MODELING AND MEASURING CO$_2$
SEQUESTRATION
DUE TO EELGRASS (ZOSTERA MARINA)
WITHIN AN ESTUARY

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- **Environmental Stewardship** since 1993
  - Mission: Education, Habitat Restoration
- **Shallow estuary (4 m tide)**
  - 50% of the shoreline disturbed
  - Log booming and dredging
  - Dams and river diversion
  - Ongoing eelgrass and salt marsh restorations
OUR BLUE CARBON OBJECTIVE

• How to determine if an eelgrass (*Zostera marina*) meadow can provide the means and/or tissue for sequestering carbon into sediments or elsewhere for over 100 years.

• And if so, how much carbon can be sequestered under ideal and non-ideal conditions.

• Case study: K’omoks Estuary
Reviewed over 200 scientific references to understand:

Under what conditions C could be sequestered.

Empirical data

Methods of quantifying including models and measurements
The conditions under which C could be sequestered

- Increase size of eelgrass meadow
- Collection and use of sloughed material.
- Burial of eelgrass and the organic particles trapped by eelgrass shoots
The amount of C sequestered depends on many factors:

- Sub-tidal or intertidal meadow
- Quality and availability of light
- Water temperature, salinity and substrate (sand, mud, rock)
- Likelihood of storm damage
- Epiphytes
- Season
- Genetics
- Long term effects of climate change
- Disease
Eelgrass standing density (above and below ground biomasses) (kg dry wt/m²) and C sequestration (kg/m²) in ideal intertidal and sub-tidal growing conditions as extracted from literature.

<table>
<thead>
<tr>
<th></th>
<th>~ 30% air exposure</th>
<th>~ 15% air exposure</th>
<th>No air exposure (light saturation)</th>
<th>No air exposure (sub saturation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max</td>
<td>0.2</td>
<td>0.5</td>
<td>2.4</td>
<td>1.8</td>
</tr>
<tr>
<td>After winter</td>
<td>0.08</td>
<td>0.3</td>
<td>1.8</td>
<td>1.2</td>
</tr>
<tr>
<td>In between</td>
<td>0.1</td>
<td>0.35</td>
<td>2.14</td>
<td>1.6</td>
</tr>
<tr>
<td>Annual avg.</td>
<td>0.1</td>
<td>0.37</td>
<td>2.09</td>
<td>1.5</td>
</tr>
<tr>
<td>Carbon</td>
<td>0.04</td>
<td>0.13</td>
<td>0.73</td>
<td>0.53</td>
</tr>
<tr>
<td>Ha for 1 ton C</td>
<td>2.4</td>
<td>0.77</td>
<td>0.14</td>
<td>0.19</td>
</tr>
</tbody>
</table>
Mitigate negative stressors linked to decreases in standing density to receive carbon credits.

• **Improve water quality leading to murky conditions that**
  • have drastic effects on sub-tidal light transmission, and
  • promote epiphytic growth.

• **Climate change predicts rising sea levels, which would negatively affect sub-tidal areas.**

Murky water and epiphytes
The conditions under which C could be sequestrered

- Increase size of eelgrass meadow
- Collection and use of sloughed material.
- Burial of eelgrass and the organic particles trapped by eelgrass shoots
Eelgrass sloughed (kg dw/m$^2$/yr), carbon sloughed (Kg/m$^2$/yr) and collection area (ha) for sequestering 1 ton C during a 3 mo mass sloughing period as extracted from literature.

<table>
<thead>
<tr>
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<th>No air exposure (light saturation)</th>
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<tbody>
<tr>
<td>0.02</td>
<td>0.05</td>
<td>0.34</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>0.007</td>
<td>0.02</td>
<td>0.11</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>0.3</td>
<td>0.23</td>
<td></td>
</tr>
</tbody>
</table>
How has sloughed material been used and could be used to obtain C credit?

• Insulation, Animal feed,
• Baskets, Stuffing material,
• Soil amendment
• Not used, only land filled
• Ecosystem services: Not a preferred natural food source

Substitute for non local products (offset the carbon burned in fuel to delivery the item)

• Have local environmental groups manage the resource

Little Qualicum, B.C. Dec. 2013
The conditions under which C could be sequestrered

- Increase size of eelgrass meadow
- Collection and use of sloughed material.
- Burial of eelgrass and the organic particles trapped by eelgrass shoots
Long term burial of eelgrass and the organic particles trapped by eelgrass shoots.

Z. marina C sequestration potential << Posidonia oceanica’s

• Understory biomass is considerably less
• Leaves detach and float away (are fixed in P. oceanica)
• Therefore, Z. marina C sequestration via burial depends on particle trapping efficiency.

Dense eelgrass beds act like particle traps.
Ideal conditions for sequestration via sediment burial:

• Abundant organic particles of the right type and size during the period of max eelgrass standing density.

• Eelgrass canopy, substrate and current conditions must be just so to enable particle trapping over re-suspension

• C degradation rate within sediment must be lower than the C input rate

• The environment must be conducive for dense eelgrass growth
Ideal conditions for sequestration via sediment burial, and burial rates

- Not pristine watersheds (too little organic matter makes it more likely it all will be consumed; surplus is needed).
- Dense, sub-tidal meadows that receive organic debris from watershed and estuarial derived plankton and are not broken up by storm waves.
- Not overly polluted areas (high levels of nutrients and sediment indirectly or directly effect light transmission).

Burial rate estimates:

- zero (pristine env.),
- 36.7 (±2.8) g C m⁻² yr⁻¹ (10 yr post rehabilitation) to
- 52.4 g C m⁻² yr⁻¹ (dense bed, mass balance, assumed canopy debris buried below bed).
How much C is sequestered in the K’omoks Estuary?

Measures and decisions are needed to answer that question:

- Max standing densities.
- Bathymetrics and water clarity to determine max possible depth of sub-tidal eelgrass and distinct intertidal eelgrass populations.
- Timing and duration of mass sloughing events.
- Decide what to do with sloughed material, and how to manage and collect it.
- Decide whether to plant more eelgrass or work on improving the environment to increase or protect the current standing density.
Measurements for estimating C sequestration via burying

• Analyze current speed, and particle size and composition within eelgrass beds to see if conditions are ripe for particle trapping according to literature.

• Take long sediment cores from the centers of dense eelgrass beds, and
  • measure radio isotopes to estimate C and sediment accretion rates (MacReadie et al 2013; Larsen et al 2010; Johannessen et al 2012; Greiner et al 2013) and
  • examine stable isotopes to identify C sources (e.g. Barrón et al 2005).
  • Compare these data to data obtained from a high intertidal bed.
Conclusions

- Prime sub-tidal meadows have the most potential for C sequestration:
  - An increase in standing density of 0.14 Ha could result in 1 Ton C
  - Managing sloughed material from 0.29 Ha could result in 1 Ton C/yr.
  - The burial of trapped organic particles in 2.7 Ha could result in 1 Ton C/yr.
- Standing densities and other indicators can be measured and compared against the ideal set reported on herein to arrive at site specific estimations and make decisions related to improving C sequestration.