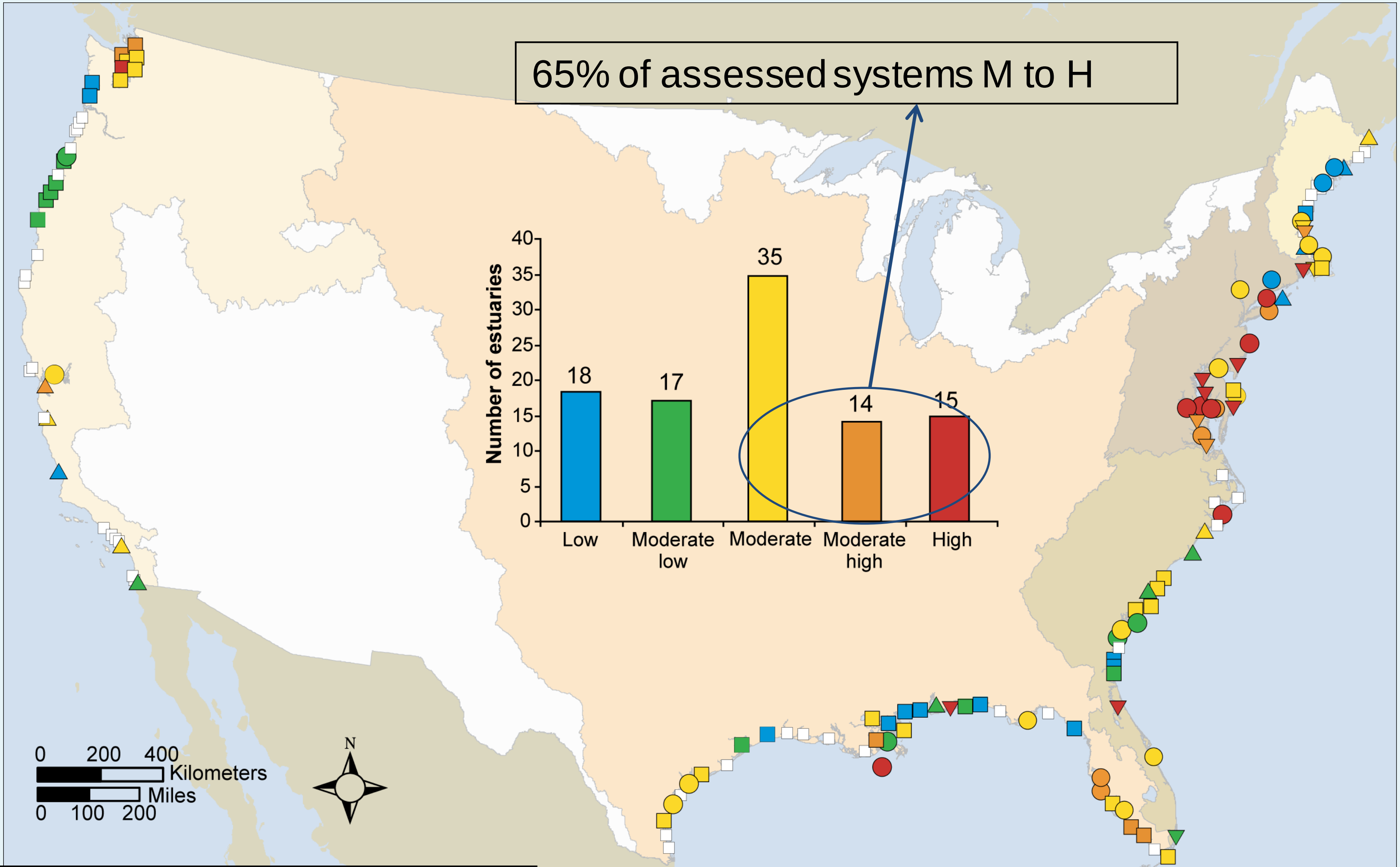
How important is nutrient removal through shellfish harvest in Long Island Sound and Great Bay Piscataqua Estuaries ?

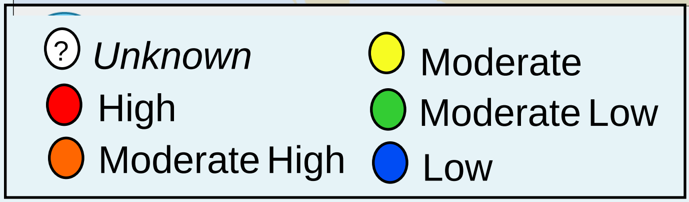
Suzanne Bricker[1] , Joao Ferreira[2], Changbo Zhu[2], Julie Rose[3], Eve Galimany[3], Gary Wikfors[3] , Camille Saurel[2], Robin Landeck Miller[4], James Wands[4], Katharine Wellman[5], Robert Rheault[6], Philip Trowbridge[7], Raymond Grizzle[8], Mark Tedesco[9], Jacob Steinberg[1], Annie Jacob[1]

[1]NOAA National Ocean Service, [2]Longline Environmental, Ltd., [3]NOAA National Marine Fisheries Service, [4]HydroQual, [5]Northern Economics, [6]East Coast Shellfish Growers Association, [7] Piscataqua Region Estuaries Partnership, [8]University of New Hampshir e, [9]EPA Long Island Sound Study

Coastal and Estuarine Research Federation 2013
Nutrient Theme Session SCI-004
Alternative nutrient management strategies: creative solutions to a complex problem
San Diego, CA, November 3-7, 2013

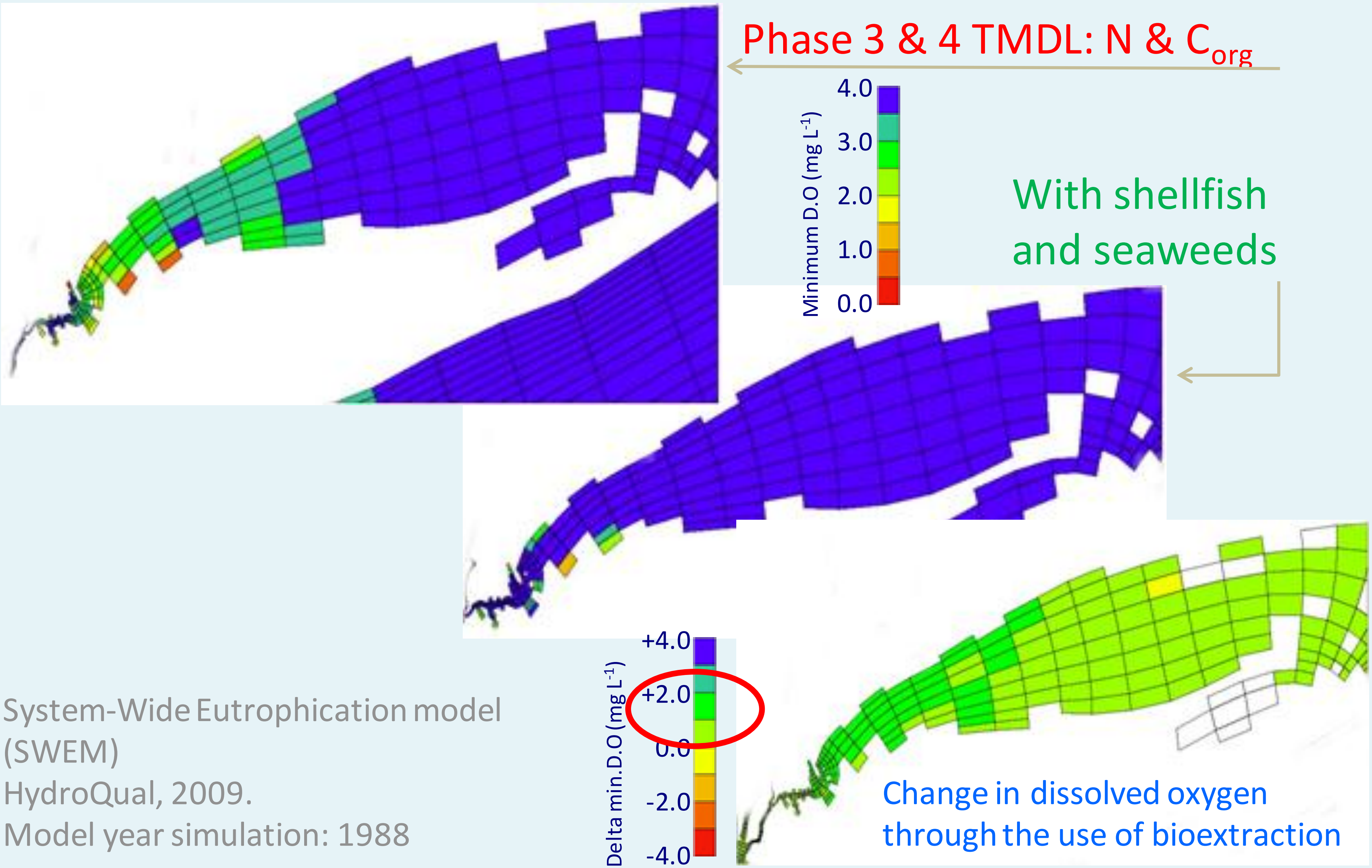
Eutrophic Condition in US Estuaries





Assessment of Estuarine Trophic Status (ASSETS)
http://www.eutro.us
http://www.eutro.org/register

Long Island Sound: Preliminary simulations of biomass harvesting show DO improvements



System-Wide Eutrophication model (SWEM)
HydroQual, 2009.
Model year simulation: 1988

Modelling eutrophication and shellfish aquaculture

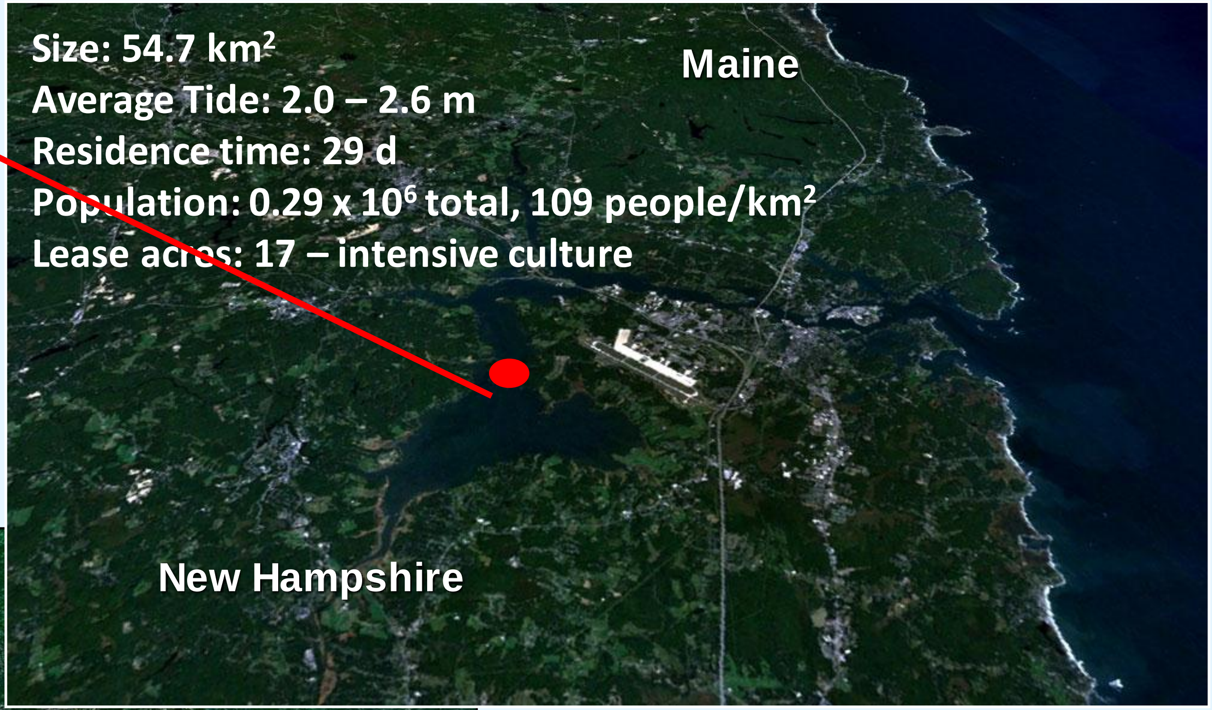
Objective: Estimate potential nutrient removal through shellfish aquaculture

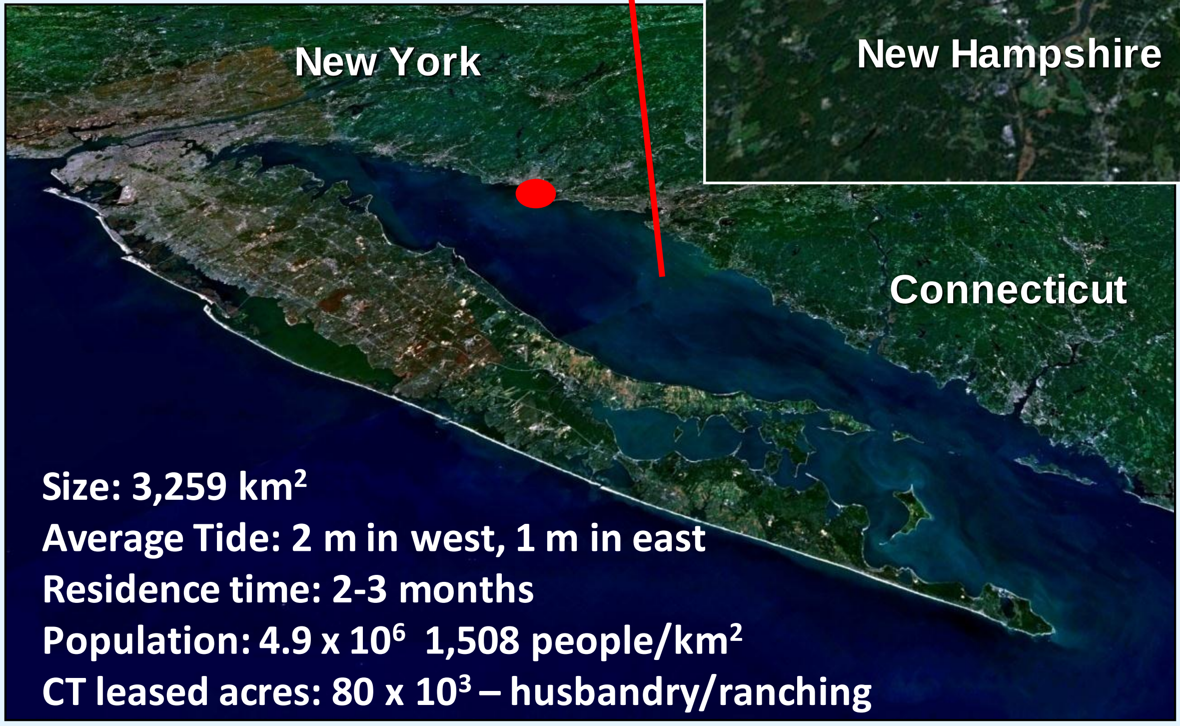
Sites: Long Island Sound (LIS)
Great Bay Piscataqua (GBP)

Today:

- LIS - Merging of high resolution 3D model and coarser scale ecosystem model, GBP - No 3D model
- Farmscale model simulation for sites in LIS and GBP
- Upscaling site specific results to system scale using 3D model in LIS, simpler approach in GBP

Study Sites:
Long Island Sound and Great Bay Piscataqua Estuaries



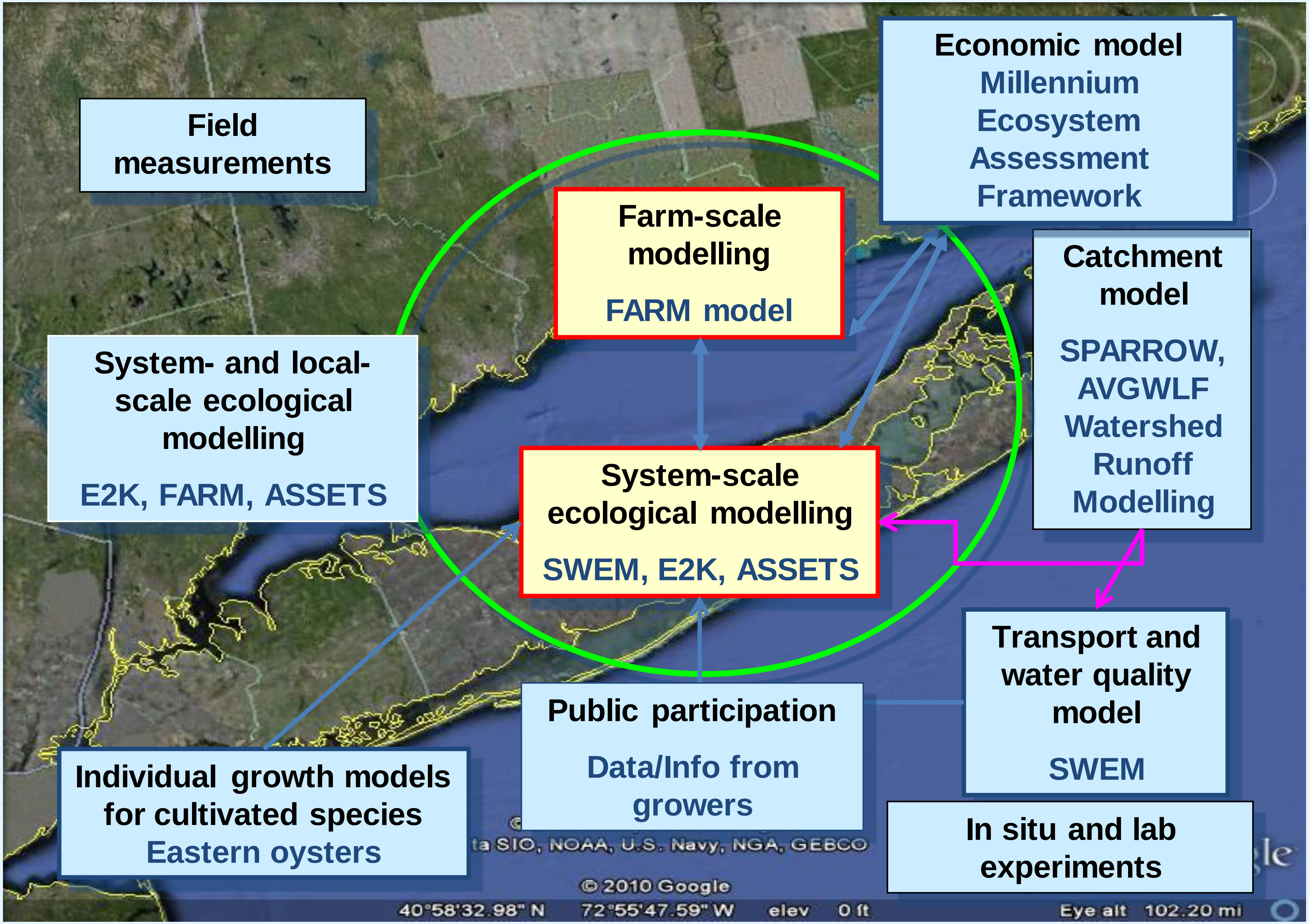


Bioextractors

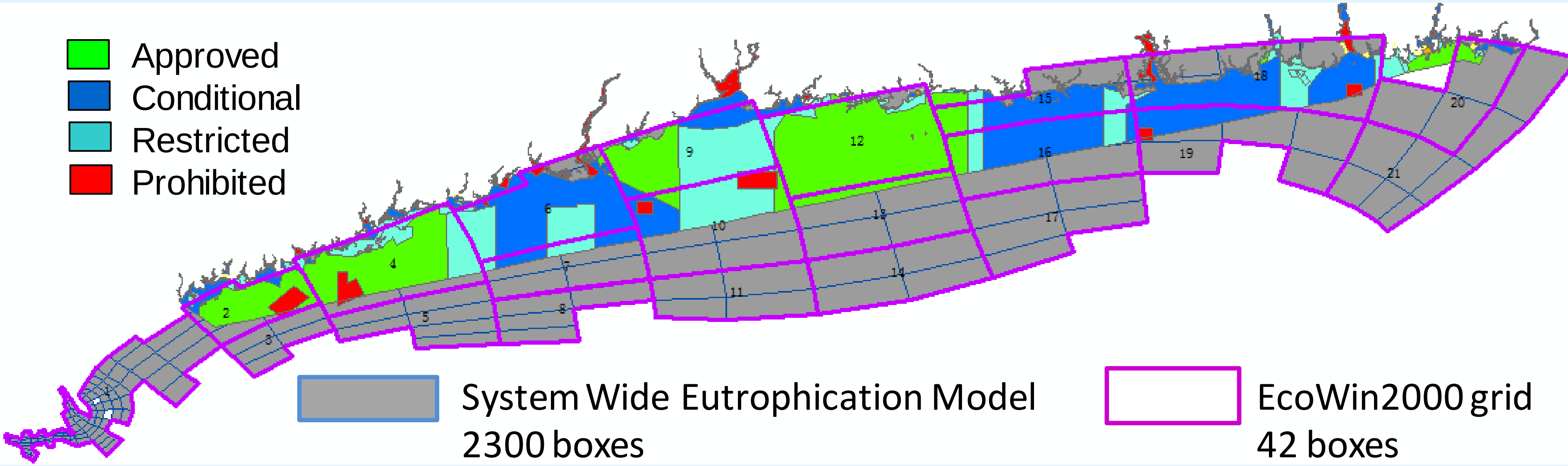
Eastern Oyster
Crassostrea virginica

Northern Quahog
Mercenaria mercenaria

The Regional Ecosystem Services Program Bioextraction Framework



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

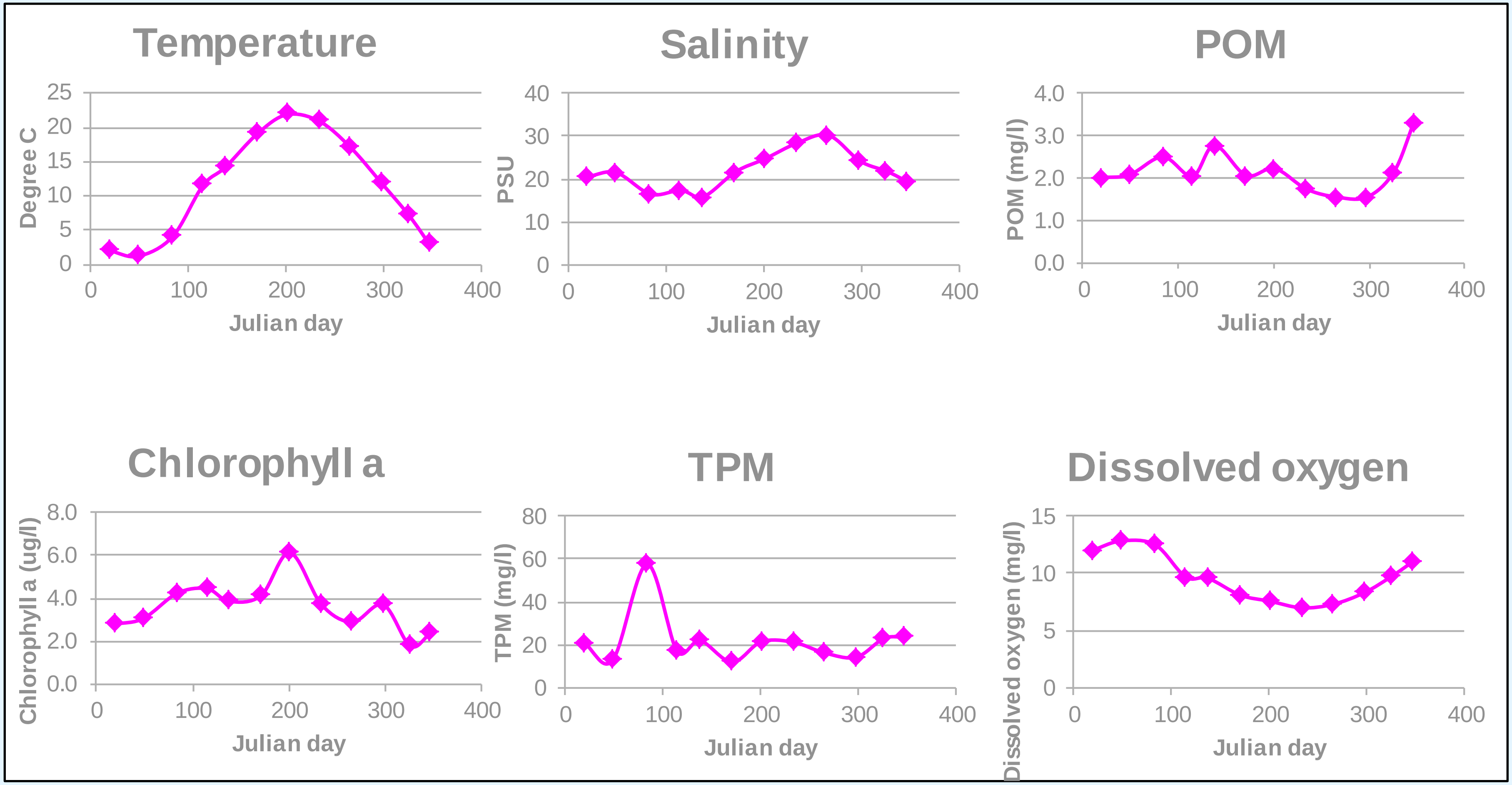


Model	Timeframe	Focus
System Wide Eutrophication Model (SWEM)	one year	water circulation, water quality
EcoWin2000 (E2K)	decadal	aquaculture, water quality, economics

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 (*no ecosystem model for GBP*)

Example environmental driver data for Farm Aquaculture Resource Management (FARM) model:

Great Bay Piscataqua Estuary



Data from station GRBAP, average 2005-2010

Application of the FARM model: Predicted harvest

One culture cycle

FARM - Onshore Farm Aquaculture Resource Management (FARM onshore Eastern oyster culture standard model)

Shellfish model live | Finfish model off | Run FARM | Exit

FARM drivers | FARM shellfish outputs | FARM shellfish mass balance

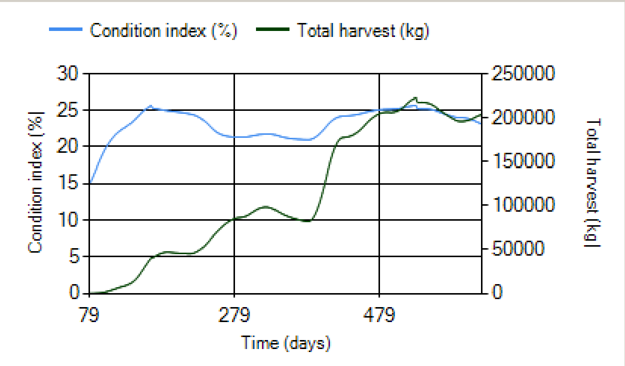
Results

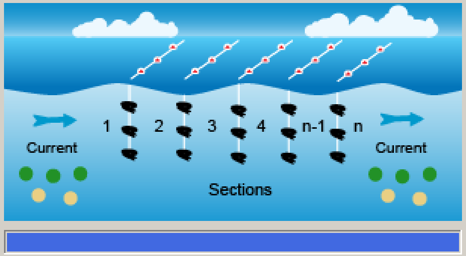
Save results

	A	B	C	D	E	F	G	H	I
1	Julian Day	Live weight	Length	Harvest	Chlorophyll a	Total POM	TPM	Dissolved oxygen	DIN
2		(g TFW)	(cm)	(kg live weight)	(ug L-1)	(mg L-1)	(mg L-1)	(mg L-1)	(umol L-1)
3	80	3.00	3.25	0.00	2.59	1.12	3.33	10.57	9.66
4	81	3.02	3.26	0.02	4.04	0.87	4.24	10.72	5.33
5	82	3.06	3.27	0.31	4.63	0.81	4.62	10.72	3.38
6	83	3.10	3.28	1.53	4.91	0.79	4.78	10.69	2.45
7	84	3.14	3.29	4.61	5.05	0.78	4.85	10.64	2.00
8	85	3.19	3.30	10.57	5.15	0.78	4.88	10.59	1.77
9	86	3.24	3.32	20.55	5.24	0.77	4.90	10.55	1.63
10	87	3.28	3.33	35.80	5.32	0.77	4.90	10.50	1.54

Drivers - interpolated data | Eastern oyster (Box 1)

Harvest





Model specs

Farm volume (m3)	900000
Box volume (m3)	900000
Timestep (days)	0.0417
Live weight (g)	25.07
Length (cm)	6.37
Nº timesteps	12960

Summary

	A	B	C	D	E	F	G	H	I
1	Section	Seed	TPP	APP	Revenue	Cost	Profit	Ind. weight	Length
2		(kg)	(kg)	(-)	(TVP $)	($)	($)	(g TFW)	(cm)
3	1	16000.0	203645.0	12.7	2036450	160000	1876450	25.07	6.37
4	Total	16000.0	203645.0	12.7	2036450	160000	1876450	25.07	6.37
5									
6									
7									

Production | ASSETS | Biodeposition

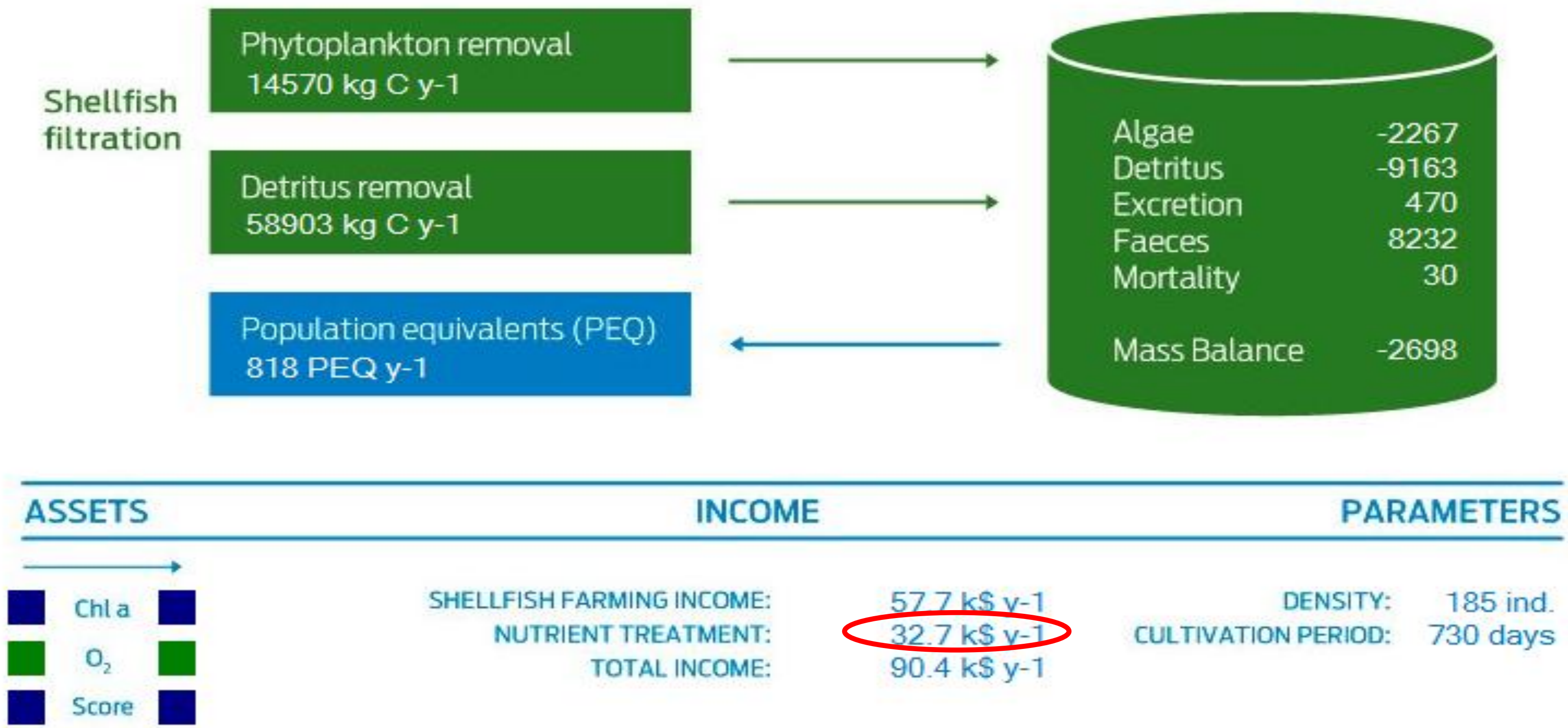
<u>LIS</u>: 50 acre farm, 540 d, 40 oysters m^{-2} => 200 tons

<u>GBP</u>: 4 acre farm, 730 d, 185 oysters m^{-2} => 192 tons

FARM also calculates the farm's ASSETS eutrophication score and biodeposition of particulates.

FARM model application: local scale results

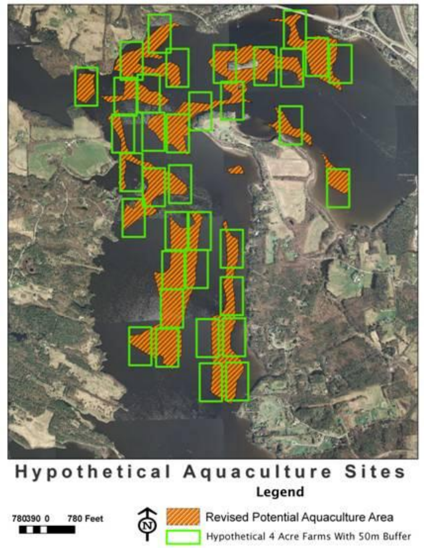
Example model output for Great Bay Piscataqua Estuary



			ecosystem service equivalent	
	Oyster harvest (mt acre $^{-1}$ cycle^{-1})	N removed* (mt acre^{-1} y^{-1})	PEQ (acre $^{-1}$ y^{-1})	Value of service ($ acre^{-1} y^{-1})
LIS	4	0.03	6	$250
GBP	48	0.67	204	$8,200

*Kellogg et al. 2013 reef restoration = 0.23 t acre^{-1} y-^{1}

Upscaling farmscale nitrogen removal to Great Bay Piscataqua Estuary



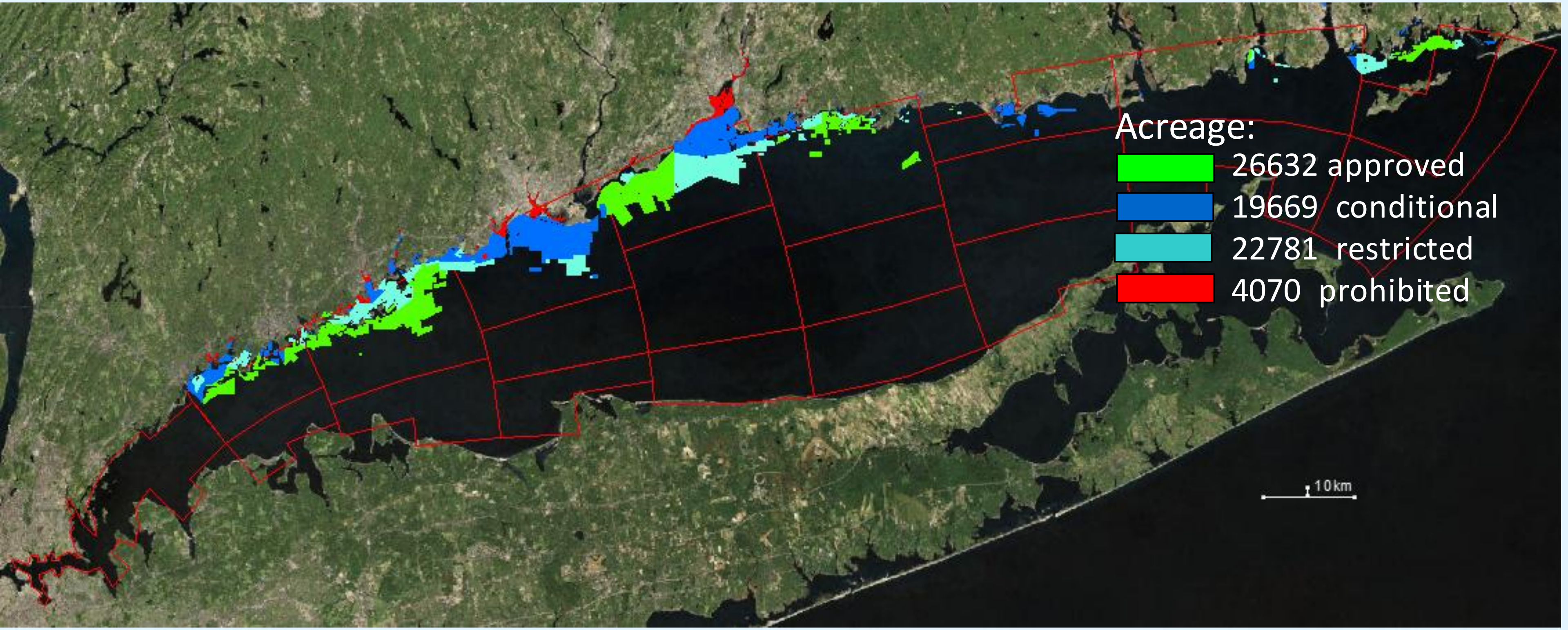
From: Nash and Elliott, 2012. 4 acre farms

Present and Potential Cultivated Acres and N Removal				
	Acres	N removal (ton y^{-1})	% total load removed+	PEQs
Simulated 4 acre farm	4	2.7	0.2	818
Present acres	17	11.5	0.9	3,477
Future acres (minimum)	56	37.8	3.1	11,452
Future acres (maximum)	92	62.1	5.1	18,814

Upscaled (max) value of ecosystem service = $565,000

total estimated input to GBP 1225 metric ton y^{-1}, 2009-2011, PREP

Upscaling farmscale nitrogen removal to Long Island Sound



	Farmscale (50 acres)	Present (conditional + approved) (45×10^3 acres)	Future (in discussion):
ton N removed	1.5	1,350	?
% total load	<1	3%	?
PEQs	468	>400,000	?

Upscaled value of ecosystem service = $12 x 10^6

Total load to LIS = 50×10^3 metric t y^{-1}, LIS Study

Summary

- Models – evaluate without financial, environmental, social, time costs of actual implementation
- LIS has more robust model framework ecosystem models (SWEM, EcoWin) local scale (FARM), stay tuned!
- Shellfish aquaculture is a promising complementary measure:
  - LIS – all conditional + approved areas will remove 3% of inputs
  - GBP – maximum expansion will remove 5% of inputs
- Complementary to land based measures (caveats include restrictions due to marine spatial planning issues)
- Cost effective compared to other BMPs (\$0 - \$150 $acre^{-1}$, Stevenson 2010), similar to N removal via reef restoration (Kellogg et al. 2013)
- Additionally, provides local seafood product, jobs, income for shellfish farmers