Applying the System Wide Eutrophication Model (SWEM) for a Preliminary Quantitative Evaluation of Biomass Harvesting as a Nutrient Control Strategy for Long Island Sound

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Robin Landeck Miller

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HydroQual

Environmental Engineers & Scientists

201• 529 • 5151
www.hydroqual.com

Presentation Goals

Long Island Sound Issues

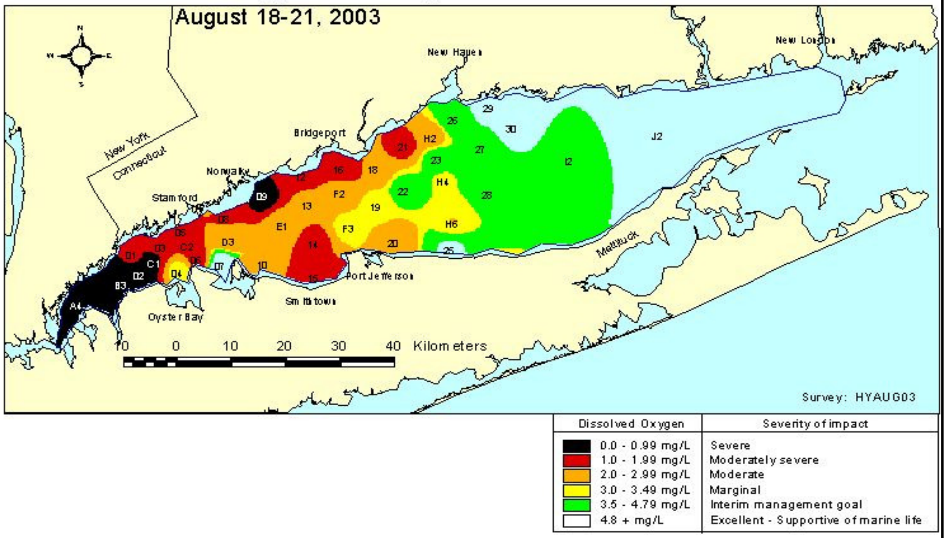
- Hypoxia
- Existing LIS N TMDL
- DO Standards & TMDL Compliance

Numerical Modeling

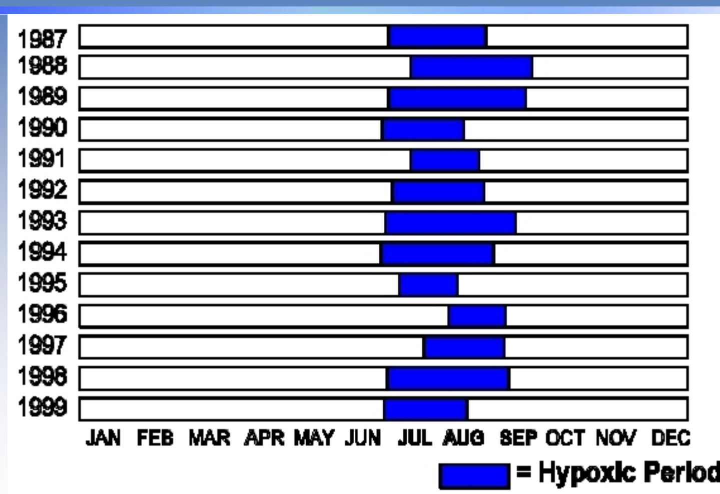
- Overview of SWEM
- Refinements to SWEM for Biomass Harvesting Evaluation
- Results for Biomass Harvesting vs. Additional Treatment Options
- Needed Next Steps

Spatial Extent of Hypoxia

Dissolved Oxygen in Long Island Sound Bottom Waters



Timing and Duration of LIS Hypoxia



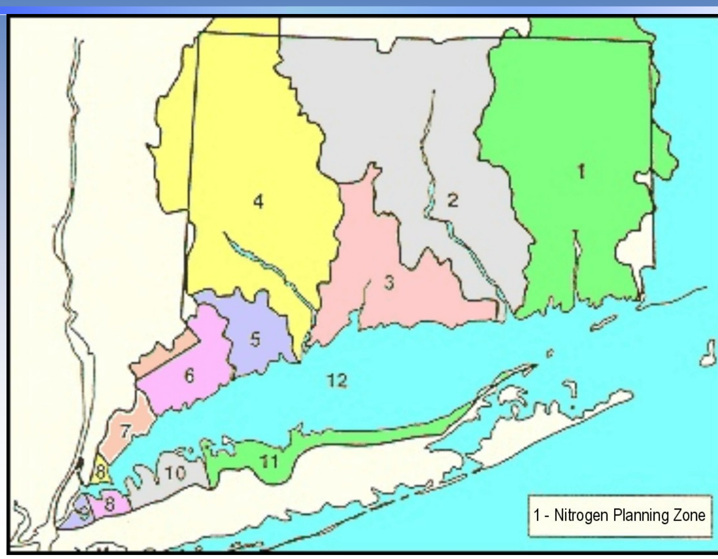
Data Sources: UCONN (1987-1990) CTDEP (1991-1999)

Long Island Sound TMDL Water Quality Modeling

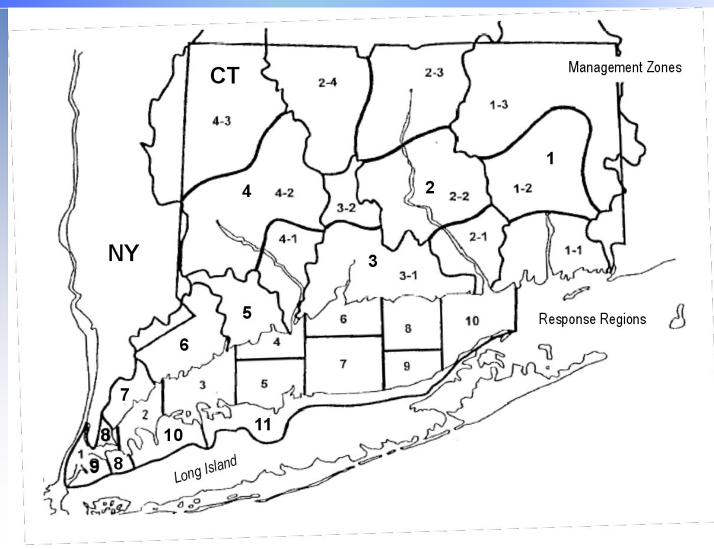
- Modeling Work Began in 1987
  - Water Quality – HydroQual
  - Hydrodynamics – NOAA/HydroQual
- Four Generations of Water Quality Models
  - LIS1.0 – 2 Dimensional/Steady-State
  - LIS2.0 – 2 Dimensional/Time-Varying
  - LIS3.0 – 3 Dimensional/Time-Varying
  - SWEM – 3 Dimensional/Time-Varying/Regional

Objective: Effect of Carbon and Nitrogen Inputs on Dissolved Oxygen Balance

Nutrient Management/Planning Zones



Management Zones and Response Regions



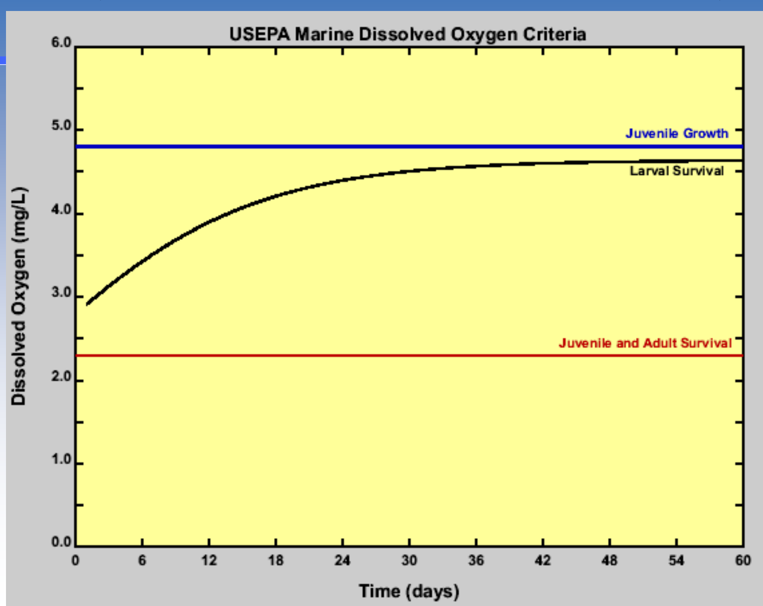
December 2000 Phase III and IV N TMDL Requirements

- 60% reduction to in-basin point source nitrogen
- 25% reduction to out-of-basin point source nitrogen
- 18% reduction to atmospheric nitrogen deposition
- 10% reduction to out-of-basin nonpoint source nitrogen
- 5.4% reduction to in-basin nonpoint source nitrogen
- Variable% concomitant TOC reductions

TMDL ENDPOINTS

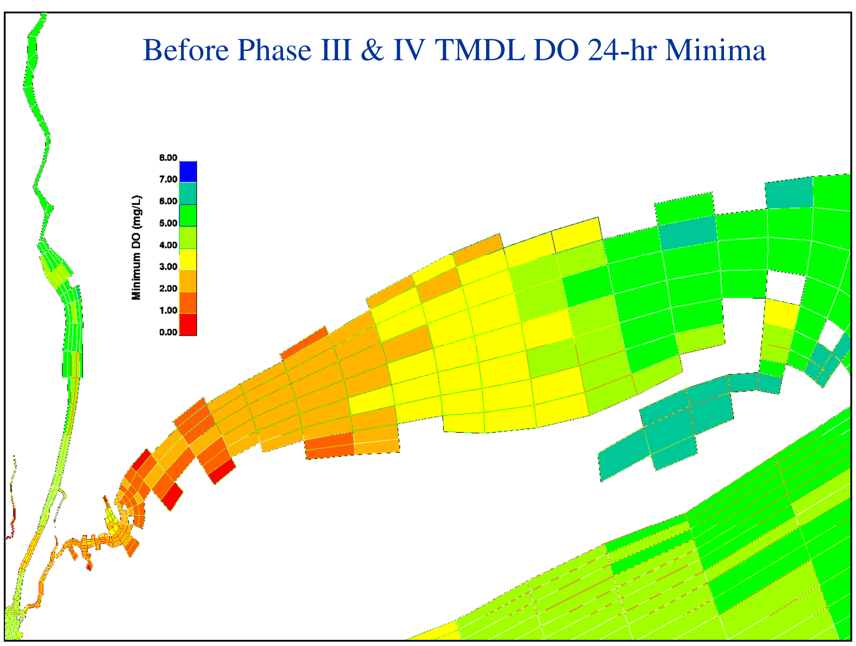
Dissolved Oxygen Targets	Federal marine DO criteria
	CT marine DO standards
	New NY marine DO standards
	Previous NY marine DO standards
Resource Targets	DO volume - days - % mortality
	DO volume - days - % biomass reduction

USEPA Marine Dissolved Oxygen Criteria (basis of current CT and NY Standards)



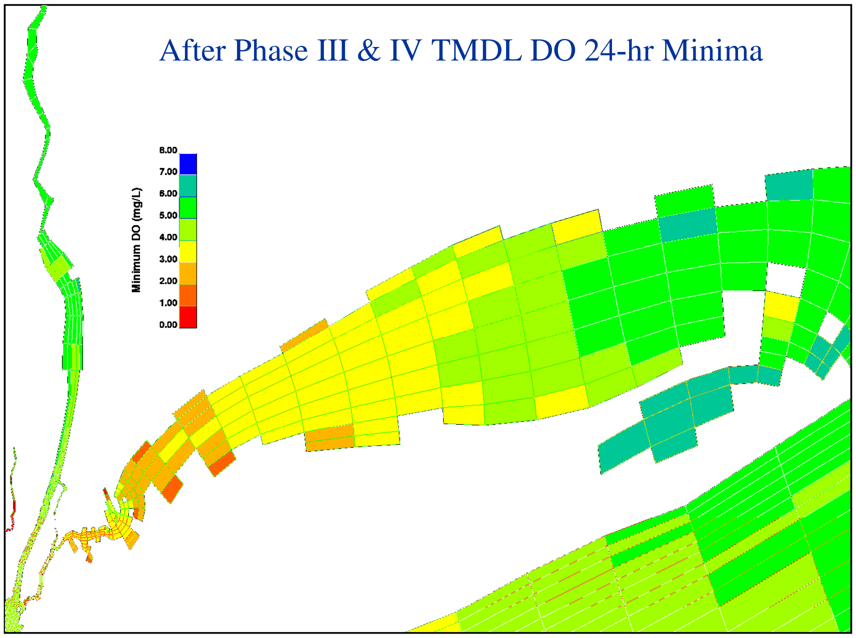
CT & NY DO Standards for Long Island Sound

TYPE	CT	NY
above pycnocline	never < 6.0 mg/L	NA
acute	never < 3.5 mg/L below pycnocline	never < 3.0 mg/L full depth
chronic	3.5 to 4.8 mg/L: 3.5–3.8 mg/L 5 days 3.8–4.3 mg/L 11 days 4.3– 4.8 mg/L 21 days below pycnocline	3.0 to 4.8 mg/L: Days set in 0.1 mg/L increments with new cohorts every 66 days full depth



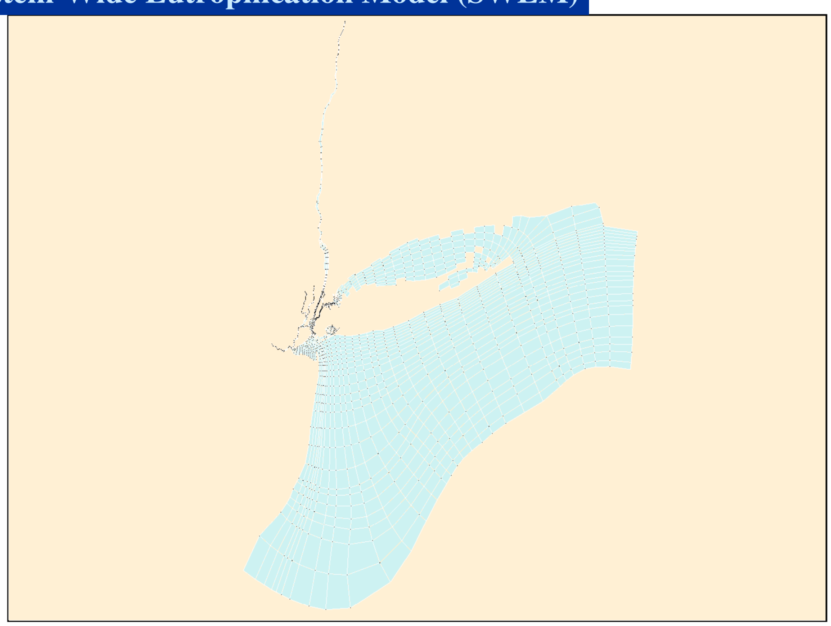
Baseline, 1988 Hydrodynamic Conditions
Minimum Daily Average Dissolved Oxygen

After Phase III & IV TMDL DO 24-hr Minima



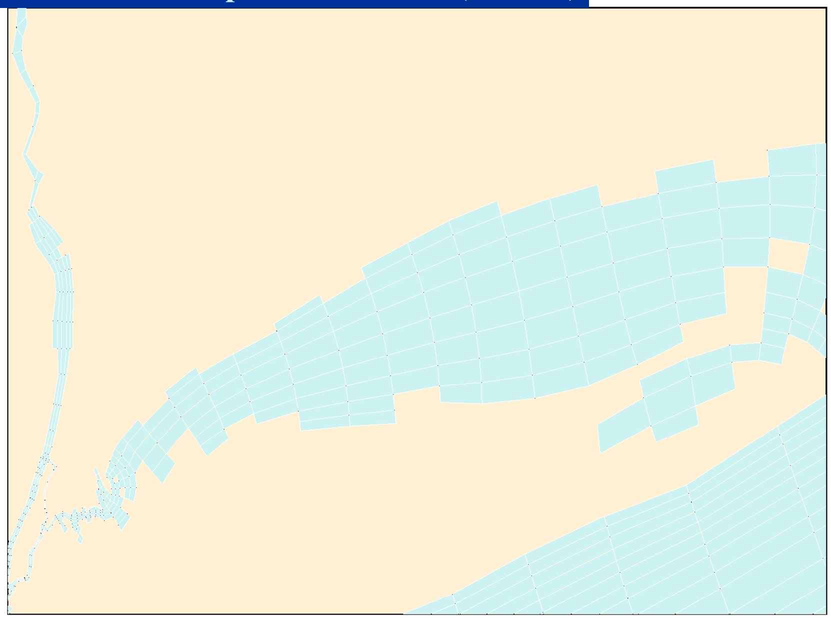
LIS Nitrgen TMDL, Phase IV + Carbon Adjustments, 1988 Hydrodynamic Conditions
Minimum Daily Average Dissolved Oxygen

System-Wide Eutrophication Model (SWEM)



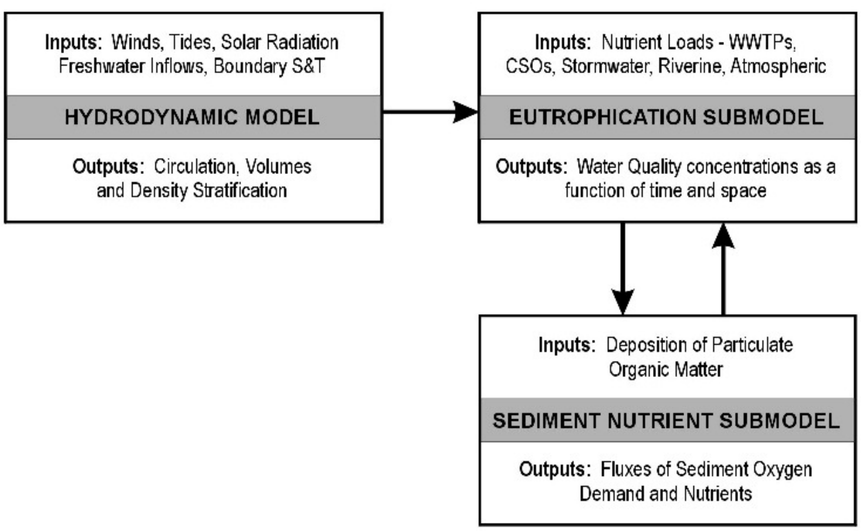
Full SWEM Model Grid

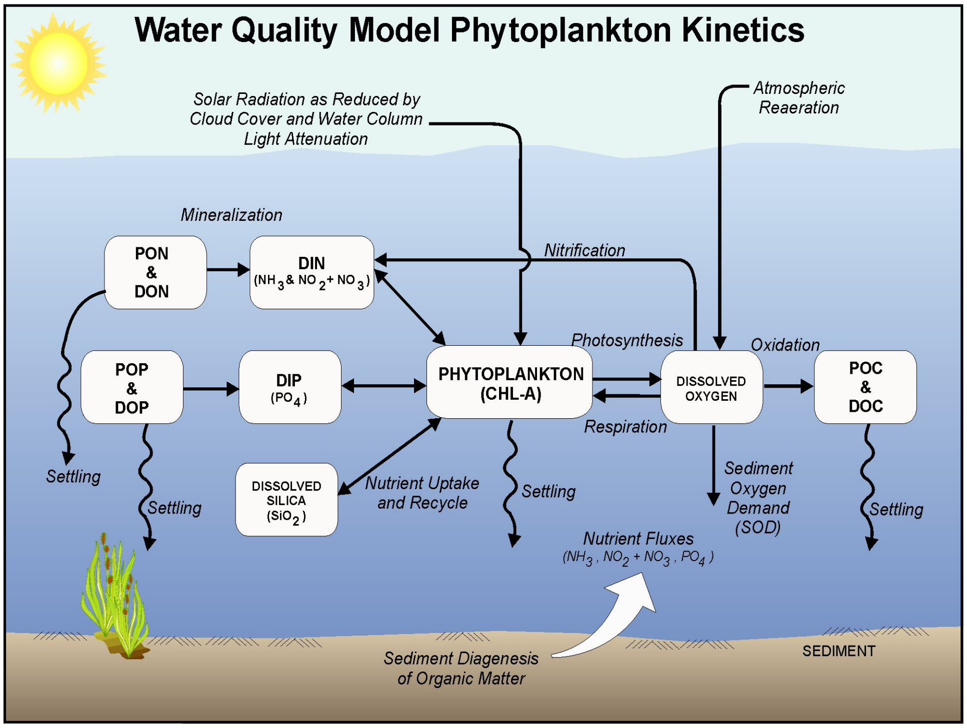
System-Wide Eutrophication Model (SWEM)



Long Island Sound Portion of the SWEM Model Grid

SWEM Conceptual Model





Representing Shellfish Functioning in SWEM

- SWEM settling terms for PON, POP, phytoplankton, & POC increased based on shellfish biomass density and filtering rate

Filtering rate = 0.033 m^{3}/g^{1} shellfish C/d^{1} at $20^{o}C$; lower than CBEMP oyster modeling

Biomass density = 500 g C/m^{2} [A]

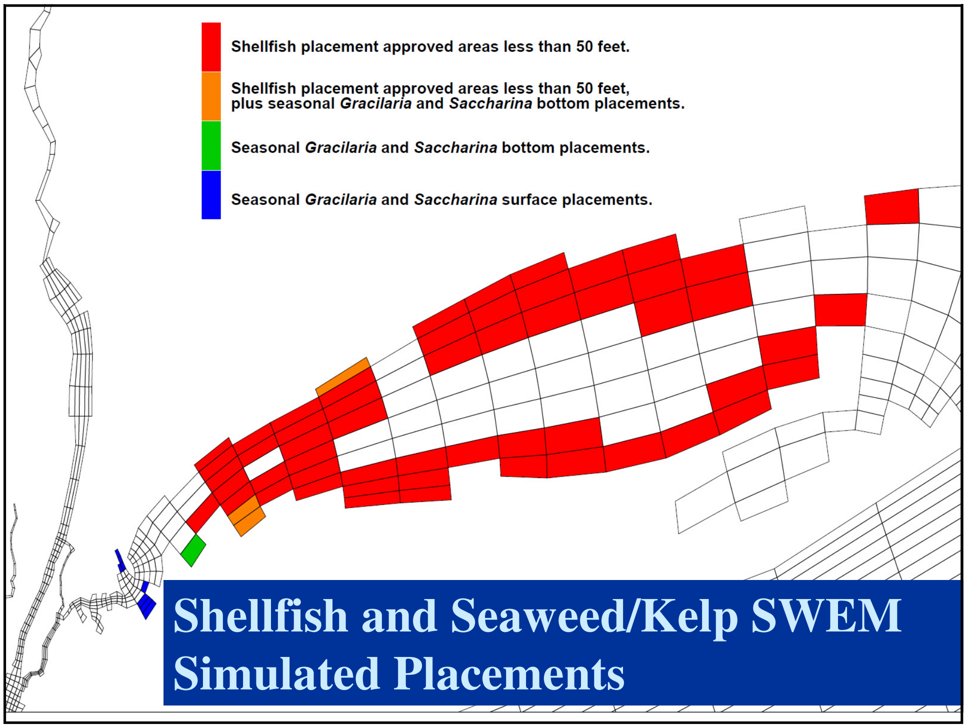
- SWEM assumes material filtered by shellfish is 75% assimilated and 25% released to sediment bed and recycled[B]
- SWEM assumes assimilated material is removed when shellfish are harvested

Representing Seaweed/Kelp in SWEM

- Loss term added to SWEM for seaweed/kelp uptake of dissolved inorganic nutrients
- Loss term based on expected seaweed/kelp density and literature stoichiometry (5% N, 1%P)[C,D]
- Near bottom (2000 g DW m^2) and suspended long-line (300 g DW m2) systems simulated
- *Saccharina* (formerly *Laminaria*) (September - May) and *Gracilaria* (May – November) target species

Shellfish & Seaweed/Kelp Placement in SWEM

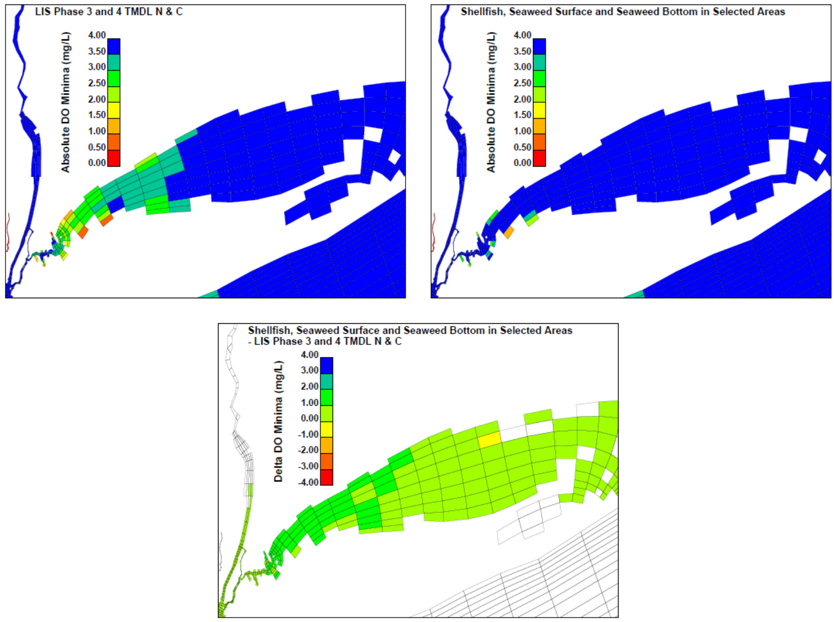
- Shellfish placement restricted to currently approved waters
- Placements restricted to depths less than 50 ft
- Seaweed/kelp placement constrained by available light – 300 uE/m^2/s reaching 6 ft above bottom at least 70% of time during daylight hours



Shellfish and Seaweed/Kelp SWEM Simulated Placements

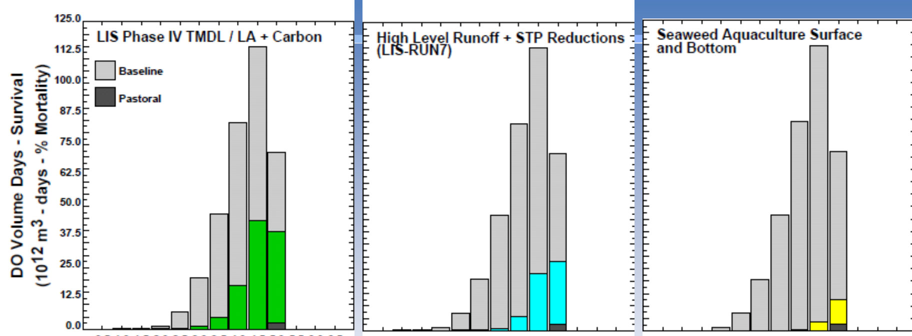
Shellfish & Seaweed/Kelp Placement in SWEM

	LIS Surface Area (km^2)	LIS Surface Area (~ football fields)
Shellfish	606.2	113,274
Seaweed/kelp Near bottom	22.7	4242
Seaweed/kelp Long-lines	10.3	1923



Absolute DO Minima, 1988 Hydrodynamic Conditions

Mortality – Volume - Days



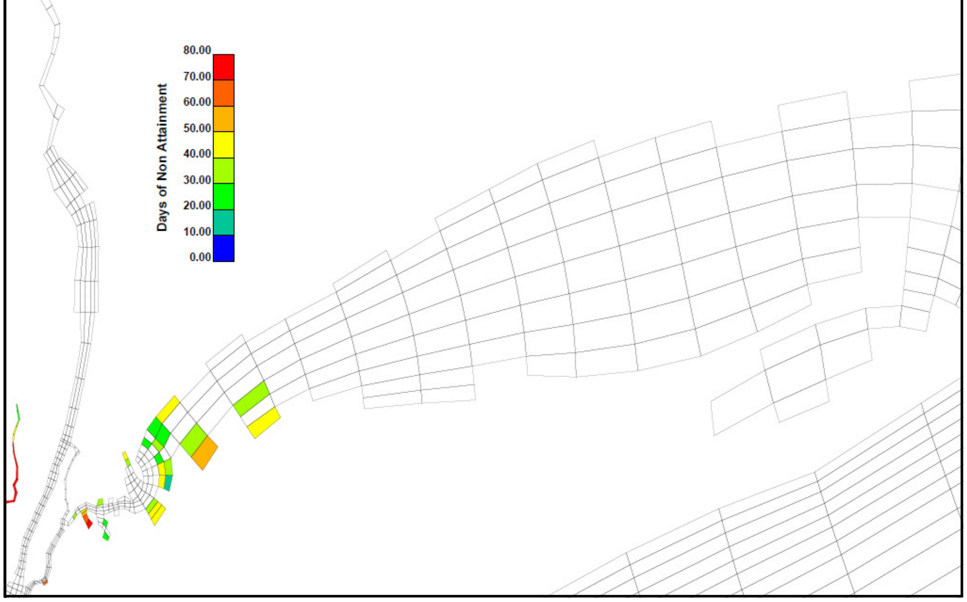
2000 TMDL

2000 TMDL plus additional high level point & nonpoint N reductions

2000 TMDL plus shellfish & seaweed/ kelp bioextraction

Bioextraction outperforms additional high level loading reductions!

Calculated remaining days of nonattainment of NY chronic standard
Greatly reduced with bioextraction & 2000 TMDL



Conclusions

- Shellfish and seaweed/kelp bioextractive technologies are promising alternatives for DO management in LIS.
- Preliminary SWEM quantitative & realistic evaluation successful in demonstrating bioextractive potential.
- Implementation of shellfish and seaweed/kelp bioextractive technologies is LIS should lead to up to 2 mg/L improvement in DO minima, reductions in living marine resources impairments & full attainment of NY chronic criteria in LIS Response Regions 3 – 10
- Further evaluation warranted

Room for Improving the Analysis

- Incorporation of more robust/mechanistic shellfish model into SWEM (e.g., CBEMP). Include multiple shellfish species, particle concentration & previous filtration dependencies on filtration rate, growth, respiration & mortality effects, etc.
- Development of mechanistic seaweed/kelp kinetics in SWEM. Detail analogous to SWEM phytoplankton modeling. Include growth, decomposition, etc.
- Revisit conservative assumptions (e.g. 10% fraction dry weight for *Saccharina* and *Gracilaria,* shellfish filtration rate, etc.)

Footnotes

- [A]Shellfish density based on Newell 1990 as cited in Newell 1998 for a harvest upper limit for a productive bottom mussel site in Maine
- [B]Rates of shellfish assimilation efficiency based on Tenore and Dunstan 1973; Valente and Epifanio 1981; Langefoss and Maurer 1975 as cited in Powell et al. 1992 and Cerco and Noel 2007; and Newell et al. 1998.
- [C]Stoichiometry for seaweed/kelp based on Gerard 1992, Merrill et al. 1992, He et al. 2008, Carmona et al. 2006, Chung et al. 2002, Kim et al. 2007.
- [D]Density for seaweed/kelp near bottom systems based on Buck and Buchholz 2004 and Egan and Yarish 1990 in Merrill et al.1992. Density for seaweed/kelp long-line systems based on Duarte et al. 2003.

Technical report with full citations to be submitted to EPA LISS

Acknowledgements

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- Mark Tedesco
- Charles Yarish
- Gary Wikfors