Development of Subaqueous Soil Interpretations

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Specific Subaqueous Soil Resource Based Interpretations

- Seagrass Restoration
- Crab Habitat
- Clam Stocking
- Sustainable Production Clam, Oyster, and Scallop
- Nutrient Reduction
- Pathogens Pfesteria Cyst Residence Sites
- Benthic Preservation Site Identification
- Wildlife Management
- Habitat Protection for Horseshoe Crab and Diamondback Terrapin

- Dredging Island Creation
- Tidal Marsh Protection and Creation
- Bathymetric Map
- Navigational Channel Creation/Maintenance
- Effects of Dredging on Benthic Ecology
- Off Site Disposal of Dredge Spoil
- Acid-Sulfate Weathering Hazards
- Dune Maintenance and Replenishment
- Carbon Sequestration
Subaqueous Soil Interpretations

- Upland placement of dredged soil material
- Shellfish management
- SAV restoration
- Carbon sequestration
- Contaminant Accumulations
Upland Placement of Estuarine Dredged Material

• Benefits and Uses
  – Beach replenishment
  – Eelgrass (SAV) bed restoration
  – Marketable topsoil
  – Island creation

• Hazards
  – Heavy Metals
  – Toxins (organic and inorganic)
  – Petroleum products
  – Salts
  – Formation of acid sulfate conditions
What happens to marine dredged material when placed in a subaerial environment and exposed to natural conditions?

Collected Simulated Dredged Material to a Depth of 25 cm

- **Embayments**: Wickford Cove and Greenwich Bay Spit, Submerged Mainland Beach, Bay Bottom, Mainland Cove

- **Coastal Lagoons**: Ninigret and Quonochontaug Ponds Flood Tidal Delta, Washover Fan, Lagoon Bottom, Mainland Cove
Material and Leachate Analysis

- Rainfall leachate analyzed for:
  - Conductivity
  - pH
  - Sulfate ppm

- Lab Analysis of Soil Material
  - Salinity
  - Incubation pH
  - PSD
  - Inorganic Sulfides (CRS + AVS)
  - Total Sulfur (XRF)
  - Pollutant Metals (XRF)
Leachate pH among high and low energy soil-landscape units
Oxidation of Sulfide Bearing Materials

- Produce extreme acidity
- Mobilization of Heavy Metals

Courtesy: Maggie Payne
Wickford Harbor leachate conductivity (salinity)

Leachate conductivity among high and low energy soil-landscape units
Implications: Even a small percentage of lagoon bottom material (5%) will affect the chemistry of the dredged materials and lower the pH < 4.0 within a year.
Summary and Conclusions

- Upland placement of fine textured materials quickly resulted in acidic conditions (< 2 months) and formation of acid sulfate soils

- Sulfide distribution is the controlling factor for creation of acid sulfate conditions

- As little as 5% of fine textured sulfidic materials (Lagoon Bottom) may influence the extent and duration of the development of acidic conditions

- Salts washout fairly quickly (within 10 months)

- Subaqueous soils should be managed accordingly and separately from one another due to the development of acid sulfate conditions
• *Zostera marina* (eelgrass) is a submerged flowering vascular plant

• Obtains nutrients from soil via roots
Why is Eelgrass Important?

- High biological productivity (200 to 600 gCm\(^{-2}\)yr\(^{-1}\)) *Mann, 2000
- Habitat for spawning fish, shellfish and benthic infauna
- Food source for waterfowl
- Trap sediment from water column
- Buffer wave activity

Courtesy: NOAA
Eelgrass Restoration

A lot of interest in restoring eelgrass because of significant losses in eelgrass habitat due to:

- Eutrophication
- Wasting disease
- Increasing water temperatures
- Other disturbances such as boat propellers

Success rates of restoration projects often low

- Poor site selection is often cited as a contributing factor

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**Table 10. Success of eelgrass restoration projects in the northeastern US. Sites include full-scale transplant efforts (hectares) and test-transplants of less than 0.01 ha per location (T)**

<table>
<thead>
<tr>
<th>Location</th>
<th>Project</th>
<th>Sites attempted</th>
<th>Sites successful</th>
<th>Size</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Maine</td>
<td>Wells NERR Project</td>
<td>2</td>
<td>0</td>
<td>T</td>
<td>Short et al. (1993)</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>NH Port Mitigation Project</td>
<td>5</td>
<td>2</td>
<td>2.52 ha</td>
<td>Short et al. (1995), This study</td>
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<tr>
<td></td>
<td>NH TERFS™ Method Development</td>
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<td>2</td>
<td>T</td>
<td>Short et al. (2002)</td>
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<td>Massachusetts</td>
<td>NOAA New Bedford Harbor Project</td>
<td>8</td>
<td>5</td>
<td>1.62 ha</td>
<td>Kopp &amp; Short (2000), This study</td>
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<tr>
<td></td>
<td>EPA Boston Harbor Project</td>
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<td>0</td>
<td>T</td>
<td>P. Colarusso &amp; M. Chandler (pers. comm.)</td>
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<tr>
<td>Rhode Island</td>
<td>RI Aqua Fund Project</td>
<td>6</td>
<td>1</td>
<td>T</td>
<td>Kopp et al. (1994)</td>
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<tr>
<td></td>
<td>NOAA ‘World Prodigy’ Mitigation</td>
<td>10</td>
<td>2</td>
<td>T</td>
<td>B. S. Kopp (unpubl. data)</td>
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<td></td>
<td>RI DEM Narragansett Bay Project</td>
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<td>0</td>
<td>T</td>
<td>Fonseca et al. (1997)</td>
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<td></td>
<td>Save the Bay, Wickford Harbor</td>
<td>1</td>
<td>1</td>
<td>T</td>
<td>M. S. Fonseca (pers. comm.)</td>
</tr>
<tr>
<td></td>
<td>NOAA/NERR Seeding Project</td>
<td>3</td>
<td>1</td>
<td>T</td>
<td>Adamowicz (1994)</td>
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<tr>
<td>Connecticut</td>
<td>Niantic River Pilot Eelgrass Restoration</td>
<td>1</td>
<td>1</td>
<td>0.04 ha</td>
<td>Richardson (pers. comm.)</td>
</tr>
<tr>
<td>New York</td>
<td>NY Sea Grant, Great South Bay Project</td>
<td>1</td>
<td>1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>T</td>
<td>Churchill et al. (1978)</td>
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<td>New Jersey</td>
<td>NOAA/NMFS Raritan Bay Project</td>
<td>5</td>
<td>0</td>
<td>T</td>
<td>Reid et al. (1993)</td>
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</table>

<sup>a</sup>Survival monitored for less than 1 yr

*Short et al./Mar Ecol Prog Ser 227 (2002) 253-267*
Objectives

• Assess relationship between soil-landscape units and eelgrass distribution, growth, and transplant success in three coastal lagoons in southern Rhode Island

• Identify soil-landscape units most capable of supporting successful restoration projects
METHODS

• Point intercept vegetation transect method for eelgrass density

• TERF Transplant Method

• Leaf marking technique for determining growth

• Collected soil samples for physical and chemical properties

• Compared parameters across landscape unit types
Soil-landscape units group soils that have similar physical and chemical properties. These soil-landscape units offer a wide range in soil properties. These soil-landscape units are the most common units in coastal lagoon ecosystems.
TERF Transplant Method

- Developed by Dr. Fred Short of University of New Hampshire

- Harvest healthy eelgrass and tie shoots to the TERF frame (50 shoots per frame)

- Shoots were arranged so rhizomes within top 1 cm of soil

- Health of the eelgrass transplants determined by counting surviving shoots
## Ninigret Pond Eelgrass Density

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Average eelgrass cover (% ± S.D.) (n)</td>
<td>Average eelgrass cover (% ± S.D.) (n)</td>
</tr>
<tr>
<td>Flood Tidal Delta Slope</td>
<td>82 ± 14 (4) Silt loam</td>
<td>68 ± 2 (9) (^b) Very fine sandy loam</td>
</tr>
<tr>
<td>Lagoon Bottom</td>
<td>66 ± 37.9 (15) Silt loam</td>
<td>98 ± 1 (6) (^a) Silt loam</td>
</tr>
<tr>
<td>Flood Tidal Delta Flat</td>
<td>0 (2) Very fine sand</td>
<td>4 ± 1 (9) (^c) Fine sand</td>
</tr>
<tr>
<td>Washover Fan Flat</td>
<td>0 (4) Sand</td>
<td>1 ± 1 (9) (^c) Fine Sand</td>
</tr>
<tr>
<td>Washover Fan Slope</td>
<td>0 (2) Coarse sand</td>
<td>1 ± 3 (9) (^c) Fine sand</td>
</tr>
</tbody>
</table>

\(^a\) Indicates significant difference from Bradley (2001), \(^b\) indicates significant difference from Pruett (2010), \(^c\) indicates significant difference from both Bradley (2001) and Pruett (2010).
<table>
<thead>
<tr>
<th>Landscape Unit</th>
<th>n</th>
<th>Average Eelgrass Cover (%)</th>
<th>USDA Soil Texture Classification Range</th>
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<tr>
<td><strong>Potter Pond</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lagoon Bottom</td>
<td>9</td>
<td>100 0^a</td>
<td>silt loam</td>
</tr>
<tr>
<td>Flood Tidal Delta-Slope</td>
<td>9</td>
<td>92 9^a</td>
<td>very fine sandy loam</td>
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<tr>
<td>Flood Tidal Delta-Flat</td>
<td>9</td>
<td>66 23^c</td>
<td>loamy sand to fine sand</td>
</tr>
<tr>
<td>Washover Fan-Slope</td>
<td>9</td>
<td>80 7^b</td>
<td>loam to fine sandy loam</td>
</tr>
<tr>
<td>Washover Fan-Flat</td>
<td>6</td>
<td>4 7^d</td>
<td>sand</td>
</tr>
<tr>
<td><strong>Quonochontaug Pond</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lagoon Bottom</td>
<td>9</td>
<td>16 31^bc</td>
<td>Silt loam</td>
</tr>
<tr>
<td>Flood Tidal Delta-Slope</td>
<td>6</td>
<td>33 35^a</td>
<td>loamy sand to fine sand</td>
</tr>
<tr>
<td>Flood Tidal Delta-Flat</td>
<td>6</td>
<td>11 15^bc</td>
<td>loamy sand to fine sand</td>
</tr>
<tr>
<td>Washover Fan-Slope</td>
<td>9</td>
<td>3 3^b</td>
<td>sand to coarse sand</td>
</tr>
<tr>
<td>Washover Fan-Flat</td>
<td>9</td>
<td>8 20^c</td>
<td>sand to coarse sand</td>
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### Ninigret Pond:
#### Eelgrass Distribution and Soil Properties

<table>
<thead>
<tr>
<th>Variable</th>
<th>High (mean se)</th>
<th>Moderate</th>
<th>Low (mean se)</th>
<th>No (mean se)</th>
<th>P-value</th>
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<tr>
<td></td>
<td>&gt; 60%</td>
<td>60 to 20%</td>
<td>20 to 1%</td>
<td>0%</td>
<td></td>
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<tr>
<td>TOC (%)</td>
<td>2.7 0.9</td>
<td>-</td>
<td>0.4 0.1</td>
<td>0.5 0.1</td>
<td>0.04</td>
</tr>
<tr>
<td>CaCO₃ (%)</td>
<td>4.0 1.2</td>
<td>-</td>
<td>1.0 0.1</td>
<td>0.9 0.2</td>
<td>0.05</td>
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<tr>
<td>Salinity (mS)</td>
<td>5.3 0.4ᵃ</td>
<td>-</td>
<td>3.1 0.2ᵇ</td>
<td>3.1 0.2ᵇ</td>
<td>0.0032</td>
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<tr>
<td>pH</td>
<td>8.1 0.1</td>
<td>-</td>
<td>7.9 0.1</td>
<td>7.9 0.1</td>
<td>0.18</td>
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<tr>
<td>Sand (%)</td>
<td>39.2 13.7ᵃ</td>
<td>-</td>
<td>94.0 1.9ᵇ</td>
<td>95.9 1.2ᵇ</td>
<td>0.0019</td>
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<tr>
<td>Silt (%)</td>
<td>48.8 9.1ᵃ</td>
<td>-</td>
<td>3.8 1.7ᵇ</td>
<td>3.2 1.3ᵇ</td>
<td>0.0004</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>12.1 5.2</td>
<td>-</td>
<td>2.4 0.8</td>
<td>1.2 0.7</td>
<td>0.10</td>
</tr>
<tr>
<td>AVS (ug g⁻¹)</td>
<td>38.5 5.5ᵃ</td>
<td>-</td>
<td>2.9 0.7ᵇ</td>
<td>2.0 0.3ᵇ</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>CRS (ug g⁻¹)</td>
<td>305.3 122.0</td>
<td>-</td>
<td>52.6 22.8</td>
<td>61.9 23.1</td>
<td>0.09</td>
</tr>
<tr>
<td>TS (ug g⁻¹)</td>
<td>343.8 121.9</td>
<td>-</td>
<td>55.5 23.2</td>
<td>63.9 23.3</td>
<td>0.05</td>
</tr>
<tr>
<td>n=</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>4</td>
<td></td>
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</table>
Soil Properties and Eelgrass Distribution

• In Ninigret Pond:
  – Landscape units with high eelgrass cover (>60%) had:
    • High soil salinities
    • High silt contents
    • High acid-volatile sulfide contents
    • Low sand contents

• In Potter Pond:
  – Most landscapes (11 out of 14) had high eelgrass cover (>60%)
  – Each of the 3 remaining transects split between Moderate cover (20 to 60%), Low cover (1 to 20%), and No cover (0%).
  – Made statistical comparisons between cover classes impossible but same trends were seen as in Ninigret Pond (salinity, silt, and AVS higher in high classes vs. Moderate, Low, No classes)

• In Quonochontaug Pond:
  – Very little eelgrass so no significant differences between eelgrass cover classes
Why lower success in LB units?

- These units had higher SOC and total sulfide contents
- SOC levels >2% have been shown to deter SAV establishment.
- LB units had 6% SOC while FTDS and WFS had 2%.
### Production Measurements Results

<table>
<thead>
<tr>
<th></th>
<th>Ninigret Pond</th>
<th></th>
<th></th>
<th></th>
<th>Potter Pond</th>
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<tbody>
<tr>
<td></td>
<td>WFS</td>
<td>FTDS</td>
<td>LB</td>
<td>p</td>
<td>WFS</td>
<td>FTDS</td>
<td>LB</td>
<td>p</td>
<td></td>
<td></td>
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<tr>
<td><strong>Early Summer</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Shoot Growth Rate</strong></td>
<td>49.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>50.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.006</td>
<td>19.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>31.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.001</td>
<td></td>
<td></td>
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<tr>
<td>(mg dw shoot&lt;sup&gt;-1&lt;/sup&gt; day&lt;sup&gt;-1&lt;/sup&gt;)</td>
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<tr>
<td><strong>3&lt;sup&gt;rd&lt;/sup&gt; Leaf Length (cm)</strong></td>
<td>72.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>57.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>122.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&lt;0.0001</td>
<td>77.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>45.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>108.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&lt;0.0001</td>
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<tr>
<td><strong>Shoot:Root ratio</strong></td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<td>(mg/mg dw)</td>
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<td><strong>Late Summer</strong></td>
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<tr>
<td><strong>Shoot Growth Rate</strong></td>
<td>7.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.029</td>
<td>11.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0002</td>
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<td>(mg dw shoot&lt;sup&gt;-1&lt;/sup&gt; day&lt;sup&gt;-1&lt;/sup&gt;)</td>
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<tr>
<td><strong>3&lt;sup&gt;rd&lt;/sup&gt; Leaf Length (cm)</strong></td>
<td>41.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>43.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>67.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&lt;0.0001</td>
<td>56.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>45.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>67.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Shoot:Root ratio</strong></td>
<td>4.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.9&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.0002</td>
<td>5.5</td>
<td>3.7</td>
<td>5.3</td>
<td>0.124</td>
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<tr>
<td>(mg/mg dw)</td>
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<tr>
<td><strong>Water Depth (m)</strong></td>
<td>1.4</td>
<td>1.4</td>
<td>1.9</td>
<td></td>
<td>1.1</td>
<td>0.8</td>
<td>1.7</td>
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</table>

**Eelgrass allocates growth to aboveground biomass from belowground biomass under low light and high SOM conditions.**

**Higher growth rates in LB units in Ninigret Pond in late summer corresponded with higher shoot:root ratios.**
Summary of Eelgrass Data

• Percent eelgrass cover varies by soil-landscape unit

• Lagoon Bottom and Flood Tidal Delta-Slope units contained highest eelgrass cover

• Lagoon Bottom units had highest growth rates

• High soil salinities, silt contents, and AVS contents were correlated with high eelgrass cover

• Landscape units that supported the most eelgrass and the highest aboveground growth rates (LB) had lower success rates for transplantation
  – May be due to reducing conditions or high SOC stressing transplanted eelgrass
Conclusions and Future Work

• Soil landscape unit type is important to eelgrass distribution, growth, and transplant success

• Transplant data suggests that the best units for transplant success included:
  – Flood Tidal Delta Slope
  – Washover Fan Slope

• Need to study the success rate of different transplant methods on soil landscape units
Subaqueous Soils and Carbon Pools

- Global warming concerns have sparked interest in investigating the global C cycle
- Upland and wetland SOC pools are often important carbon sinks
- Subaqueous soils have been largely overlooked in soil organic carbon pool studies
- More precise estimates of C sinks and sources are needed to better understand the global C cycle
Objectives

• Explore carbon storage and soil-landscape unit relationship

• Do SOC pools differ among soil type?

• Do subaqueous soils in Rhode Island coastal lagoons contain significant SOC pools?
### Study Area

#### Landscape unit

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<tr>
<th>Landscape unit</th>
<th>NP</th>
<th>PJP</th>
<th>QP</th>
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<tr>
<td>FTDF</td>
<td>43 (7%)</td>
<td>126 (19%)</td>
<td>54 (18%)</td>
</tr>
<tr>
<td>FTDS</td>
<td>*</td>
<td>11 (2%)</td>
<td>*</td>
</tr>
<tr>
<td>WFF</td>
<td>135 (15%)</td>
<td>*</td>
<td>18 (6%)</td>
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<tr>
<td>WFS</td>
<td>25 (3%)</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>SMB</td>
<td>71 (8%)</td>
<td>40 (7%)</td>
<td>27 (9%)</td>
</tr>
<tr>
<td>MC</td>
<td>18 (2%)</td>
<td>39 (6%)</td>
<td>*</td>
</tr>
<tr>
<td>LB</td>
<td>289 (43%)</td>
<td>267 (41%)</td>
<td>162 (52%)</td>
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</table>

<table>
<thead>
<tr>
<th>Area of Pond (ha)</th>
<th>NP</th>
<th>PJP</th>
<th>QP</th>
</tr>
</thead>
<tbody>
<tr>
<td>678</td>
<td>650</td>
<td>312</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage of Area</th>
<th>NP</th>
<th>PJP</th>
<th>QP</th>
</tr>
</thead>
<tbody>
<tr>
<td>78%</td>
<td>75%</td>
<td>85%</td>
<td></td>
</tr>
</tbody>
</table>
High Energy (WFF) Results

Low Energy (LB) Results

SOC (%)

Pedon Depth (cm)

QPWFF

NPWFF1

NPWFF2

NPLB

QPLB

PJLB

Low Energy (LB) Results

SOC (%)

Pedon Depth (cm)

NPLB

QPLB

PJLB

Results
• MC units had highest SOC pools and highest variability
  - Due to buried O horizons and one organic soil (Wassist)
• LB units had higher SOC pools than the “Flat” units
• Similar relationships seen when each of the coastal lagoons are assessed individually
- Sulfiwassents have fine textures and presence of sulfides
- Sulfiwassents make up the majority of each coastal lagoons studied (> 50%)
- Similar relationships were seen when ponds were assessed individually
Mean SOC Pools in Select Soil Subgroups

- Subaerial data from forested upland and wetland soils (Ricker, 2010 and Davis, 2004)
- SOC pools in subaqueous subgroups are comparable to forested soils in southern New England
Soil Organic Carbon Conclusions

• SOC pools significantly differed by soil great group and landscape unit

• Type of depositional environment and presence of buried O horizons important for SOC pools

• Subaqueous SOC pools are comparable to regional and national averages for subaerial SOC pools

• Should be included in global and regional estimates of soil organic carbon pools

• Sequestration rates need to be studied in these subaqueous soils.
Heavy Metals and Subaqueous Soils

• What is the spatial distribution of surficial metal concentrations in RI estuaries?

• Do metal concentrations differ by soil type?

• Are specific soil types more likely to contain metal pollution?
Methods

- Analyzed 91 surface soil samples for heavy metals
- Dried and homogenized samples
- Niton XL3t XRF
- Pb, Zn, As, Cu, and Cr
- Classified soils and separated by great group and soil series
- Compare to DEM background levels and NOAA limits for biological effects
Results

• For As, Cu, and Cr majority of concentrations < LOD

• Pb and Zn most prevalent metals in high concentrations

• Possible Sources:
  – Atmospheric deposition (Pb and Zn)
  – Surface water runoff (Pb and Zn)
  – Incinerator waste (Pb and Zn)
  – Gasoline (Pb usage stopped in 70’s)
  – Car tires (Zn)
- Widespread distribution of Pb and Zn above background levels across all estuaries studied

- Pb concentrations highest near freshwater/surface-water inputs and lowest near tidal inlet

- Proximity to potential sources and tidal inlets important to spatial distribution of metal conc.

- Same trends for Zn
- Hydro and Sulfiwassents contain greater fine materials, SOC contents, and sulfides which bind metals
Conclusions

• Pb and Zn were the most common metals >LOD, the majority of samples were <LOD for Cu, Cr, and As

• Proximity to potential sources and tidal inlets, and soil physical and chemical properties are important to the spatial distribution of metal concentrations in estuaries

• Pb and Zn differed by soil great group, due to the differing physical and chemical properties of the soil types studied

• It is possible to create an interpretations map based on this data that groups soils with the most potential to accumulate metal pollution
Subaqueous Soil and Shellfish Growth

• **Objective**
  – Estimate shellfish growth on different soil landscape units
  – Eastern Oyster *Crassostrea virginica*
  – Quahog (*Mercenaria mercenaria*)

• **What affects shellfish growth?**
  – Seston (Food availability)
  – Flow Rates
  – Temperature

• **Soils as a surrogate for shellfish growth**
  – Able to map out areas
Shellfish Growth Experiment

- **Small scale aquaculture**
  - Ninigret Pond
  - Quonochontaug Pond

- **Landscape units**
  - Washover Fan
  - Washover Fan Slope
  - Lagoon Bottom
  - Mainland Cove
  - Submerged Mainland Beach

- **Soil Characterization**
  - Vibracores taken at each site
  - Described and analyzed

- **Oysters**
  - Grow-out in trays (1m x 1m)
  - 3 trays per site

- **Quahogs**
  - Grown in soil (2 x 2 meter plots)
  - Covered with predator netting

- **Sampling**
  - Growth measured at end of 15 week study period
  - 2 seasons
  - Oysters measured by long axis
  - Quahogs measured by hinge width

- **Water Quality**
  - DO, Salinity, Temperature
  - TSS, Chlorophyll a
Oyster Growth Experiment

June 2008 Oysters put out in Ninigret Pond

- ~ 11,000 oysters mean size of 3.0 cm
- 4 Liters of biovolume were placed into 24 grow-out bags
- 1 Liter of biovolume = 110 - 120 oysters
- 3 Oyster trays per site

Sampling in October 2009

30 Oysters random sampled from each tray (90 per site) and measured across the long axis
# Site Characteristics

<table>
<thead>
<tr>
<th>Site</th>
<th>Water Depth (m)</th>
<th>Surface Texture</th>
<th>Subgroup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ninigret Pond</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WFS</td>
<td>0.96</td>
<td>loamy fine sand</td>
<td>Typic Fluviwassent</td>
</tr>
<tr>
<td>WF</td>
<td>1.04</td>
<td>fine sand</td>
<td>Sulfic Psammowassent</td>
</tr>
<tr>
<td>MC</td>
<td>1.00</td>
<td>fine sand</td>
<td>Haplic Sulfiwassent</td>
</tr>
<tr>
<td>LB</td>
<td>1.00</td>
<td>silt loam</td>
<td>Typic Sulfiwassent</td>
</tr>
<tr>
<td>Quonochontaug Pond</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WFS</td>
<td>1.49</td>
<td>sand</td>
<td>Typic Psammowassent</td>
</tr>
<tr>
<td>WF</td>
<td>0.79</td>
<td>coarse sand</td>
<td>Fluventic Psammowassent</td>
</tr>
<tr>
<td>SMB</td>
<td>0.99</td>
<td>sand</td>
<td>Aeric Haplowassent</td>
</tr>
<tr>
<td>LB</td>
<td>3.19</td>
<td>silt loam</td>
<td>Typic Sulfiwassent</td>
</tr>
</tbody>
</table>
Different letters indicate significant differences. Note slow growth on Lagoon Bottom soils
# Oyster Growth Analysis

## Percentage of Legal Sized Oysters

<table>
<thead>
<tr>
<th>Aquaculture Site ID</th>
<th>October 2008</th>
<th>June 2009</th>
<th>October 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% ≥ 76 mm</td>
<td>% ≥ 76 mm</td>
<td>% ≥ 76 mm</td>
</tr>
<tr>
<td>NWFS</td>
<td>0</td>
<td>20</td>
<td>73†</td>
</tr>
<tr>
<td>NWF</td>
<td>0</td>
<td>30</td>
<td>44</td>
</tr>
<tr>
<td>NMC</td>
<td>0</td>
<td>13</td>
<td>45</td>
</tr>
<tr>
<td>NLB</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>QWFS</td>
<td>3</td>
<td>19</td>
<td>62</td>
</tr>
<tr>
<td>QWF</td>
<td>1</td>
<td>24</td>
<td>62</td>
</tr>
<tr>
<td>QSMB</td>
<td>2</td>
<td>16</td>
<td>61</td>
</tr>
<tr>
<td>QLB</td>
<td>N/A</td>
<td>3</td>
<td>24</td>
</tr>
</tbody>
</table>

Initial shell sizes = 30 mm

† vandalism, July 2009 unknown lost, number based on 1 oyster tray
Grain Size of Surface Horizon Predicting Oyster Growth

\[ y = 0.7192x + 33.937 \]

\[ R^2 = 0.85 \]
Shellfish Summary

- Oyster Growth (both ponds) 31 mm/year
- Shellfish grew faster on coarser textured soils
  - Increased growth rates
  - Greater biovolume
  - Greater survival
- Grain size of surface horizon predictor of oyster growth ($R^2 = 0.85$)
- Landscape units containing increases in sand (Washover Fan, Submerged Mainland Beach) more suitable for shellfish aquaculture
- Existing soil surveys can provide managers with a tool for siting future aquaculture farms
Conclusions

• The systematic distribution of soil types in a soil survey are relative to eelgrass distribution, growth, and transplant success, variations in SOC pools, and accumulation of heavy metals.

• Once included in subaqueous soil surveys, these tools will be valuable reference information for coastal resource managers, policy makers, and research scientists.