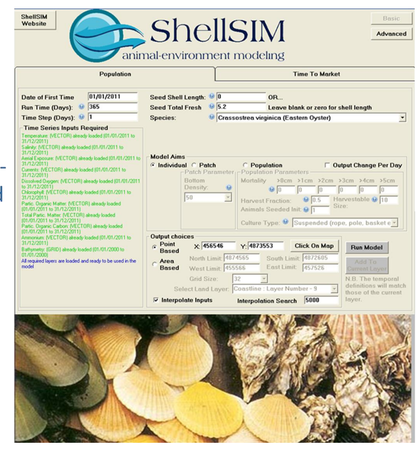
Flow 3D simulation of chlorophyll distribution in and downstream of aquaculture rafts (http://www.flow3d.com)



Flow 3D simulation of flow through an aquaculture raft (floats are green, areas occupied by shellfish are transparent blue) (http://www.flow3d.com)

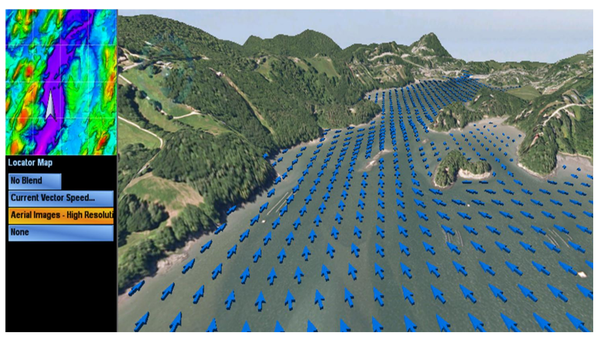


3. User-friendly interface includes options to analyse common trade-offs associated with spatial planning, as agreed with growers and regulators

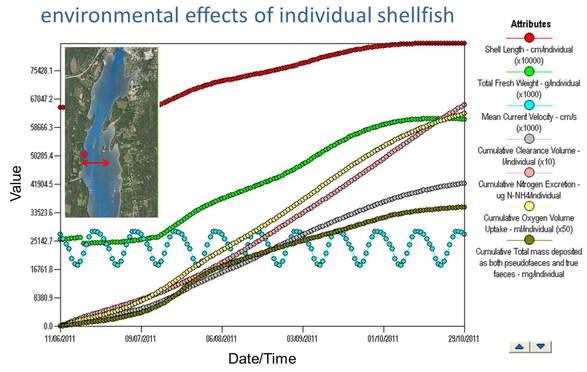


Some results to date

1. Hydrodynamics (i.e. velocity, direction, volume flux) can be visualized dynamically with the STEMgis 3D Viewer

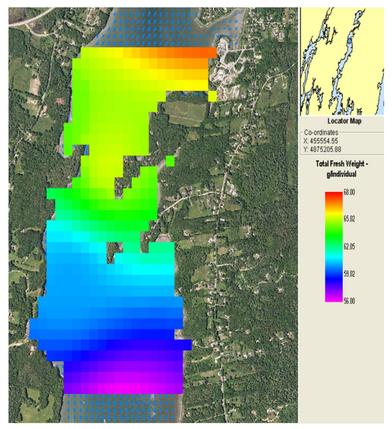


2. Points or transects in the domain can be queried for hydrodynamic data, including growth and environmental effects of individual shellfish

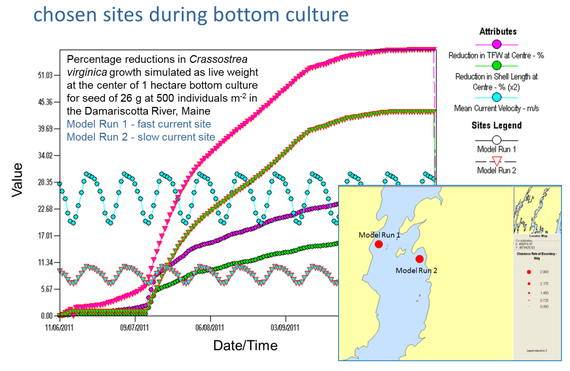


3. Growth and environmental effects can be compared for individual shellfish through the domain

Crassostrea virginica growth simulated as total fresh weight in the Damariscotta River, Maine following culture from June (seed size was 26 g) to October

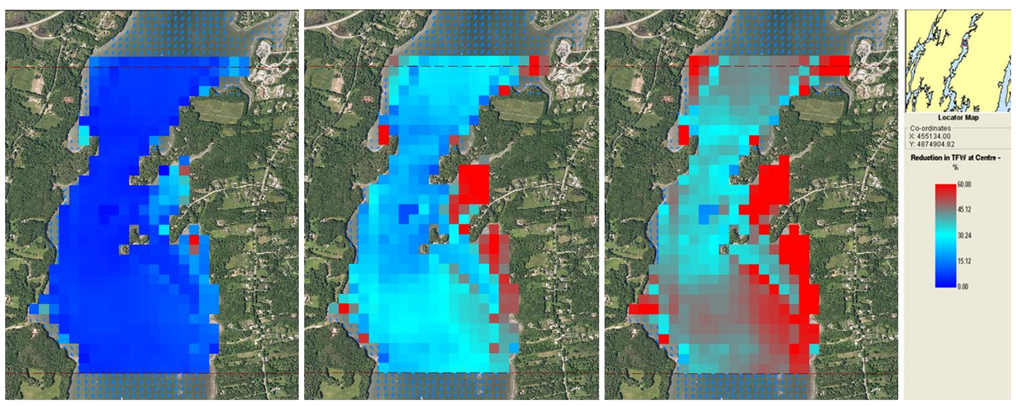


4. Interactive effects of seeding density and hydrodynamics on growth and environmental effects can be assessed at chosen sites during bottom culture



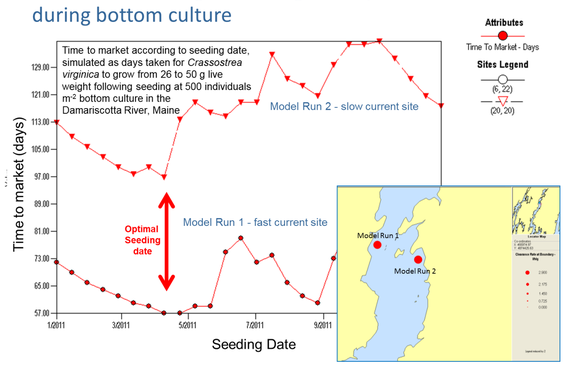
5. Shellfish growth and environmental effects can be assessed according to seeding density through the domain, illustrating both where and when affected by current flow

Percentage reduction in *Crassostrea virginica* growth simulated as live weight at the center of 1 hectare bottom culture in Damariscotta River, Maine, as a function of seeding density following normal culture from June to October



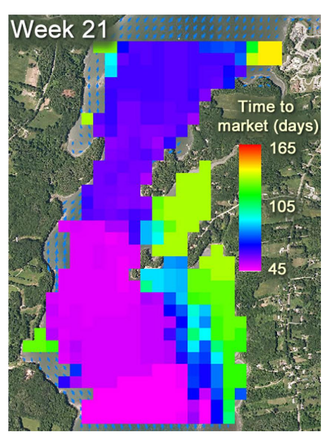
100 m^{-2} 500 m^{-2} 1000 m^{-2}

6. Effects of seeding date on time to market can be assessed according to seeding density at chosen sites during bottom culture



7. Effects of seeding date on time to market can be further optimized upon comparison through the domain

Time to market simulated as the days taken for *Crassostrea virginica* to grow from 26 to 50 g fresh weigh following seeding at 500 individuals m^{-2} during week 21 for bottom culture in the Damariscotta River, Maine



Summary and conclusions

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- Integrating flow (MIKE 21 and FLOW 3D) and shellfish (ShellSIM™) models in a custom application of temporal geographic information system (STEMgis), ShellGIS™ is providing exciting opportunities, both scientific and applied, for dynamic analyses of shellfish production and environmental effects according to culture practice at both fine (farm) and course (system) scales
- Stakeholder meetings have proven essential, stressing the need for range of user interfaces to suit different interests, with tailored outputs that answer frequently-asked questions
- Resulting emphasis is upon user-friendly software that is transferable and cost-effective, with options that simplify both the requirements for and entry of data defining new locations, capitalising upon ShellSIM™'s ability to predict for wide range of shellfish species
- Results to date exemplify how ShellGIS™ can help to optimise site selection, seeding date and seeding density during bottom-culture through defined domains
- Current work is adding similar options for suspended culture systems, dependent upon associated three dimensional hydrodynamic influences
- Coincident options are being added to consider other marine-dependent uses, including marginal analyses of aquaculture profitability, based on costs and returns
- We welcome hearing of collaborative interest, ready to develop underlying science and outputs to satisfy further requirements

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