National Environmental Research Program

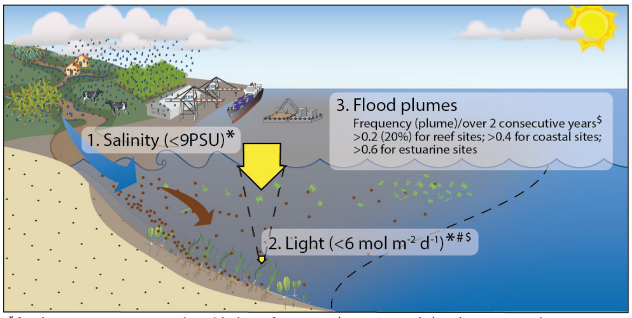
Towards water quality thresholds for healthy seagrass habitats in the Great Barrier Reef



A summary of research from the National Estuarine Research Program Tropical Ecosystem hub (NERP TE) project 5.3

Flood plumes affect seagrass health

- Seagrass meadows are exposed to a range of potential impacts including cyclones, physical disturbance, wind-induced resuspension of sediment, dredging operations, sedimentation and flood plumes.
- Flood plumes generally cover large areas of the inshore GBR and are characterized by low salinity, high nutrient concentrations (triggering "green water"), toxicants, and both dissolved ("coloured water") and particulate matter ("brown water"). Plume waters reduce light penetration, which can reduce seagrass growth and overall health.
- Dredge plumes generally cover relatively small areas of the inshore GBR and can also create brown water with similar characteristics and consequences to seagrass as flood plume waters.
- Repeated exposure to this range of potential impacts resulted in the loss of seagrass meadows in the GBR during 2009-2011 (abundance fell below regional guidelines at 67% of sites). Some signs of recovery are now being observed.
- This research has focused on the impact that salinity, low light and nutrients may have had on the growth and overall health of seagrasses.



*for short-term exposure, varies with time of exposure (up to 3 months) and among species
#affected by temperature $threshold is established for seagrass loss of greater than 50%

Figure 1. Salinity (1), light (2) and flood plume (3) thresholds were identified in this research.

- Findings indicate that low light conditions could have been a major contributor to the observed loss of seagrass meadows.
- Salinity, light and flood plume thresholds for these seagrasses have been developed in this research (Figure 1).

Frequency of exposure to flood plumes

- *F(plume)* is a proxy measurement representing a combination of colour classes that relate directly to the quality of the waters and impact on each seagrass habitat (estuarine, coastal, reef intertidal and subtidal) differently.
- For example, high turbidity waters, represented by a combination of colour class (CC) 1-4, are the main water type influencing the ecological condition of the estuarine seagrass sites. Estuarine seagrass beds exposed to CC 1:4 for >60% of the wet season are predicted to decline >50% in seagrass cover. Annual and multi-annual measurements of ocean colour can be related to broad scale water quality measurements, including annual values of light attenuation over the total seagrass bed.

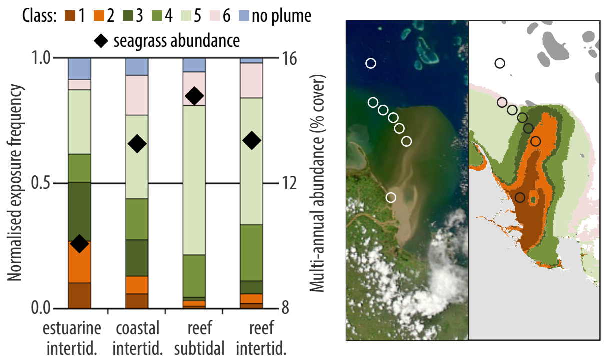


Figure 2. (Left) The combination of ocean colour classes measured (expressed as a normalized frequency) within each seagrass habitat and corresponding multi-annual (2007–2012) seagrass cover. (Right) MODIS image and corresponding colour-class map.

Salinity thresholds

- Floodwater is low in salinity, but the tolerance limit of seagrasses to low salinity was not known.
- Seagrass (three species) responses to salinity ranging from seawater at 36 practical salinity units (PSU) to 3PSU (almost fresh water) were tested over 10 weeks.
- Seagrasses were quite tolerant of short-term exposure to low salinity.
- They showed what is likely to be a mild stress response with density (number of leafy shoots) actually increasing by 400% at low-moderate salinity (6-9 PSU) for *Zostera muelleri*, and by almost 200% at 9-15 PSU for other species (Figure 3).
- Density declined sharply at the lowest salinity, indicating a salinity threshold of <9PSU.
- Because of their broad salinity tolerance, and the limited scope for management of salinity, establishment of salinity guidelines is a low priority.

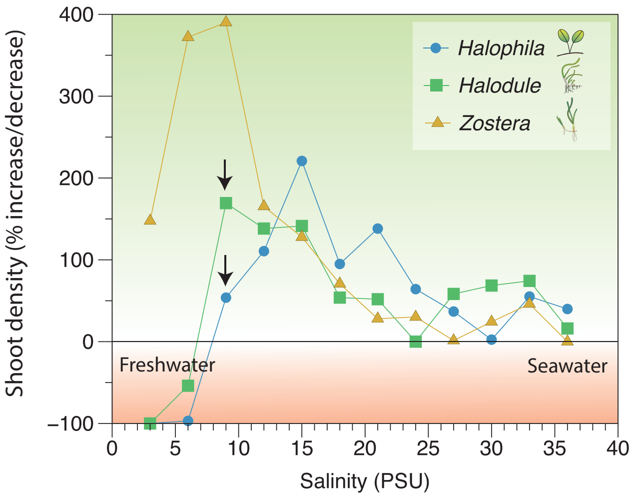


Figure 3. Change in seagrass shoot density (leaf pair density for *Halophila*) relative to week zero, after 10 weeks exposure to low salinity ranging from almost freshwater (3 PSU) to marine seawater (36 PSU). Density declined sharply below 9 PSU (↓).

Light thresholds

- Density and growth responses of seagrass species to low light (shading) was measured for just over 3 months in cool (22°C) and warm (27°C) water.
- In very low light (simulating muddy water) density and growth declined (Figure 4). There was more decline as the duration of exposure increased and in warm water.
- In warm water there was complete mortality (no seagrass remaining) of the most sensitive species, *Halophila*, after only 17 days. This was followed closely by *Zostera* (30 d), whereas *Halodule* survived for more than 3 months.

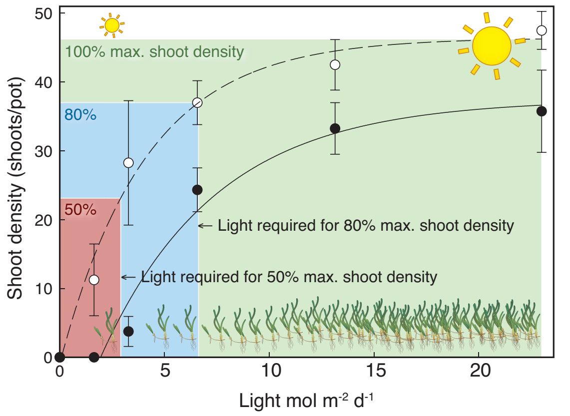
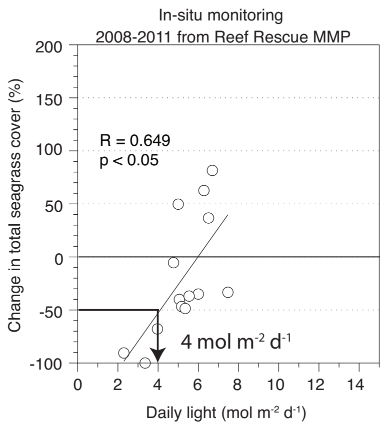


Figure 4. Shoot density of *Zostera* after almost 3 months at light levels ranging from no sunlight (complete darkness) to 23 mol m^{-2} d^{-1} (70% of full sunlight) in cool (white circles) and warm (black circles) water. From this data we can calculate the light level that caused 20% or 50% decline of seagrass. This calculated light level is a "threshold".

- The light level causing 20% decline (80% saved) ranged from 4 to 10 mol photons m^{-2} d^{-1} over 3 months, and for 50% decline ranged from 3 to 6 mol photons m^{-2} d^{-1} depending on species and water temperature.
- These values are relevant to short-term low light events (up to 3 months), but do not represent long-term minimum light requirements.
- Figure 4 shows aquarium-based threshold calculations for *Zostera*. Using the same method for *Halodule*, 50% loss occurred at 3.8 mol photons m^{-2} d^{-1} in warm water after 3 months. In situ loss of 50% occurred at 4 mol photons m^{-2} d^{-1} after 3 months (Figure 5). These very similar thresholds suggest aquarium results can be used for further threshold development.

Figure 5. Change in the abundance of *Halodule*-dominated meadows at Magnetic Island, with each point representing change over a 3 month period, and average light reaching the seagrass canopy. 50% loss of seagrass was occurred at a light level of 4 mol m^{-2} d^{-1}.



How can this information be applied?

Monitoring and reporting

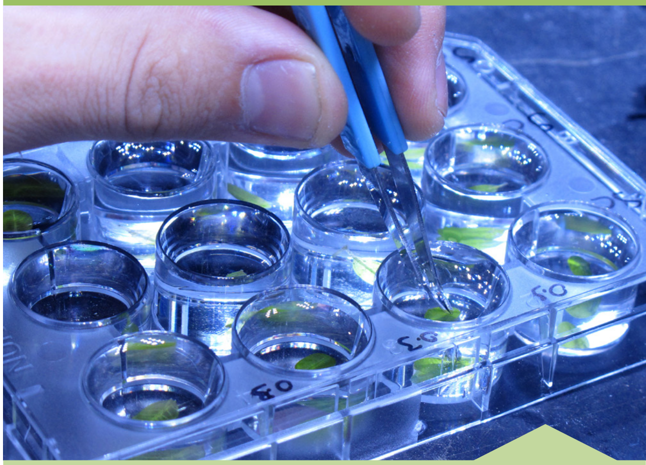
The Reef Rescue Marine Monitoring Program (MMP) measures and reports annually, on water quality and seagrass health. These seagrass salinity and light tolerance thresholds can be used to explain some of the observed changes in seagrass meadow health. There are additional environmental factors that can affect seagrass health, and these are also considered when explaining changes in seagrass health.

Development of water quality guidelines

Researchers have proposed that results of this research be used to develop short-term guidelines for these seagrasses. These guidelines could be an important consideration in determining and managing potential environmental impacts on seagrass meadows associated with dredging operations. For these thresholds to become operational, information on what reduces the available light is also required. Management actions that can be taken will primarily relate to catchment management actions that target the reduction of sediment and/or organic matter input.

Figure 6. Long-term seagrass monitoring for the Reef Rescue MMP (a-c) includes ongoing measurement of light received in the seagrass canopy (b) as well as water quality (c). The development of water quality guidelines for seagrass will help managers reduce the associated impacts of dredging operations (d).

RELATED PROJECTS



Herbicides

In a related NERP TE project led by Dr Andrew Negri (AIMS), the effect of herbicides on seagrasses were tested. Threshold levels of herbicide exposure that reduce seagrass photosynthetic efficiency and affect seagrass energetic balances were identified.

Figure 7 (above). A bioassay for rapidly screening seagrass exposure to herbicides has been developed. This is just one of the techniques being used to identify seagrass herbicide thresholds.

Port Curtis seagrass light requirements

Developing a light-based seagrass management strategy using locally derived light thresholds for *Zostera muelleri* was implemented as part of a dredge management plan in Port Curtis. The work used in situ shading studies, long term light and seagrass monitoring and lab based manipulative experiments to derive locally relevant light thresholds. These were adapted into traditional turbidity-based monitoring programs. Sub-lethal indicators of light stress and the effect of spectral quality of light were also invested in this project.

Dynamics of deep-water seagrasses

The TropWATER seagrass group also has research programs established to determine the light requirements of deep-water Halophila species (>15m). These studies include a range of field and laboratory manipulative studies focusing on light requirements and their interactions with temperature, season and spectral shift, as well as establishing sub-lethal indicators for management. Study sites are at Green Island, Lizard Island, Abbot Point and Mackay.

Further details can be found at: http://research.jcu.edu.au/research/tropwater/research-programs/seagrass-ecology-1/seagrass-ecology

Publications arising from this work:

Collier, C.J., Villacorta-Rath, C., van Dijk, K.-j., Takahashi, M., and Waycott, M. (2014). Seagrass Proliferation Precedes Mortality during Hypo-Salinity Events: A Stress-Induced Morphometric Response. *PLoS ONE* 9, e94014.

Collier, C.J., Langlois, L., McKenzie, L., and Waycott, M. (In Prep). Seagrass protection guidleines developed from experimental light response curves.

Collier, C.J., Waycott, M., and McKenzie, L.J. (2012). Light thresholds derived from seagrass loss in the coastal zone of the northern Great Barrier Reef, Australia. *Ecological Indicators* 23, 211-219.

Petus, Caroline, Catherine Collier, Michelle Devlin, Michael Rasheed, and Skye McKenna. "Using MODIS data for understanding changes in seagrass meadow health: A case study in the Great Barrier Reef (Australia)." *Marine environmental research* 98 (2014): 68-85.

Devlin, Michelle J., Eduardo Teixeira da Silva, Caroline Petus, Amelia Wenger, Daniel Zeh, Dieter Tracey, Jorge G. Álvarez-Romero, and Jon Brodie. "Combining in-situ water quality and remotely sensed data across spatial and temporal scales to measure variability in wet season chlorophyll-a: Great Barrier Reef lagoon (Queensland, Australia)." *Ecological Processes 2*, no. 1 (2013): 1-22.

Contributors:

Catherine Collier, Michelle Devlin, Cecilia Villacorta-Rath, Lucas Langlois, Matthew Adams, Kate O'Brien, Len McKenzie, Carol Honchin, Katherine Martin, Caroline Petus, Eduardo da Silva, John Statton, Kathryn McMahon, Michelle Waycott.

National Environmental Research Program

JAMES COOK UNIVERSITY AUSTRALIA

THE UNIVERSITY of ADELAIDE

THE UNIVERSITY OF QUEENSLAND AUSTRALIA