The FARM model in Long Island Sound:

How important is nutrient removal through shellfish harvest?

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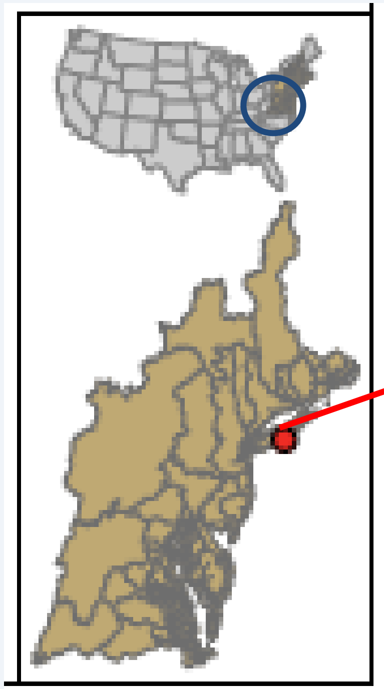
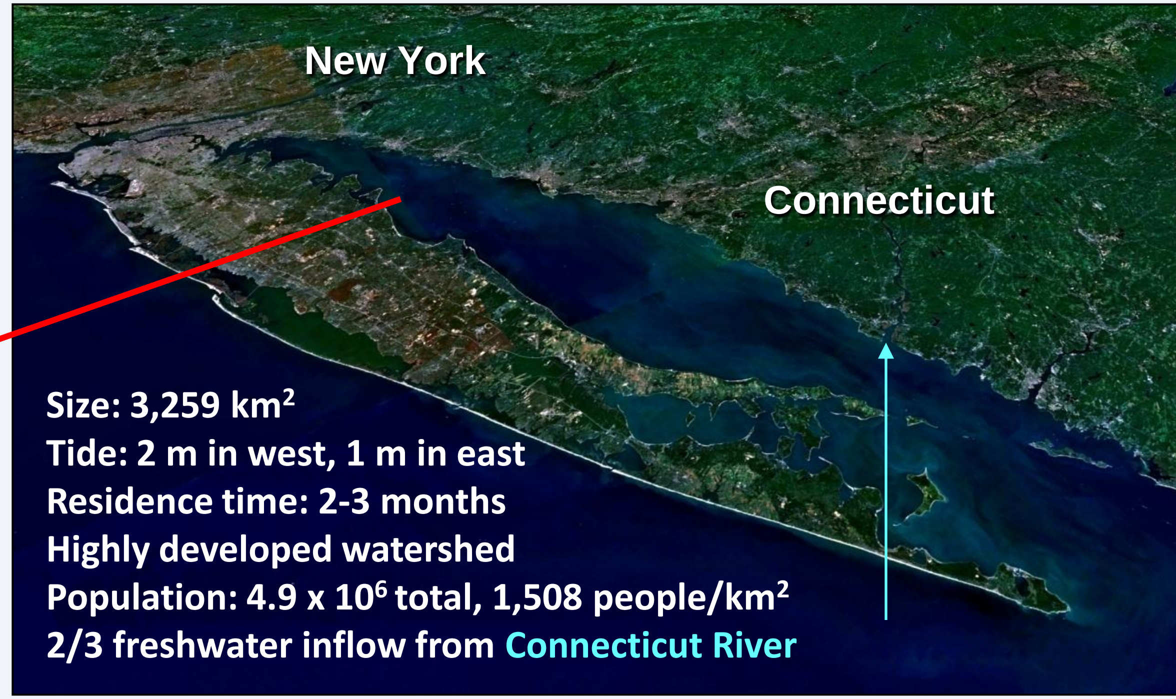
Chesapeake Bay Program Modeling - Quarterly Review Meeting
April 9-10, 2013
CBPO Conference Room – The Fishshack
410 Severn Avenue, Annapolis, MD

Long Island Sound: Background





Long Island Sound bioextractors

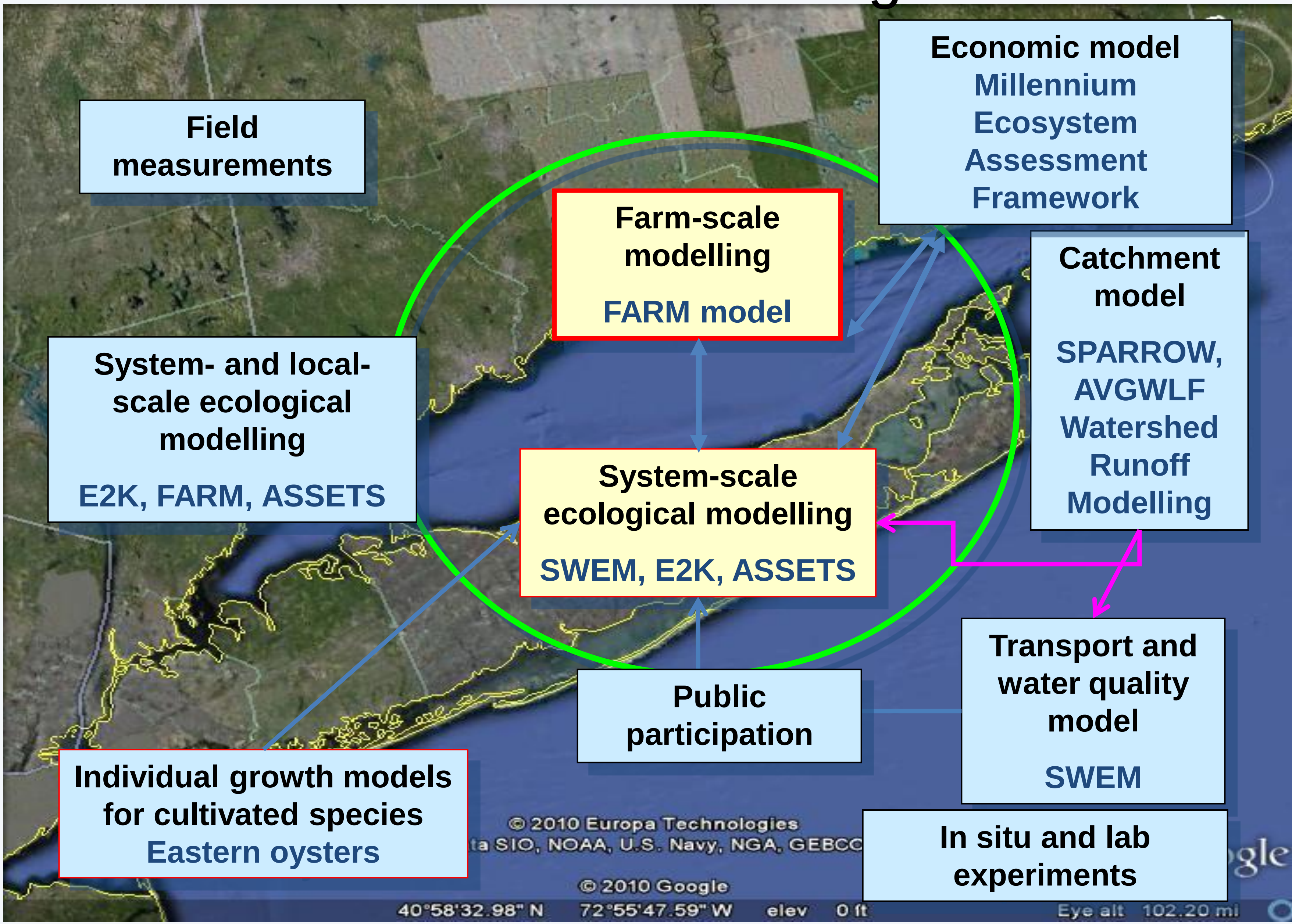
Eastern Oyster
Crassostrea virginica

Northern Quahog
Mercenaria mercenaria

Project results will inform:

- Long Island Sound TMDL
- 2011 NOAA Aquaculture Policies
  National Shellfish Initiative

The Regional Ecosystem Services Program Bioextraction Framework: Long Island Sound

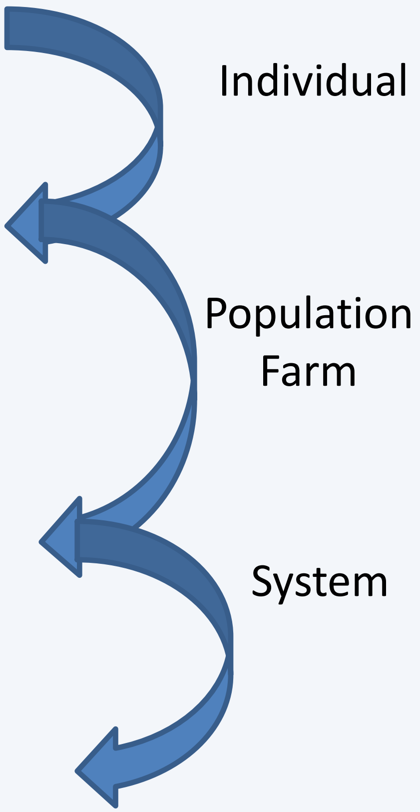


Modelling Eutrophication and shellfish aquaculture

Objective: to estimate the potential nutrient removal from Long Island Sound through shellfish aquaculture.

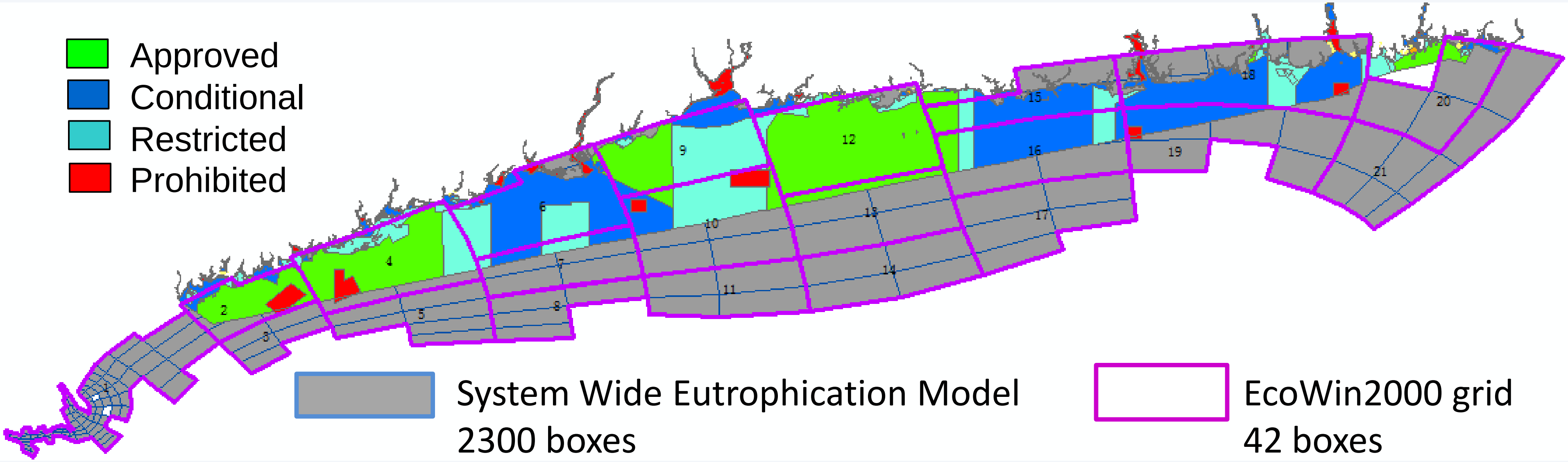
For today:

- Individual growth model (AquaShell) scaled to population for Eastern oyster,
- Farmscale model (FARM) for Eastern oyster at a site in Long Island Sound,
- Ecosystem services and optimization,
- Ecosystem models merging of high resolution 3D model (SWEM) and coarser scale (EcoWin2000) ecosystem models,
- Upscaling site specific results to system scale.



But first, since ecosystem scale should come before local scale, a couple of points about the system-scale modeling

Scaling farm results to Long Island Sound
High Resolution 3D → Coarser Ecosystem Model Grid: Merged using legal, physical, water quality, aquaculture criteria



Model	Timeframe	Focus
System Wide Eutrophication Model (SWEM)	one year	water circulation, water quality
EcoWin2000 (E2K)	decadal	aquaculture, water quality, economics

Water quality results for E2K and SWEM can be compared, both models can be used to generate outputs for use in ASSETS eutrophication assessment, as an overall synthesis model, and FARM, as a local scale model

Individual Growth Model: AquaShell Eastern Oyster

Developed to:

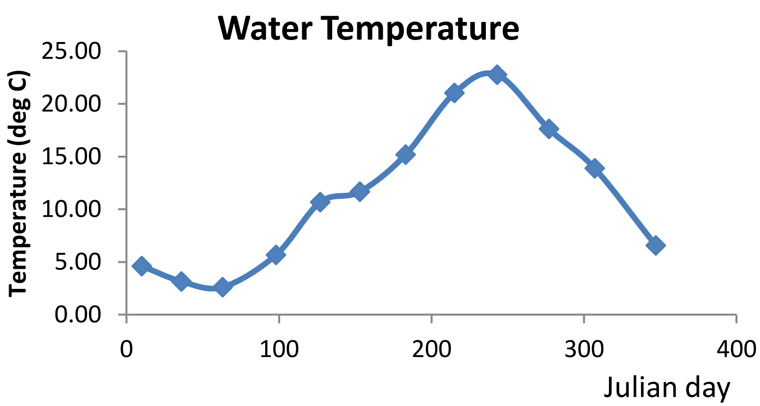
a) simulate change in individual weight (tissue dry weight, total fresh weight, shell length);

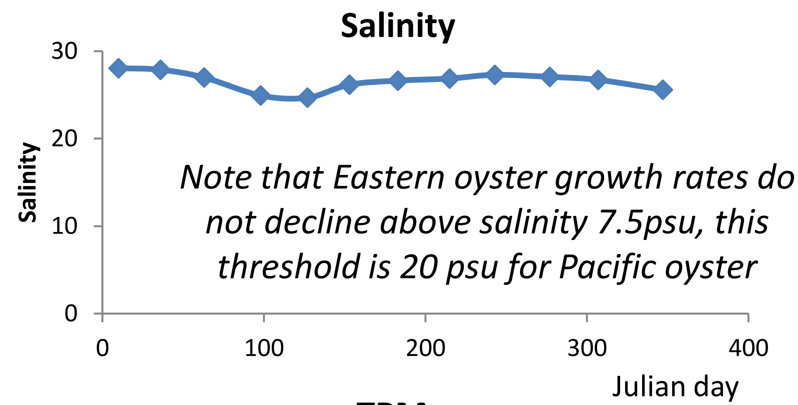
b) integrate relevant physical and biogeochemical components, (chlorophyll, temperature and salinity, and partition phytoplankton and detrital food resources);

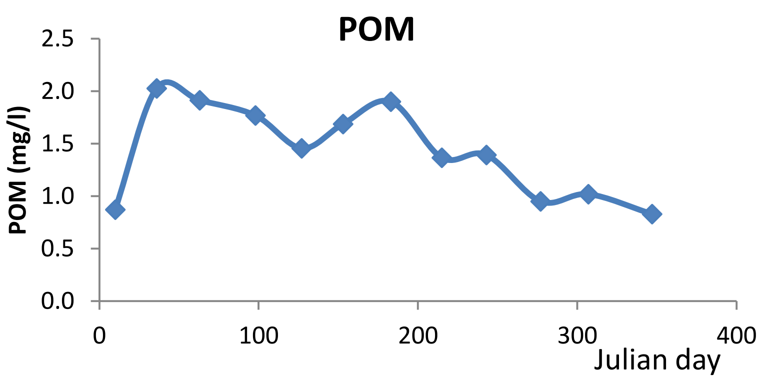
c) provide environmental feedbacks for production of particulate organic waste (feces and pseudofeces), excretion of dissolved nitrogen, and consumption of DO;

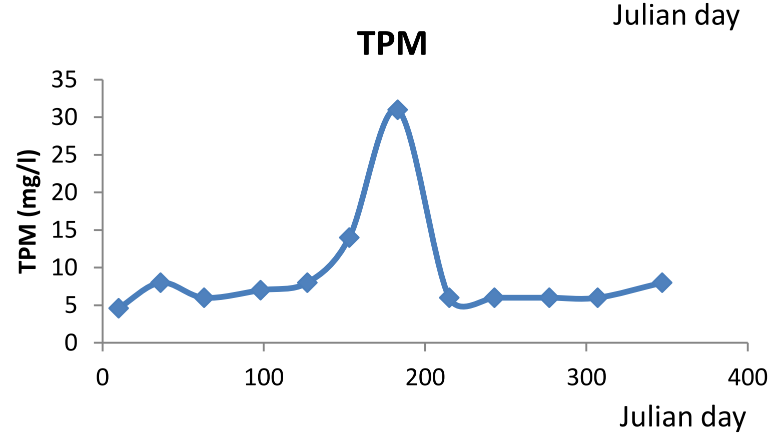
d) scale to both local (farm) and ecosystem models for full analysis of production and environmental effects.

Drivers for Individual Growth Model: AquaShell Eastern Oyster

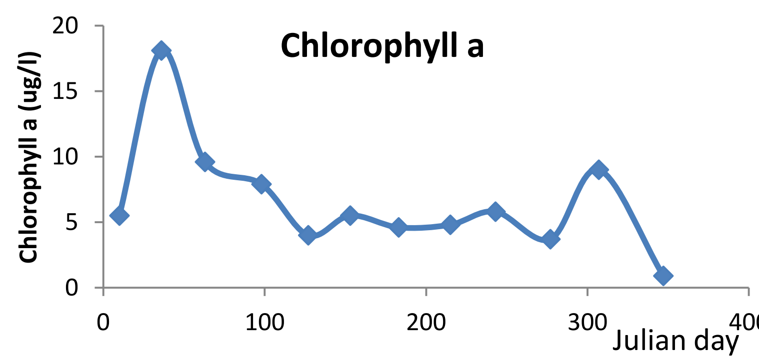






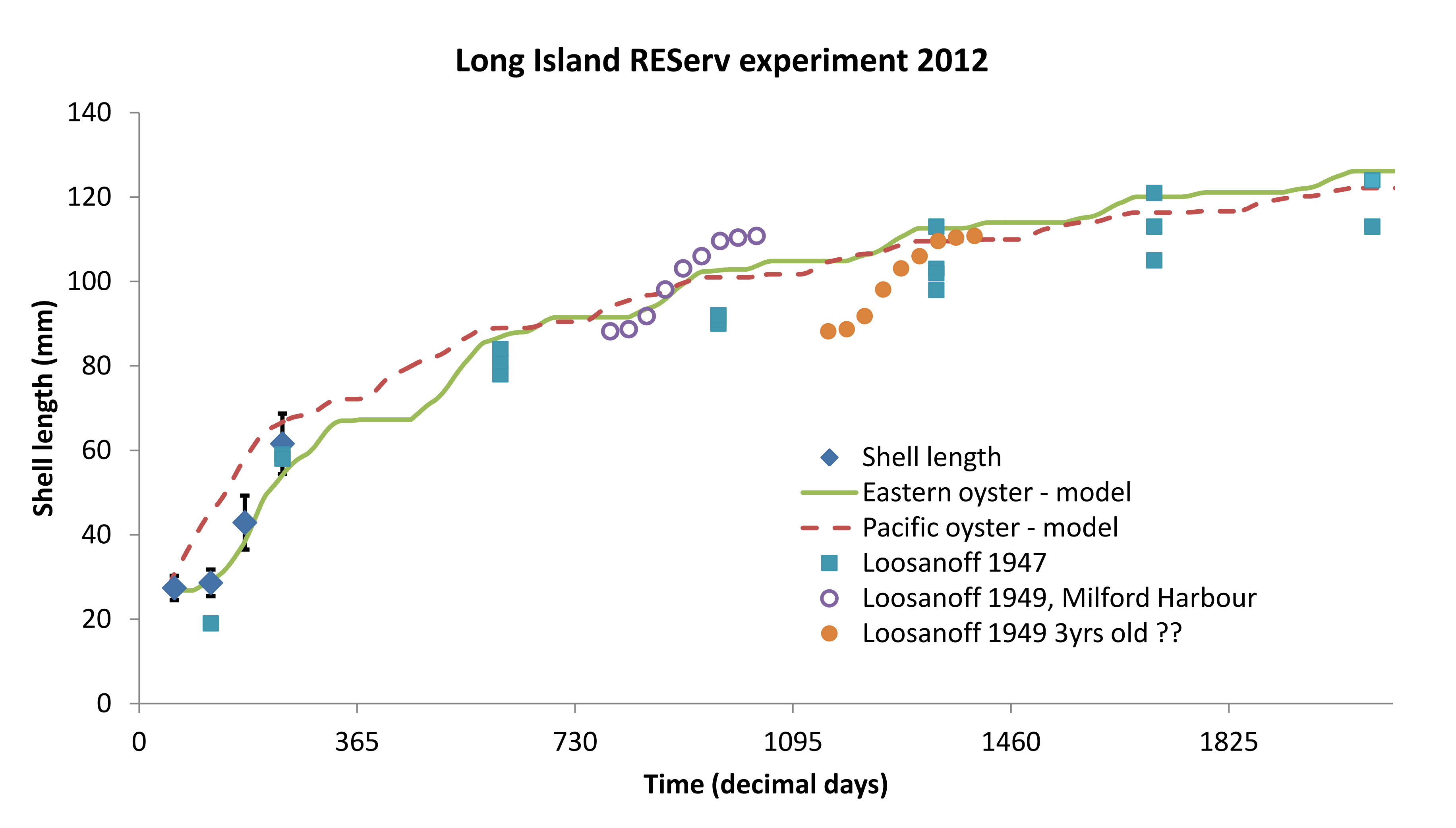


Individual oyster growth is modeled as a function of food supply and environmental parameters



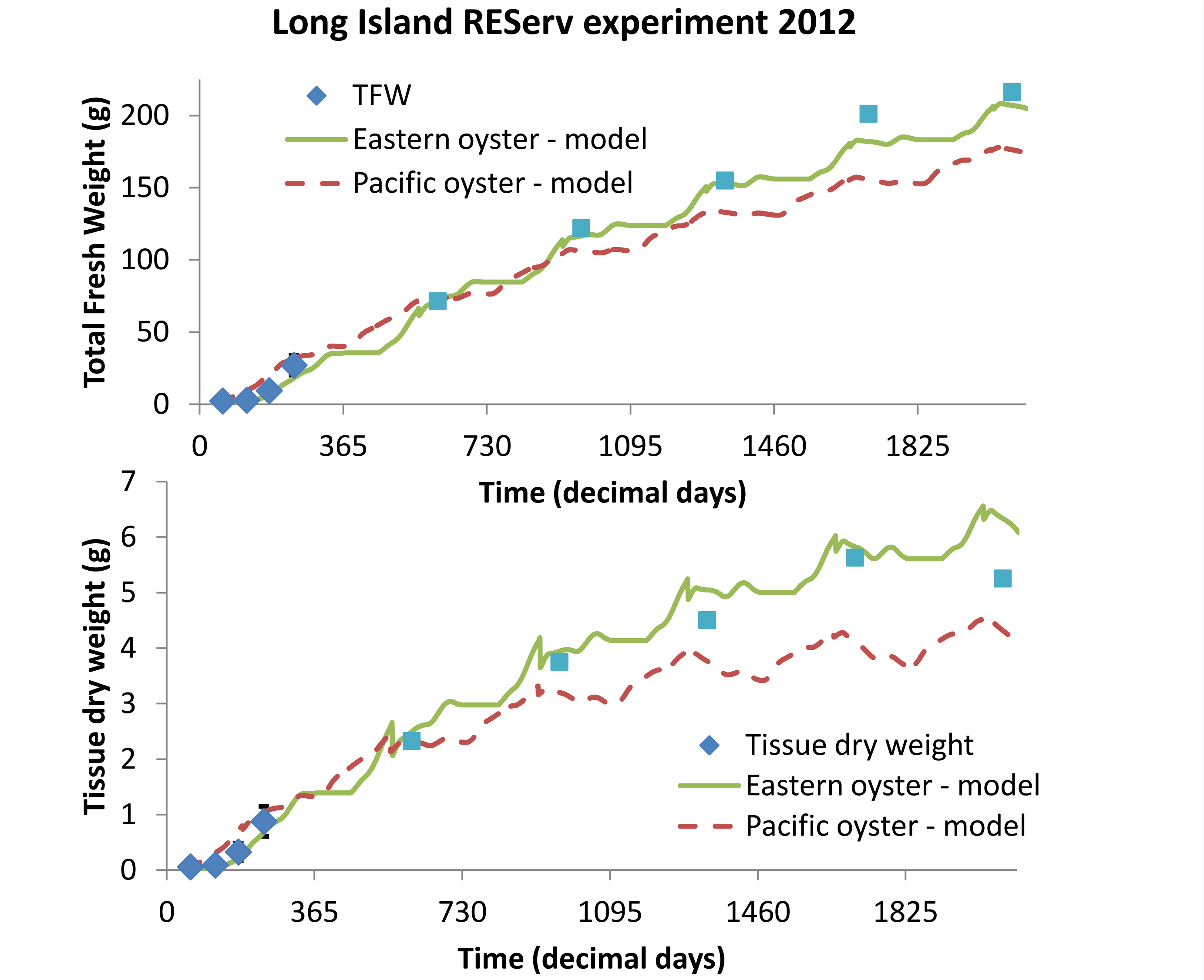
LIS Data from M. Lyman, CT DEP

Simulation of oyster shell length with Long Island Sound environmental drivers



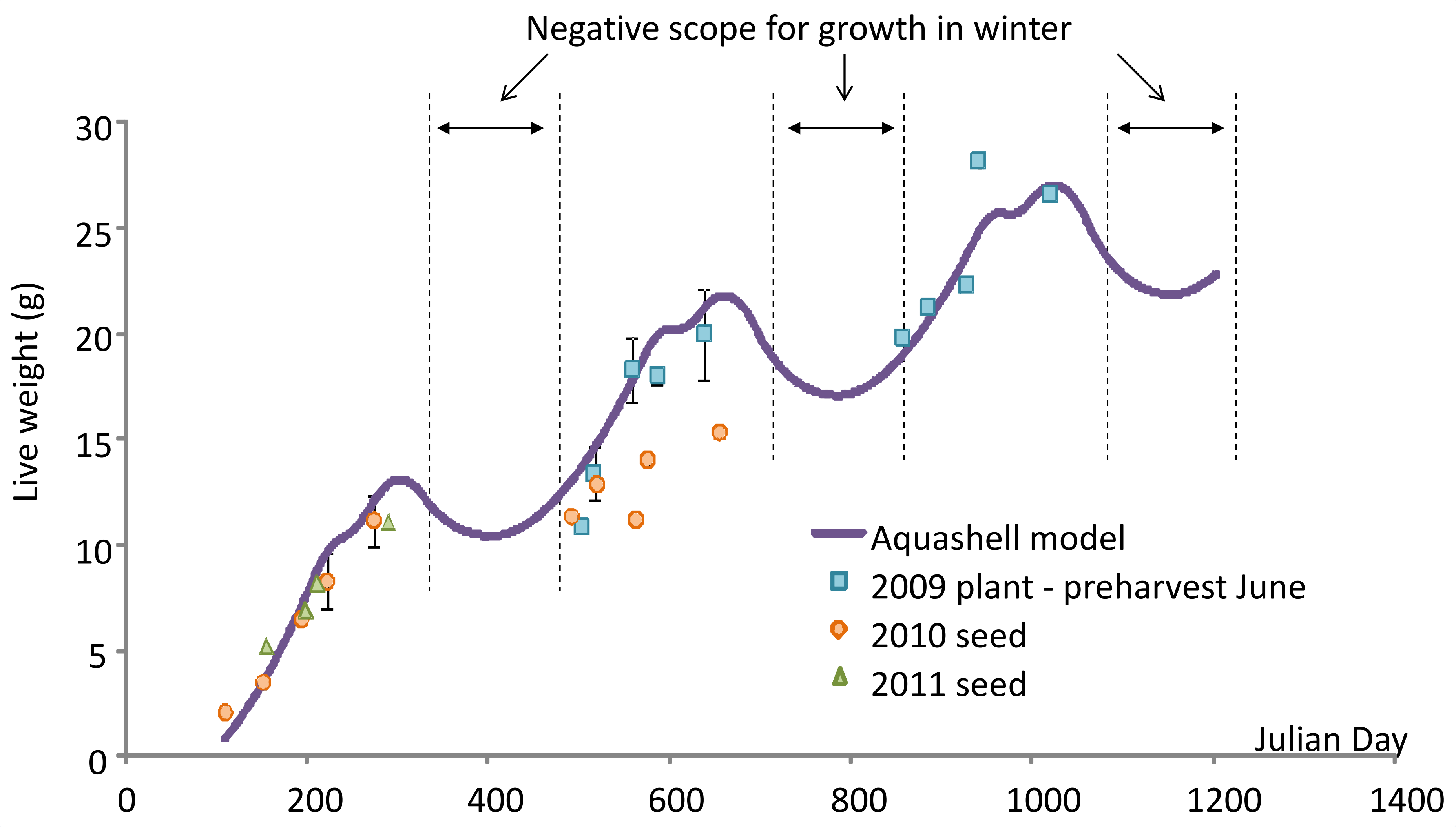
The individual model provides a good fit to project data for shell length.

Simulation of oyster fresh and dry weight with Long Island Sound environmental drivers



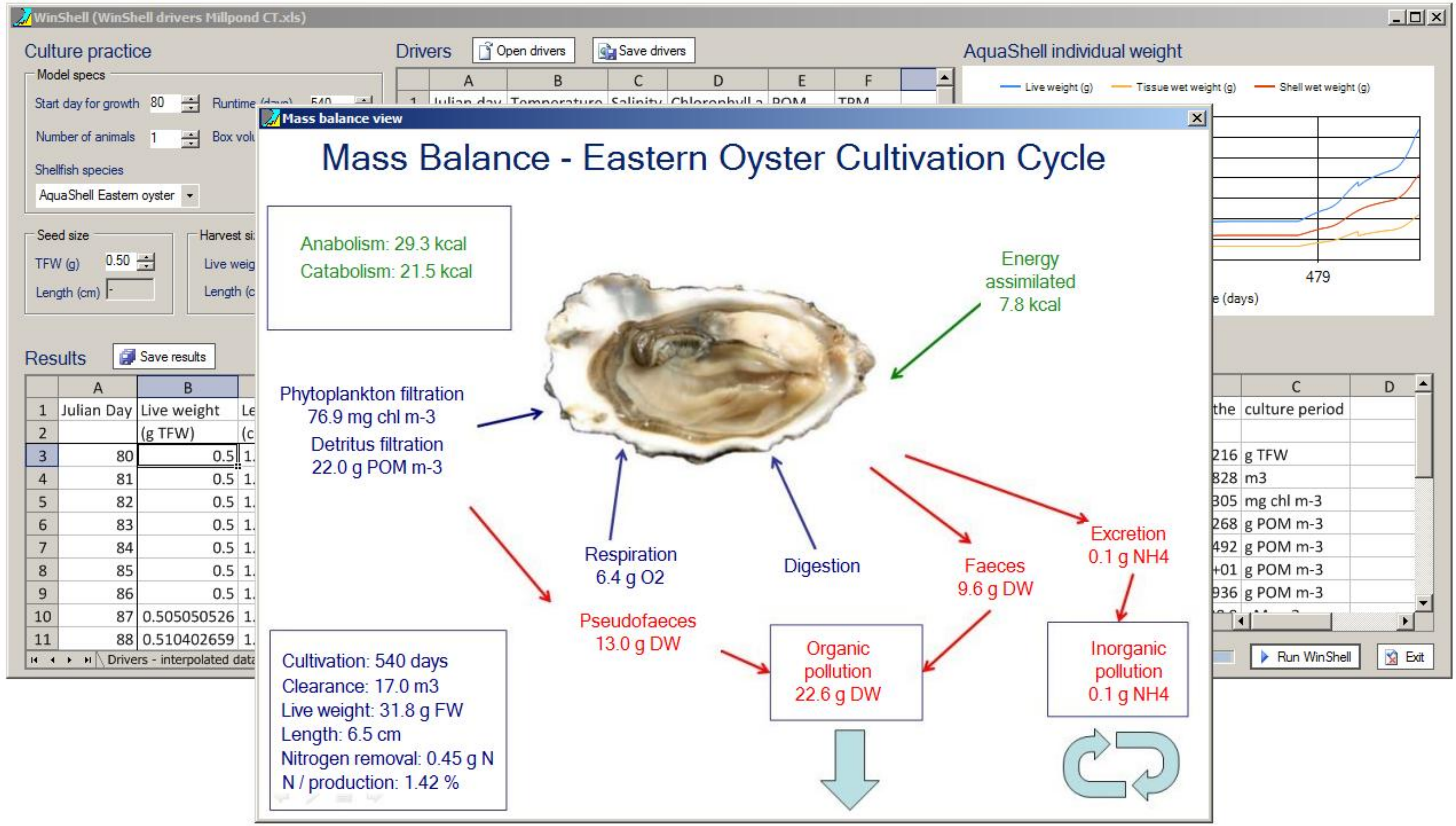
The AquaShell model also shows a good fit to project data for live weight and for tissue dry weight. So we're okay to move to the farm scale. But first…

Simulation of Manila clam live weight with Samish Island environmental drivers



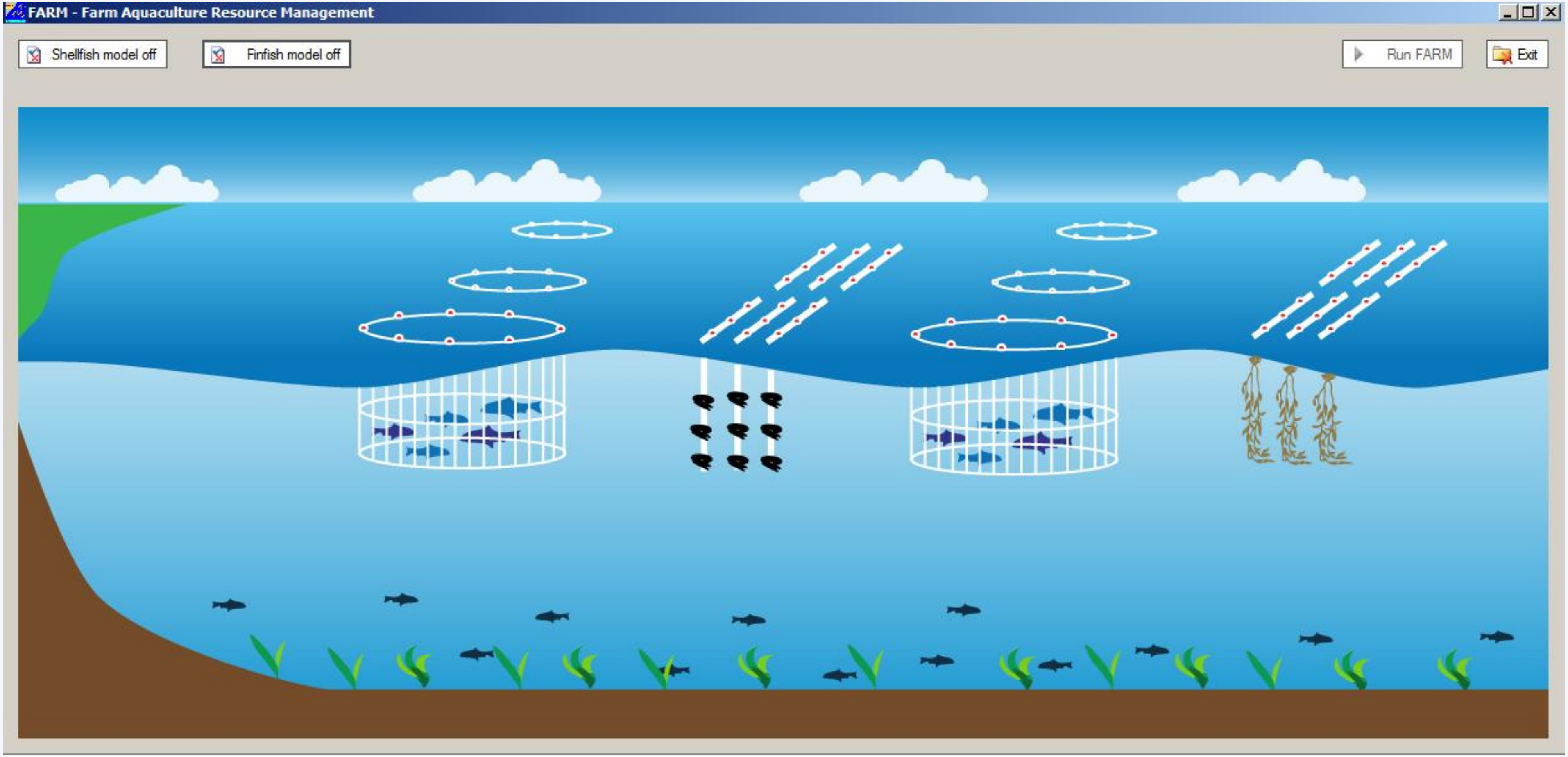
The AquaShell Manila clam model also shows a good fit to project data for live and dry tissue weight.

AquaShell Eastern oyster growth model
simulated mass balance



Growth simulation of oysters feeding on algae and detritus provides production and environmental effects outputs, allows population scale models to examine top-down control of eutrophication by shellfish

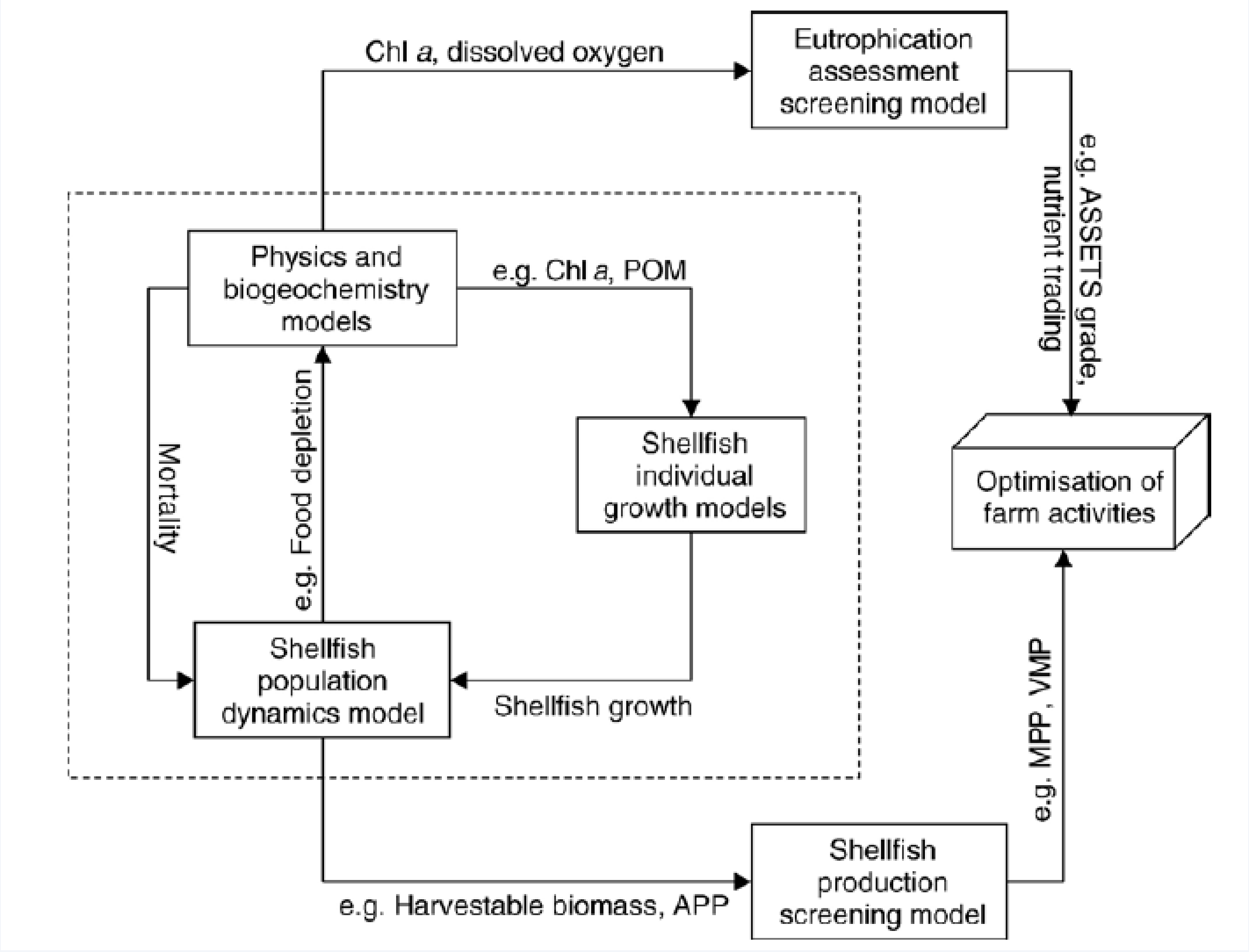
Farm Aquaculture Resource Management (FARM) Model
Shellfish Aquaculture



The FARM model can also be used for finfish monoculture and IMTA.

Ferreira et al., 2007. The FARM model. Aquaculture 264: 160-174.
Ferreira et al., 2012. Cultivation gilthead bream and IMTA in the FARM model. Aquaculture 358-359, p. 23-34.

The FARM Model – shellfish aquaculture



Ferreira et al., 2007. The FARM model. Aquaculture 264: 160-174.

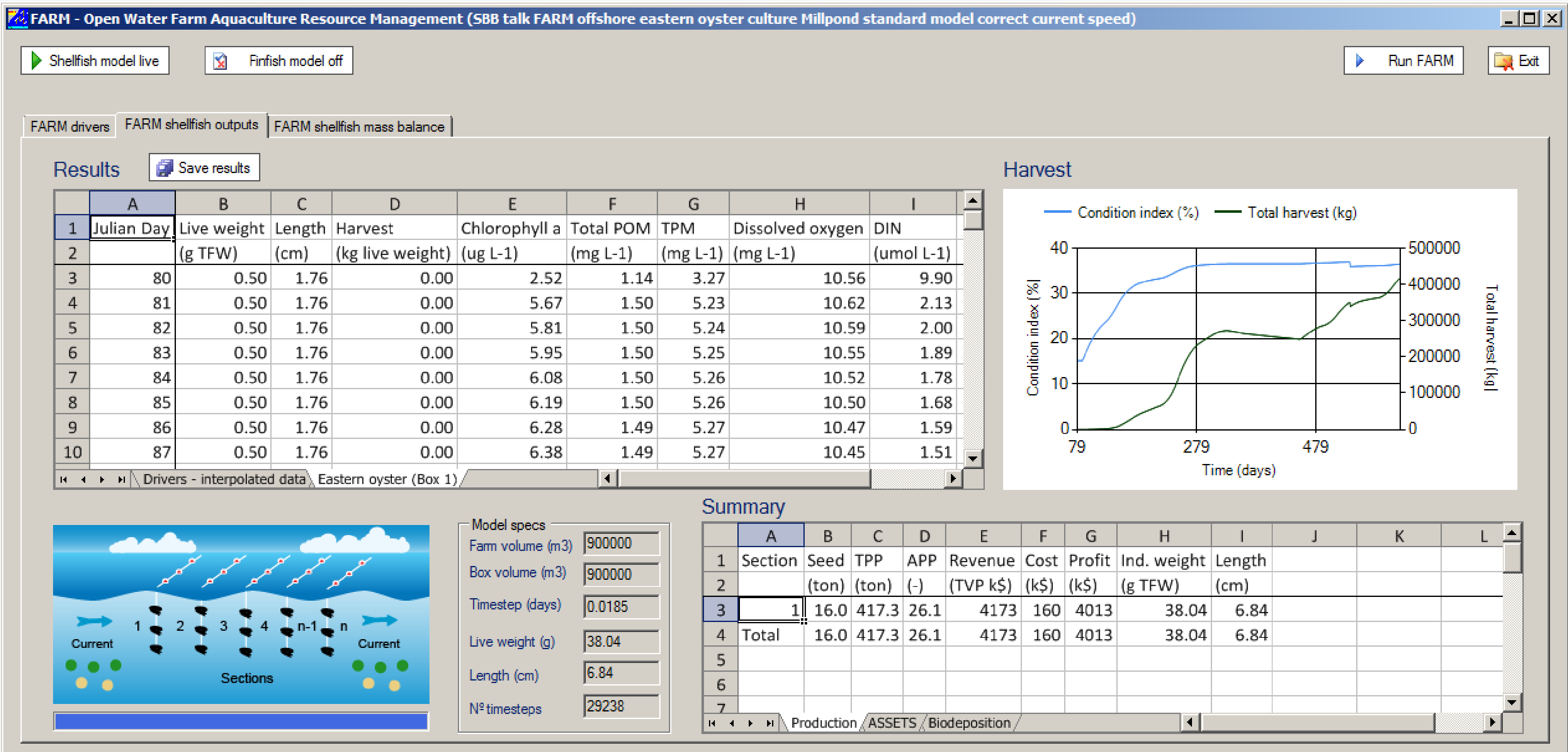
The FARM model in Long Island Sound

MODEL INPUTS		MODEL OUTPUTS
Farm layout:	**Environment:**	Weight (g)
Farm width	Water temperature	Length (cm)
Farm length	Current speed	Harvest (tons)
Farm depth	Chlorophyll concentration	Time to market size
Number sections	Particulate Organic Matter (POM)	Chlorophyll
Section volume	Total particulate matter (TPM)	POM
Total animals	Dissolved Oxygen (DO)	TPM
	Dissolved Inorganic Nitrogen (DIN)	Dissolved Oxygen
Shellfish Cultivation:		Dissolved Inorganic Nitrogen
		Total physical product (TPP)
Species	*Water Quality data inputs ideally at least once per month*	Average physical product (APP)
Cultivation period		Total revenue (TR)
Density		Total cost (TC)
Population		Profit

Although FARM was designed to be as simple as possible, i.e. as a screening model for farmers, it can be used for detailed simulations.

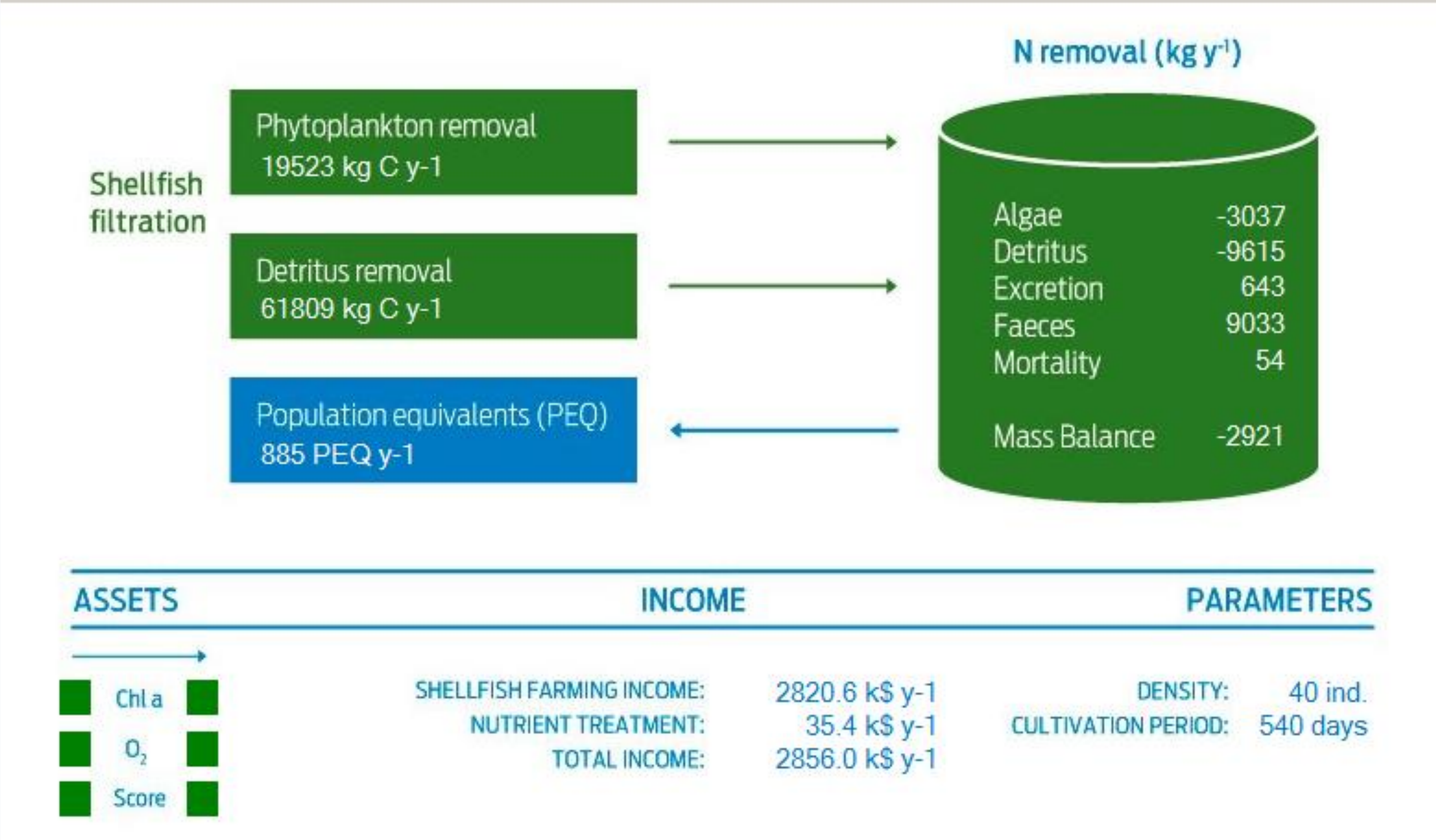
http://farmscale.org/

Scaling individual growth to FARM model: Application to a CT farm using water quality data for Long Island Sound



Predicted oyster harvest for this 50 acre farm in Connecticut is ~420 metric tons for a culture cycle. FARM also calculates the farm's ASSETS eutrophication score and biodeposition of particulates.

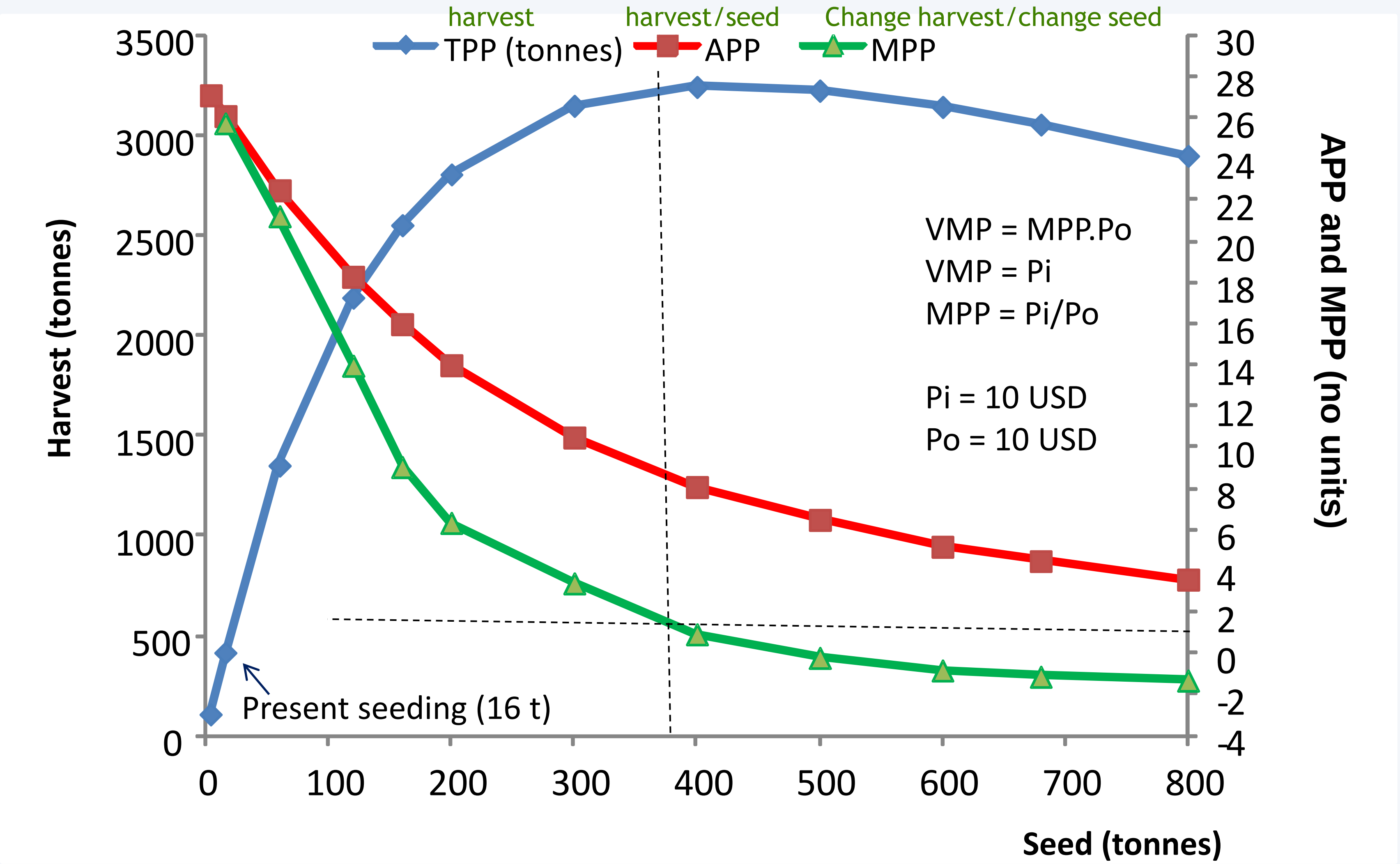
Long Island Sound oyster farm:
FARM model simulation for nutrient trading



Oyster cultivation in this 50 acre farm provides an ecosystem service equivalent to nutrient treatment for almost 900 people.

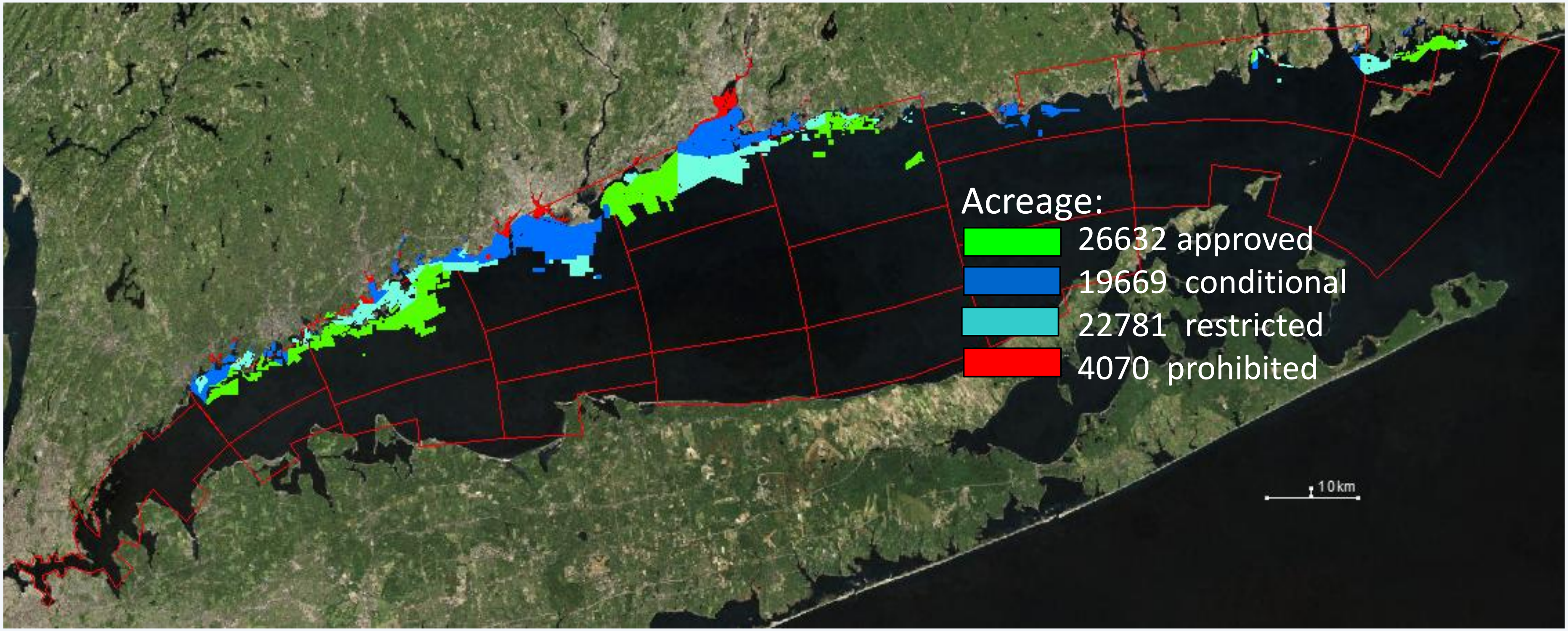
Economic Marginal analysis

FARM model – application to a CT farm in Long Island Sound



Marginal analysis for a farm allows the farmer to determine the optimum profit point - this is not usually the maximum harvest point.

Upscaling Site Specific Nitrogen Removal to Long Island Sound system



	Site specific (50 acre farm)	Long Island Sound (~45,000 acres conditional + approved)
PEQs (avoided cost)	885	800,000
m ton N/y	2.92	2,629
Avoided cost N treatment	$35.4K	$32,000K

Each year, oyster cultivation provides Long Island Sound with an ecosystem service equivalent to ~800,000 people, or ~ $32 million, in removing primary symptoms of eutrophication.

The Aquaculture Mapping Atlas
a resource for Connecticut's aquaculture industry and managers

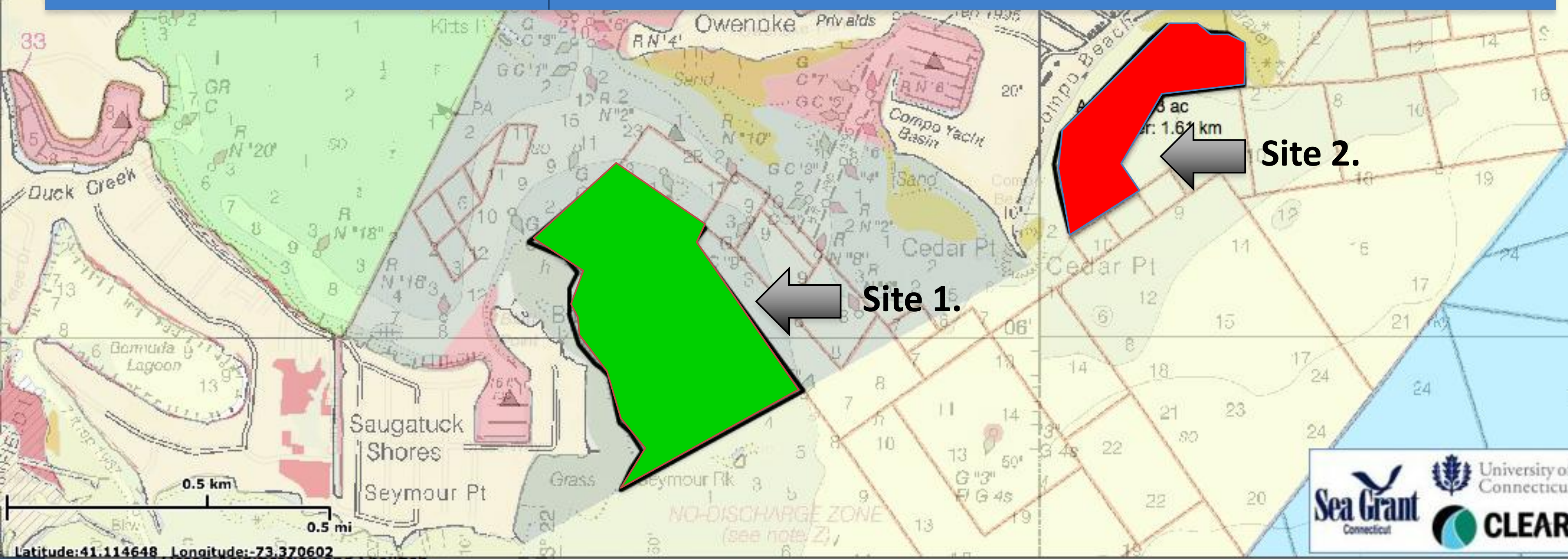
Simple | Street Map | Aerial Imagery | Topography

FARM model: coastal spatial planning & aquaculture siting

After exclusion of unsuitable areas via Shellfish Mapping Atlas, FARM model applied to evaluate shellfish growth in "suitable" areas

Oyster production (time to market size):

- (red) 4+ years = not feasible
- (yellow) 3 to <4 yrs= feasible, low growth
- (light green) 2 to <3 yrs= feasible, moderate growth
- (dark green) <2 years = feasible, high growth



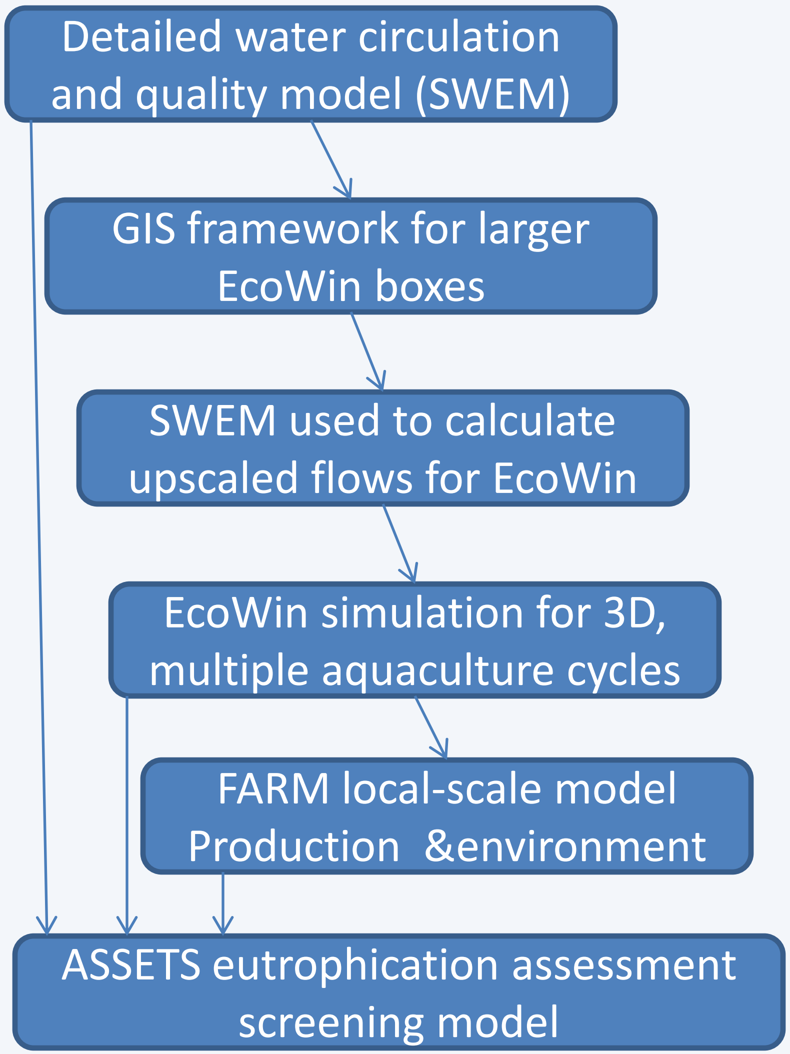
Summary

- An individual Eastern oyster growth model was developed, calibrated, and validated for Long Island Sound;
- The individual AquaShell model was incorporated in the FARM model to simulate the full production cycle and environmental effects of culture;
- Eastern oyster culture in one 50 acre farm provides a potential nutrient credit trading value of over $35K per year (~890 population-equivalents) with respect to eutrophication control. The potential income from nutrient trading would add ~1% to the annual revenue from oyster sales;
- Marginal analysis provides basis for optimization of eutrophication reduction and commercial viability of shellfish culture;
- A preliminary scaling to the whole of Long Island Sound suggests that it could provide a significant ecosystem service, of the order of ~800,000 PEQ per year; $32 milllion per year;
- Optimistic - highlights what we can do to provide domestic seafood, improve environment, create jobs.

http://farmscale.org/

Long Island Sound ecological modelling framework
Why do we need various models?

What



Why - Question and Scale

Accurate representation of water movement is critical for dynamics of food supply and waste, and for food depletion interactions across culture areas

Ecological carrying capacity model runs at a broader scale, 10+ years, many (100+) state variables. Less spatial detail is needed – typically from 10000+ cells to around 100 boxes

Preserve sufficient hydrodynamic detail to capture key timescales for phenomena of interest. Comparisons can be made for indicators such as residence time and salinity

Decadal scale allows 3-4 culture cycles, and also becomes interesting for economic models. System–scale analysis allows integrated approach to changes in stocking density

Farm scale modeling driven by outputs from EcoWin and SWEM, as well as measured data. Allows farmers to determine production, impact, and economic optimization

ASSETS provides a management level tool: it relies on results from other models for scenario analyis, and on measured data for baseline characterization

Complementary models address different questions – the combination is all important