Local and global declines of seagrass: is there a glimmer of hope?

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Outline

• What is seagrass?

• Why is seagrass important?

• What are the global trends?

• What are the Chesapeake trends?

• A glimmer of hope? (discussion)
What is a seagrass?

**Epiphytes:** Small algae and animals often grow attached to the leaves and stems of seagrass.

**Flowers:** Seagrasses are flowering plants. In most species, pollination occurs underwater, resulting in abundant seeds.

**Leaves:** Photosynthesise using sunlight and carbon dioxide ($CO_2$) to make sugars and oxygen ($O_2$) to support plant functions. They also take up nutrients and send $O_2$ through air tubes called lacunae down to the rhizome and roots.

**Rhizome:** Stores sugars and/or starch during summer to help seagrass survive during winter.

**Roots:** Take up nutrients, anchor shoots in sand, or for some species, attach to rocks (e.g., *Amphibolis*, *Thalassodendron*).
Land plants vs. seagrasses

- Waxy cuticle
- Gas exchange
  - Secondary growth (woody plants)
  - Reduced cuticle
  - Gas canals
  - Little secondary growth (leafy plants)
Is a seagrass a seagrass?

- Halophila
- Halodule
- Ruppia
- Zostera
- Phyllospadix
- Cymodocea
- Syringodium
- Amphibolis
- Thalassodendron
- Thalassia
- Enhalus
- Posidonia

**Ephemeral**
- Halophila
- Ruppia
- Zostera
- Phyllospadix
- Cymodocea
- Syringodium
- Amphibolis

**Persistent**
- Halodule
- Zostera
- Phyllospadix
- Cymodocea
- Syringodium
- Amphibolis
- Thalassodendron
- Thalassia
- Enhalus
- Posidonia

**Zostera**

**Halophila**

**Thalassia**

**Posidonia**
Seagrasses ‘reinvaded’ the sea from terrestrial ancestors

Another great moment in evolution
Indo-west Pacific has highest seagrass diversity
Seagrasses evolved in a very different marine environment from today.
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Seagrasses evolved in a very different marine environment from today.
Seagrasses are abundant in tropical and temperate regions

- **Halophila**: Bocas del Toro, Panama
- **Thalassia**: Kuna Yala, Panama
- **Ruppia**: Morro Bay, USA
- **Zostera**: Ria Formosa, Portugal
Seagrass provides critical food source in tropical regions

Manatee (*Trichechus*)
In *Thalassia* meadow, Puerto Rico

Green Sea Turtle (*Chelonia*)
In *Cymodoceoa* meadow, Yucatan, Mexico
Ecosystem services of tropical seagrass

- High biomass seagrass meadows trap sediments and nutrients.
- Seagrass meadows provide a nursery for finfish and shellfish.
- Seagrasses and associated algae have high primary production.
- Seagrass promote trophic transfers and cross habitat utilization.
- Tropical seagrasses provide food for dugongs, manatees and turtles.
Seagrass provides critical habitat in temperate regions

Seahorse (*Hippocampus*)
In *Cymodocea* meadow, Mediterranean Sea

Zebra fish (*Girella*)
In *Posidonia* meadow, Perth, Western Australia
Ecosystem services of temperate seagrass

- High biomass seagrass meadows trap sediments and nutrients.
- Seagrass meadows provide a nursery for finfish and shellfish.
- Seagrasses and associated algae have high primary production.
- Seagrass promote trophic transfers and cross habitat utilization.
- Tropical seagrasses provide food for dugongs, manatees and turtles.
Seagrasses are valuable and threatened compared to other major marine habitats.

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>Area ($10^6$ ha)</th>
<th>Loss (% year$^{-1}$)</th>
<th>Value (US$ ha$^{-1}$ year$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seagrass</td>
<td>18</td>
<td>2–5</td>
<td>19 004</td>
</tr>
<tr>
<td>Salt marsh</td>
<td>140</td>
<td>1–2</td>
<td>9 990</td>
</tr>
<tr>
<td>Mangrove</td>
<td>15</td>
<td>1–3</td>
<td>9 990</td>
</tr>
<tr>
<td>Coral</td>
<td>62</td>
<td>4–9</td>
<td>6 075</td>
</tr>
<tr>
<td>Tropical forest</td>
<td>1 900</td>
<td>0.5</td>
<td>2 007</td>
</tr>
</tbody>
</table>
Seagrass is efficient at fixing CO$_2$

- 55% of all biological carbon fixed annually captured by living marine organisms (BLUE carbon)
- Seagrass + mangrove + salt marsh is 0.05% of terrestrial plant biomass but fixes similar amount of carbon annually
More than 50% of studies report declining seagrass area

Global
25% increase
58% decrease
17% no change

Seagrass Trajectories Database
215 sites; 1128 observations
1879-2006

Waycott et al. 2009 PNAS
Rates of seagrass change accelerating over time (% yr$^{-1}$)

Waycott et al. 2009 PNAS
Measured area of loss at least one order of magnitude greater than area of gain.
Pressures to seagrass: human population

- First human use of seagrass
- Centralized agriculture
- Aristotle refers to seagrass
- Expansion of shipping
- Linnaeus identifies seagrass species
- Industrial revolution

CO₂ concentration (ppm)

History:
- Egypt ca. 10,000 years ago
- Pacific northwest, seagrass use
- Washington DC, 2006
Pressures to seagrass: human population

- First human use of seagrass
- Centralized agriculture
- Aristotle refers to seagrass
- Linnaeus identifies seagrass species
- Industrial revolution
- Present

CO₂ concentration (ppm)

Mean sea level, relative to present (m)

- Egypt ca. 10,000 years ago
- Pacific northwest, seagrass use
- Washington DC, 2006
Pressures to seagrass: human population

- First use of seagrass
- Centralized agriculture
- Aristotle refers to seagrass
- L. W. Hamilton identifies seagrass species
- Industrial revolution

<table>
<thead>
<tr>
<th>CO₂ concentration (ppm)</th>
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<tbody>
<tr>
<td>400</td>
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<tr>
<td>200</td>
</tr>
<tr>
<td>0</td>
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</table>

<table>
<thead>
<tr>
<th>Mean sea level, relative to present (m)</th>
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<tbody>
<tr>
<td>-30</td>
</tr>
<tr>
<td>-20</td>
</tr>
<tr>
<td>-10</td>
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<tr>
<td>0</td>
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<tr>
<th>Global human population (x10^9)</th>
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<tbody>
<tr>
<td>0</td>
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<tr>
<td>2</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>6</td>
</tr>
</tbody>
</table>

- Egypt ca. 10,000 years ago
- Pacific northwest, seagrass use
- Washington DC, 2006
Pressures to seagrass: increased invasive species

- Expansion of shipping
- Suez canal opened
- Water used for ballast
- Panama canal opened
- Increase in shipping

Timeline:
- 1850
- 1900
- 1950
- 2000

Caulerpa taxifolia
Pressures to seagrass: increased invasive species

Cumulative invasive species introductions to seagrass

% introductions to seagrass

Negative  Inferred negative  Unknown  Positive  Neutral

0 0.1 0.2 0.3

Panama Canal, 1907

Ballast pumping

Expansion of shipping
Suez canal opened
Water used for ballast
Panama canal opened
Increase in shipping
Pressures to seagrass: increased nutrient input (Fertilizer and sewage)

First nitrogen fertilizer plant

Global nitrogen fertilizer use

Fertilizer applied in agriculture
Wastewater Treatment Plant
Fertilizer applied to lawns
Tropical seagrass loss mechanisms (<1 km²)

Environmental
- Reports: 5
  - Vessel grounding
  - Sedimentation
  - Aquaculture

Biological
- Reports: 2
  - Urchin grazing

Event based
- Reports: 1
  - Hurricane
Tropical seagrass loss mechanisms (1-100 km²)

Environmental
- Reports: 6
  - Eutrophication
  - Dredging
  - Sediment resuspension

Biological
- Reports: 2
  - Brown tide
  - Urchin grazing

Event based
-
Aquatic grass communities are widely distributed in Chesapeake Bay.

Sources: VIMS & Maryland DNR
Seagrass (SAV) in Chesapeake Bay
Trends in Chesapeake Seagrass (increasing in low salinity)
Trends in Chesapeake Seagrass (increasingly variable mid salinity)
Trends in Chesapeake Seagrass (declining in high salinity)
Species and community shifts with increasing nutrient loading – a glimmer of hope?

Fourquarean and Rutten. 2003
Conclusions/ discussion

- Seagrass provides essential ecosystem services
- Long evolutionary history, 3 reinvasions, few species
- Seagrass is declining globally
- Increases and decreases in Chesapeake
- Some species cope better with high nutrients and warmer temperatures (such as *Ruppia*)
Acknowledgements

• Multiple colleagues including a project at National Centre for Ecological Analysis and Synthesis, University of California, Santa Barbara

(not in order) Susan Williams, Michelle Waycott, Bill Dennison, Carlos Duarte, Jim Fourqurean, Ken Heck, Randall Hughes, Gary Kendrick, Jud Kenworthy, Suzanne Olyarnik, Bob Orth, Ainsley Calladine and Fred Short
Referenced publications


• Waycott, M., Duarte, C. M., Carruthers, T. J. B., Orth, R. J., Dennison, W. C., Olyarnike, S., et al. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. PNAS, 106(30), 12377–12381.