Getting the N Out

A Search for Bioremediation Alternatives to Sewage Treatment

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The Problem:

The Massachusetts Estuaries Program (MEP) has confirmed that high nitrogen loading, especially from onsite septic systems, is the primary driver of the degraded environmental quality observed in many of the state's estuaries.

Local municipalities have been tasked with developing plans to meet the target nitrogen reductions.

Algal overgrowth courtesy of excess nitrogen
-Foot by Karney

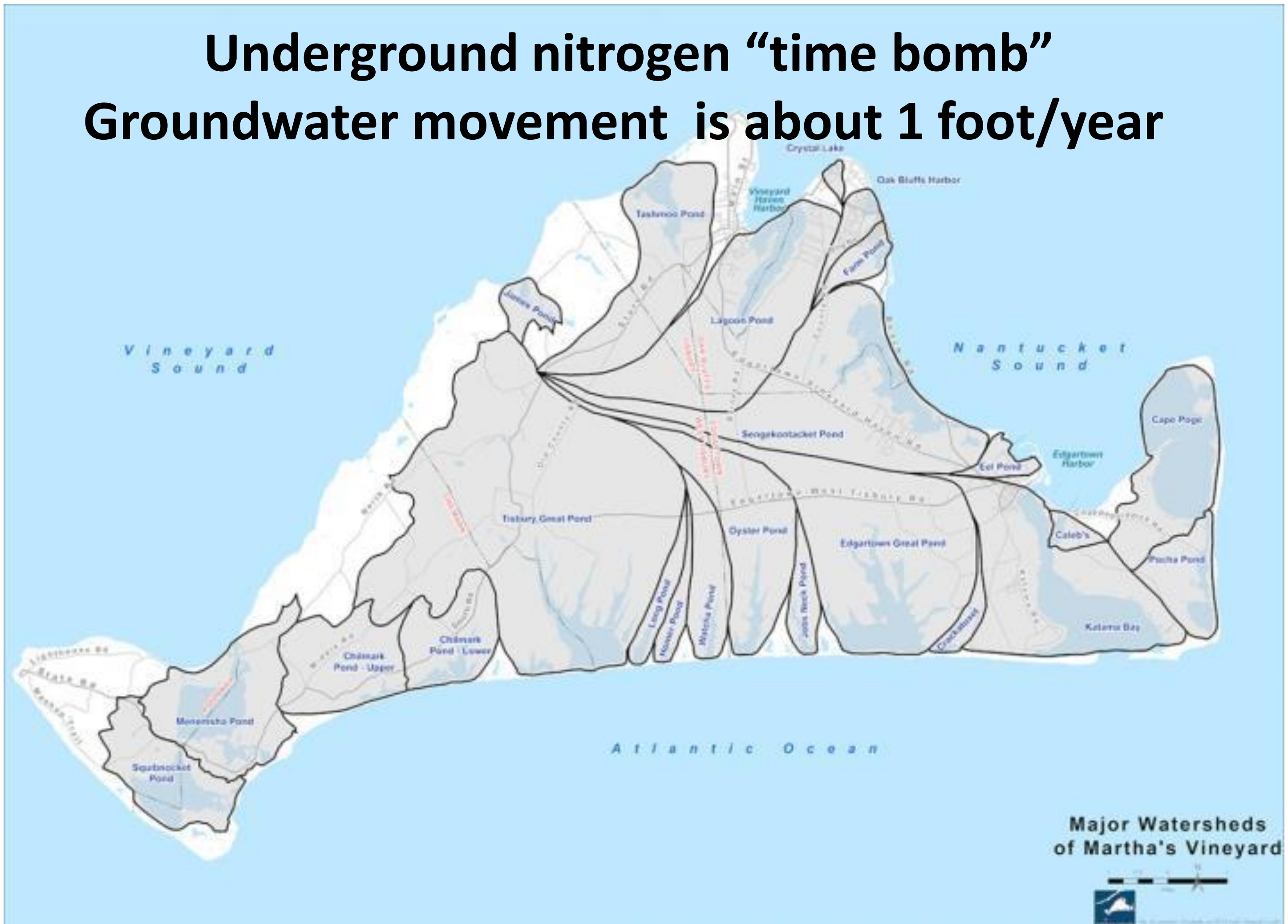
Conventional tertiary sewage treatment systems are the likely means to that end. However, because of the high costs for construction and operation of these systems, municipalities are seeking more affordable alternatives.

$ticker $hock !

“The overall cost estimate to bring nitrogen to acceptable levels in Cape waters is between six and eight billion dollars, according to Mr. Niedzwiecki.”

Martha’s Vineyard Times- November 25, 2014

Further, because much of the problematic nitrogen enters the embayments though slow moving groundwater plumes, the damaging impacts of nitrogen will continue for years even after the installation of treatment systems.



Potential bioremediation options under investigation

Pathways for bioremediation of nitrogen

1) **<u>Sequestration</u> of N in organism's tissue and removal through harvest**
   - Easier to quantify, concrete values, and more likely to be accepted by regulators
   - N removal is modest
2) **<u>Dentrification</u> to nitrogen gas by bacterial action**
   - Generally much higher N removal
   - Difficult to quantify, varies by site and season, unlikely to be accepted by regulators
3) **<u>Deep burial</u> in shellfish beds**

Lagoon Pond (583 acres)

Massachusetts Estuary Project report:

- **a reduction of 16.18 kg/N/day (about 6 million g/N/year) will be required to restore the Lagoon to a healthy state.**

Oyster Harvest

Potential:

Nitrogen content of an adult cultured oyster is ~0.4g/oyster

Challenge:

Target N reduction would require an annual harvest of about 15 million adult oysters

Limitations:

- Even a small private oyster farm was not allowed
- Public funding to culture oysters to market size unlikely

Oyster Reefs

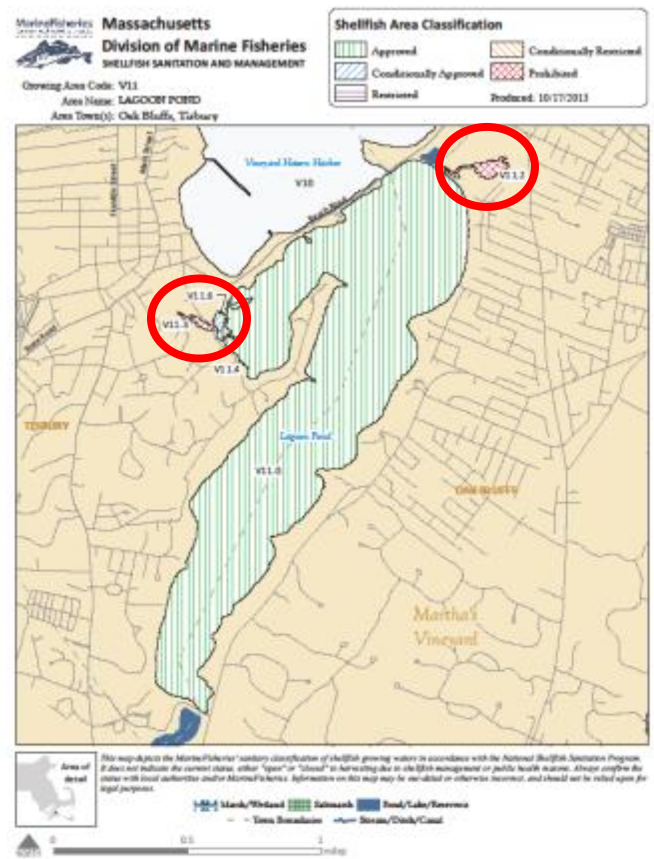
Potential: N removal via denitrification in an oyster reef can be substantial.

Challenge: To establish oyster reefs in the Lagoon where they do not naturally occur

Oyster Reefs

Limitations:

- High predation by oyster drills in high salinity water
- Reefs cannot be developed in areas where other commercial shellfish exist
- Reefs cannot be developed in waters closed to harvest



Ribbed mussels, *Geukensia demissa*

Potential:

- Excellent filtering capacities
- Can be deployed in closed areas most in need of remediation
- May create conditions favorable for denitrification

Challenge:

To develop aquaculture methods that will enable deployment of numbers higher than natural populations.

Ribbed Mussels

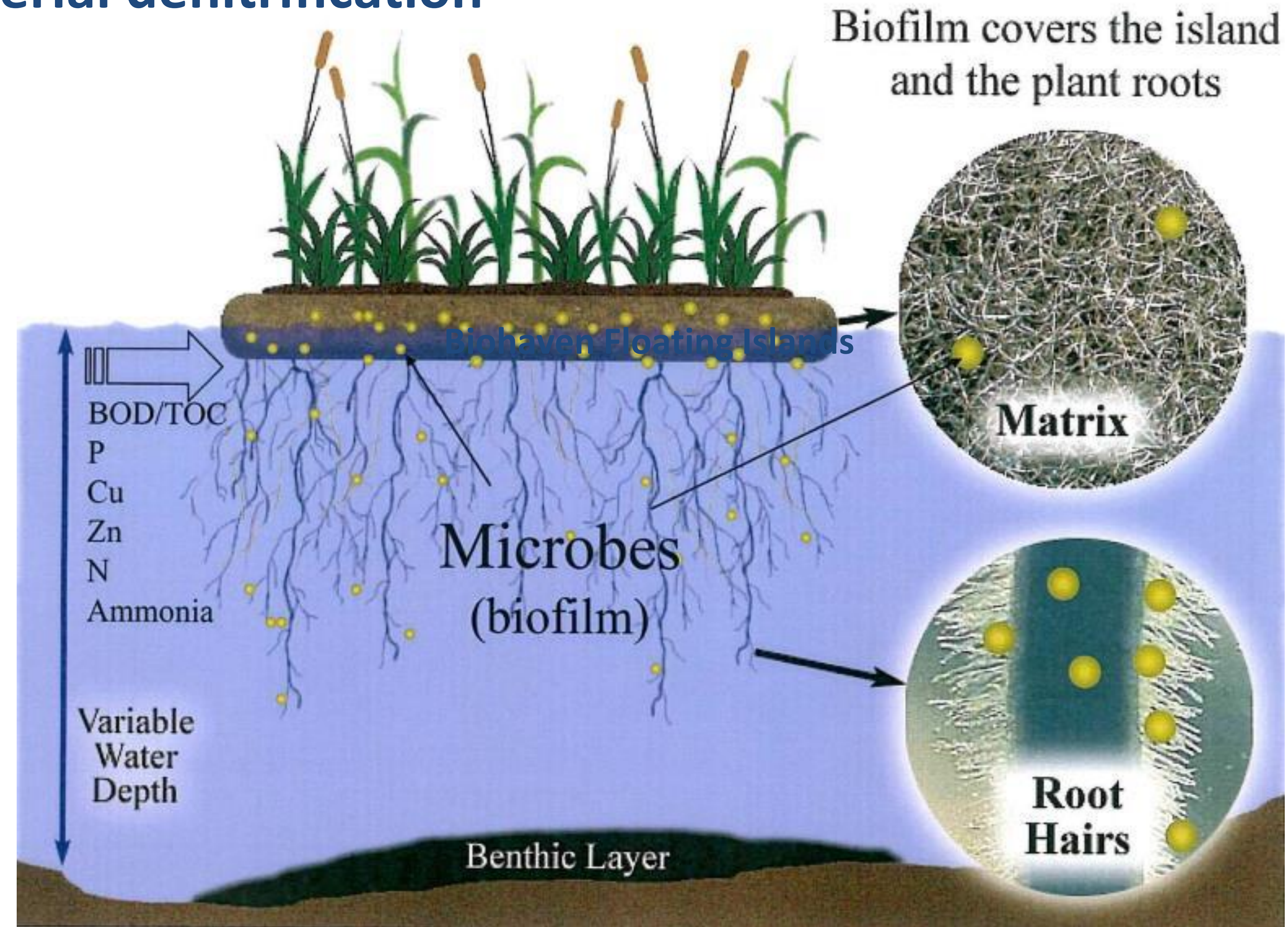
Limitations: Difficult to spawn

Healthy *Geukensia* larva

Dying from *Pseudomonas* bacteria

Biohaven® Floating Islands

Potential: Matrix provides extensive surface area for bacterial denitrification



Biohaven® Floating Islands

Challenge: Can they be deployed/function in marine waters?

Limitations:

- Limited to protected sites
- Will marine biofouling lessen/eliminate matrix surface area?

Investigation of vertically suspended matrix

Tunicate fouling in high salinity

Possible culture platform for mussels

Potential of Phragmites Harvest for Nitrogen Removal

Potential

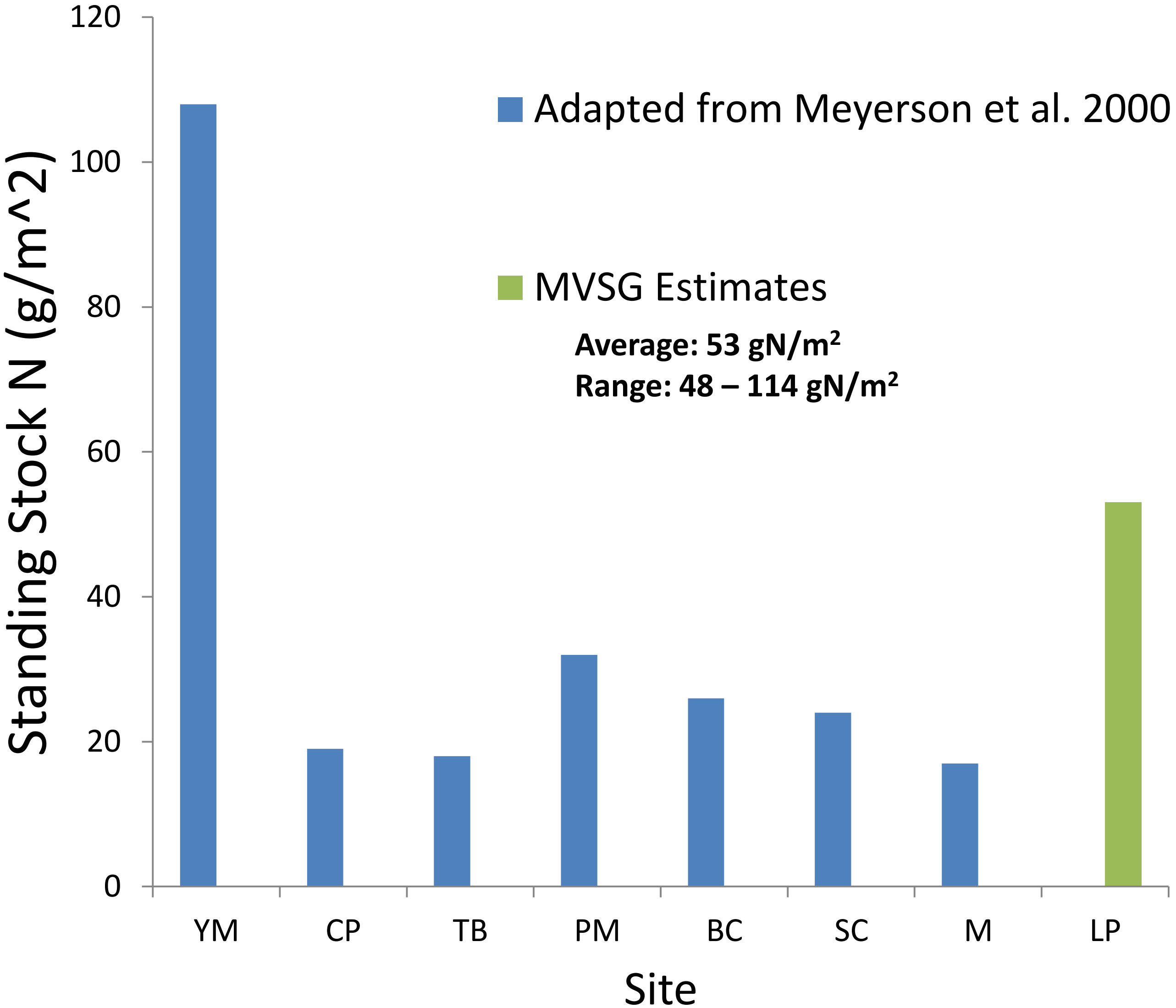
- High N uptake "green sponge"
- Invasive species
  - should make it easy to get permits
- Make Lemonade!!
  - Livestock feed
  - Compost
  - Biochar


Joe's goats liked the Phrag!

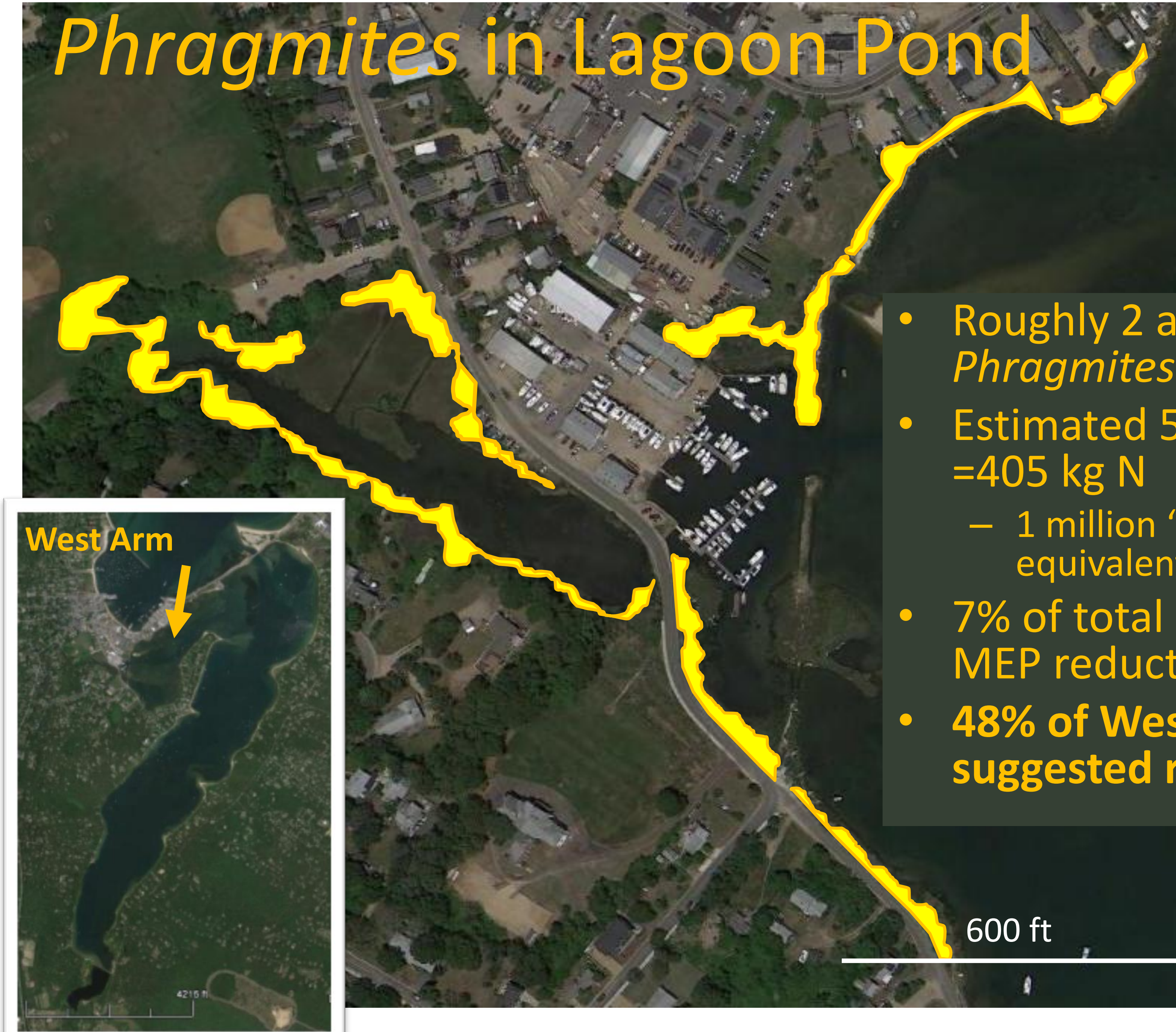
Challenges

- Exact impact on system nitrogen cycle unclear at this time
- Logistics of wetland harvest
- Access to private property
- Widespread desire to use herbicides

Estimate of Nitrogen Aboveground



Phragmites in Lagoon Pond



- Roughly 2 acres of *Phragmites*
- Estimated 50gN/m^2 =405 kg N
  - 1 million "oyster equivalents"
- 7% of total Lagoon Pond MEP reduction
- **48% of West Arm suggested reduction**

Living Shorelines

Potential:

- **Increased acreage of *Spartina* marsh will increase denitrification**
- **Marsh N demand usually exceeds N input** (Valiela & Teal 1979)
- **Increased natural habitat for ribbed mussels**

Challenge:

To determine if DELSI methodology is transferable to local environments

Living Shorelines

Limitations:

- DELSI method may not work in waters with limited suspended sediment
- Substantial increases in *Spartina* acreage costly

Summary & Conclusions

- **Sewage treatment likely required to meet N reductions**

- **Bioremediation can definitely be a tool in the tool box**

- **Much more research is needed to understand and quantify N removal by natural systems** (i.e. *Phragmites &* saltmarshes)

- **Advances in applied technologies** (aquaculture, Floating Islands, etc) **hold potential to significantly enhance natural bioremediation processes**

- **Restoration of natural systems provides ecological benefits beyond N mitigation**

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