Seagrass and climate change: implications for management

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• A quick introduction to seagrasses
• Ecology and functions
• Factors regulating ecology
• Effects of climate change
• Ideas for delivering adaptation responses
• Sexual reproduction:
  – Flowering triggered by increase in water temperature
  – Pollen dispersal is assumed to be limited to the extent of meadows themselves
  – Seed dispersal and survival is unpredictable due to stochastic events
Clonal growth is a key feature in the appearance, development, and maintenance of seagrass landscapes. Rhizome elongation rates vary, ranging from 1 to 500 cm per year. Smaller clones are characteristic of physically disturbed environments (Hämmerli, 2002).

Interesting fact:
A 1 km² seagrass bed in the Baltic was found to be over 1000 years old and to have originated from a single seed. (Reusch et al., 1999)

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Seagrass meadow near Tresco, (Source: South West Coastal Monitoring Programme)
Global value of all ecosystem services provided by seagrass beds
US$ 3.8 trillion · yr⁻¹
(Costanza et al., 1997)

In 2005 IKEA had a global turnover of US$ 22 billion
“mangroves, salt marshes and seagrasses among most cost effective carbon capture and storage systems on planet.”

“Preventing the further loss and degradation of these ecosystems and catalyzing their recovery can contribute to offsetting 3-7% of current fossil fuel emissions – over half of that projected for reducing rainforest deforestation”
Foundation/ Engineering species

Support high biodiversity

Photos: Fiona Crouch, Dominic Flint; Illustrations by Jack Sewell
Seagrass currently bind sediment and protect beaches from erosion

Mill Bay beach, Salcombe
**Zostera marina**, eelgrass
- up to 2m in length, 10mm wide
- Inter-tidal and sub-tidal down to 10m
- Ridges on seeds

**Zostera noltii**, diergrass
- Up to 0.25m long, 10mm wide
- Inter-tidal (in lower regions may create the sub-tidal)
- Smooth seed
Zostera marina distribution

Legend
- Zostera marina
- Potters Island, Jennycliff, Firestone bay, Cawsand

Plymouth area:
- Drakes Island
- Jennycliff
- Firestone bay
- Cawsand

Irving et al., 2006
Which factors regulate seagrass growth, distribution and function?

- Physical
  - Light
  - Hydrology
  - Geology
  - Temperature

- Chemical
  - Salinity
  - Oxygen
  - Nutrients

- Biological
  - Competition
  - Disease
  - Anthropogenic

Climate change has the potential to influence each of these factors.
Temperature changes?

- Positive relationship with Photosynthesis and Respiration
- But at high temperatures $R > P = -\text{ve energy balance}$
- Seagrass species vary in their temperature tolerances
  - *Zostera noltii* upper temperature tolerance of 38°C (Massa et al., 2009)
  - *Zostera marina* -1°C to 25°C

The temperature is therefore considered the overall parameter controlling the global geographical distribution of the seagrass species.
• *Zostera noltii* is at the limit of its distribution.
• Intertidal, with desiccation determining vertical distribution (*Koch, 2001*).
• Environmental factors shape the characteristics of the bed.
• *Zostera marina* is not at the limit of its distribution in UK
• Primarily subtidal
• Low exposure but a range of current velocities
• Mud to gravel but not rock
• Found at salinities as low as 6
• Environmental factors shape the characteristics of the bed
Increased temperature

- Increased seagrass metabolic processes
- New niche for invasive species colonisation
- Decrease production species at thermal tolerance
- Increased dessication for intertidal species
- Shift in distribution of species
- Enhance growth of competitive algae
- Increase metabolism of microbes
Zostera’s Wasting Disease

- Slime mold protist *Labyrinthula macrocystis*
- 1930-40s- large scale (North Atlantic wide) outbreak (Temperature?)
- Some populations survived (primarily subtidal)
- Theory that today’s populations more resilient

Genetic diversity: key to resiliency?

Fig. 4 Neighbour-joining tree based on Reynold’s distances derived from the microsatellite data for *Zostera marina*  Source: Olsen et al., 2004
Physical exposure

• Currents, wave action and tide control the upper depth limit

• Flow velocities < 1.5 m.s\(^{-1}\)

• Affect light climate of the water column

• High exposure:
  – reduce vegetative spreading
  – inhibit seedling colonisation
  – decreased accumulation of fine sediments and organic matter
  (Fonseca et al., 1983)
Deposition of Physical Materials

Increase Storm Activity

Increase sediment erosion

Strong water currents

Cropping effect - removal of leaves

Heavily epiphyte covered leaves will be more susceptible

Change structure of the bed. Increase diversity of species within the bed due to increased level of disturbance

Give competitors the edge - increase opportunistic ‘r’ strategists

Uproot plants

Destabilised sediments and redistribution of sediments

Release/re-suspension of contaminants previously trapped in sediments

Beds die off not getting enough light

Smothering plants

Increase sediment erosion

Increase rainfall and run-off thus turbidity

External Pressure

Environmental Effect

Effect on Organism

Outcome
Light

- Water column transmissivity and depth
- Controls the lower depth limit of seagrass

Photo: Steve Trewhella
Use of Zostera depth limits as a bioindicator under the WFD

Krause-Jensen et al., 2005
Relative exposure

\[
\text{REI} = \sum_{i=1}^{8} (V_i \times P_i \times F_i)
\]

\(i\) is the ith compass heading (eight readings, 45° increments), \(V\) is mean monthly maximum wind speed (ms-1), \(P\) is the percent frequency at which wind occurred from the ith direction and \(F\) is the effective fetch (m) to #m isobath.

Fonseca and Bell (1998)
CO₂: Ocean acidification

- IPCC (2001) predict increasing [CO₂]
- Increase of dissolved inorganic carbon and decrease in seawater pH of up to 0.5 units by 2100
- Increase in the HCO₃⁻/CO₂ ratio in seawater
- Seagrasses can utilise HCO₃⁻ will lead to increase in photosynthetic rate
- Alter compensation depth
- Impacts on epiphytic load but also on mollusc grazers with calcareous shells

Invers et al., 2002 (Bull Mar Sci 71(3))
See also Hall-Spencer et al 2008: Vol 454| 3 July 2008| doi:10.1038/nature07051
Ideas for delivering adaptation responses

- Resilience-building adaptation strategies:
  1. Protect diversity of seagrasses from gene to geographical distribution.
  2. Protect seagrass from manageable vectors of change which may stress or remove populations of seagrass (particularly those important to point 1).
  3. Identify and fully protect seagrass communities that are at low risk of succumbing to climate change and anthropogenic impacts.
  4. Restore critical seagrass areas that are positioned to survive climate change impacts by eliminating manageable.
  5. Raise awareness of the value and threats to seagrasses, ensure that coastal zone management or land use policies and plans address potential impacts to seagrasses and implement codes of conduct for fishing and boat anchoring to reduce disturbances.

Important text: Bjork et al., 2008
IUCN Resilience Science Group
Working Paper Series - No 3
Non climate related pressures

- Nutrient enrichment
- Invasive species
- Mooring and anchor damage
- Increases in turbidity
Adaptive management

• Develop good baseline maps (Plymouth Sound, Salcombe, Torbay, Isles of Scilly etc.)
• Implement monitoring that provide feedback on the results of coastal management, (SeagrassNet; Isles of Scilly monitoring programme) not just for reporting cycles.
• Monitor the right things at the right time (pressures and state)
• One of the most direct early warnings for declining seagrass meadows is a decrease in growth and productivity (measure PSS)
• Accept uncertainty and set appropriate operational targets and review periods
Practical steps and research needs

- Based on climate change predictions, model impacts on seagrass beds spatially to identify risk levels
- Assess genetic diversity of UK seagrass beds
- Research into the ecosystem effects of climate change on UK seagrass beds
- Support UK SeagrassNet stations (the Fal and Helford is home to the first UK site in this global monitoring network!)

http://www.seagrassnet.org/
http://zosteramarina.blogspot.com/