Seagrass

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What is happening

A southern range extension of 300km into Moreton Bay (Qld) of the tropical seagrass *Halophila minor* consistent with warming and a strengthening of the East Australian Current

What is expected

Declines in seagrass abundance and extent due to sea-level rise and increased storminess. Warming temperatures increase extinction risk for temperate species already considered Vulnerable or Near Threatened under IUCN guidelines. Decline and loss of some species of intertidal seagrass in northern Australia with warmer asir temperatures.

What we are doing about it

Ongoing monitoring and research into the impacts of climate change on seagrass beds, including quantitative modeling at local scales. Investigations into the role of seagrass beds as carbon sinks for CO2 mitigation.

Executive Summary

Seagrasses in Australia are extensive and diverse, and function as ecosystem engineers. They oxygenate the water column, regulate nutrients, stabilise sediments, protect shorelines by restricting water movement, provide food for finfish, shellfish and mega herbivores including green turtles and dugongs, and support commercially and recreationally important fisheries species.

As plants living in shallow coastal waters, the critical factors for seagrass growth are light, temperature, CO_2, nutrients and suitable substrate, all of which are affected by climate change. Seagrasses are therefore vulnerable to a changing climate, and will be sentinels for the changing marine ecosystems of Australian coastal waters.

Seagrass habitat continues to be at risk from the direct impacts of human activities along the coastline. Two temperate seagrass species found only in Australia were recently assessed using IUCN criteria as Vulnerable or Near Threatened, due to declining water quality in shallow coastal waters. These assessments were made without taking into account any potential longer term effects of climate change, because of a serious gap in understanding about how seagrass respond to interacting impacts. Monitoring of seagrasses continues in many places around the Australian coastline, but there have been no new records of range shifts for seagrass species since the first report card.

In the first report card, predictions of seagrass responses to climate change were made from a general understanding of the relationship between seagrass health and environmental variables. Expected changes included decreased productivity generally, local to large scale loss due to decreased light, community change towards heat tolerant species and distributional changes. The confidence with which prediction can be made has increased marginally since then, based mainly on a test for relationships between seagrass biomass and area and climatic variables as part of a long term monitoring program in northern Australia. Patterns of change in intertidal seagrasses show strong relationships with climate. This type of information is just beginning to be used to predict local scale changes in seagrass cover and species composition, putting scientists on the cusp of significantly more useful advice about adaptation and management.

The other major advance since the first report card is the realization that seagrass habitat potentially sequesters dissolved (and therefore atmospheric) carbon at a phenomenally high rate and for very long periods. The role of seagrass in Blue Carbon has quickly become a very active area of research, both from an Australian and global perspective.

Definition and importance of seagrasses

Seagrasses are widely distributed around the globe but are at their most extensive and diverse in Australia. They occur around the entire Australian coastline, generally in shallow marine waters such as estuaries, protected bays, lagoons and reef platforms protected from strong water movement, but also in deeper waters (to 70 m) in northern Australia where water clarity is high.

Seagrasses have been ranked as one of the most ecologically and economically valuable biological systems on earth. They are widely referred to as “ecological engineers”, because of their significant influence on their physical, chemical and biological surroundings (Orth et al. 2006, Waycott et al. 2009, Fourqurean et al. 2012).

They play an important role in:

- regulating oxygen in the water column and sediments
- regulating nutrient cycles
- stabilising sediments
- protecting shorelines through the restriction of water movements
- providing an important food source for finfish, shellfish and mega-herbivores including green sea turtles and dugongs
- providing habitat for microbes, invertebrates and vertebrates including commercially and recreationally important species, as well as crucial habitat for endangered species

- organic carbon production, which may be sequestered in situ or transported to adjacent ecosystems.

Multiple stressors

The generally shallow, coastal distribution of seagrasses that makes meadows vulnerable to climate impacts also leaves them vulnerable to coastal urbanisation, agriculture and other human activities. Recent reviews highlight substantial ongoing seagrass decline and document the massive, contemporary source of disturbance that anthropogenic stressors have on seagrass systems. These non-climate stressors are presumed to reduce the resilience of seagrasses to climate change. In Australia, losses, fragmentation and detrimental changes in seagrass health have been documented for over 60 years, and the rate and intensity of these non-climate impacts remain of great concern.

One telling development in our understanding of seagrass vulnerability comes from a recent assessment of the status of seagrass species using IUCN Red List criteria (Short et al. 2011). This global survey found that two temperate seagrass species endemic to southern Australia were of concern. Declines in distributions and on-going threats from declining water quality in shallow coastal waters left *Posidonia sinuosa* with the status Vulnerable, and *Posidonia australis* as Near Threatened. It is significant that these assessments were made without consideration of potential longer term issues relating to climate change. Any climate impacts will interact with the factors already known to affect seagrass communities. It is not known for sure whether these interactions will be antagonistic (tending to cancel out the other) or synergistic (magnifying the detrimental effect on seagrass), but it is likely that at least in some cases climate change will exacerbate the risks to seagrass.

Observed impacts

The critical factors for seagrass growth and survival are light, temperature, dissolved carbon dioxide, nutrients and a suitable substrate for anchoring (Green and Short 2003). The present-day distributions and abundances of different species of seagrass reflect their specific requirements for these factors. As climate change affects all of these factors, changes can be expected in seagrass growth, survival, distribution, abundance and community composition (Waycott et al. 2007).

Observations: Summary from First Report Card

- Observations of climate change impacts are rare, possibly due to a lack of long term datasets, with just two reported links to warming temperatures.
- Evidence of large-scale diebacks of seagrass in the Spencer Gulf, SA, suspected to occur with elevated temperatures during El Niño conditions.
- The sub-tropical seagrass, *Halophila minor*, has recently extended south into Moreton Bay, SE QLD, consistent with a strengthening of the East Australian Current and warming temperatures.

Update on First Report Card

The intention here is to provide an update of monitoring and research results relating to climate change effects on Australian seagrass systems since the first report card. The paucity of long term seagrass datasets in Australia remains, and predictions therefore are largely still limited to a process of marrying expected changes in climate with experimental evidence about seagrass responses to environmental variables. Scientists are, however, making better use of the seagrass monitoring data that do exist, and are beginning to analyse the strength of climatic variables as drivers of seagrass patterns.

The most important new evidence comes from an analysis of patterns of change in intertidal seagrass cover and biomass at Karumba, in the southern Gulf of Carpentaria, Queensland (Rasheed and Unsworth 2011). This data-set was built from detailed, on-ground community analysis of intertidal seagrass meadows using consistent methods over 16 years (Figure 1). Patterns of change in seagrass were compared with several climate variables measured over appropriate periods preceding seagrass measurements (from 3 to 12 months depending on the climate variable).

The two main seagrass species showed different patterns of abundance over the monitoring period and also correlated with different climate variables. Biomass of the dominant species at this location, *Halodule uninervis*, was lower after periods of high ambient air temperatures (negatively correlated), and higher after major river flows (positively correlated). *Halophila ovalis* biomass, in contrast, was best explained by a positive relationship with rainfall over the preceding year.

The climate variables explained as much as half of the variance in the seagrass biomass data in the study by Rasheed and Unsworth (2011). Much of the variability, however, was at relatively short time scales (e.g. from year to year). For seagrass, even a monitoring period as long as 16 years has just one or two periods of major highs and lows in abundance, limiting the confidence in the conclusion. A stronger test of climate influence would come from a longer term record of seagrass. This sort of record might possibly be gleaned from forensic analysis of some feature of the environment that contains a natural chemical marker for seagrass presence or abundance. This might, for example, be possible using dated profiles of sediment at a site (Macreadie et al. 2012).

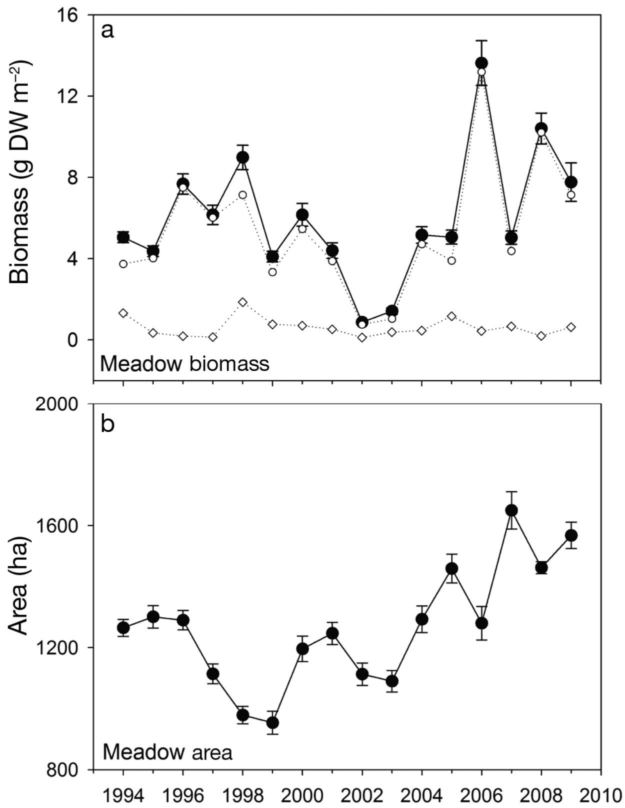

Figure 1. Long term (1994 - 2009) monitoring results for intertidal seagrass at Karumba in Gulf of Carpentaria, tropical north Queensland. For biomass, closed circles are for total biomass; open circles for *Halodule uninervis*; open diamonds for *Halophila ovalis*. From Rasheed and Unsworth (2011).

Potential impacts by 2030 (and/or 2100)

Potential impacts: Summary from First Report Card

- Elevations in sea-level and increases in the intensity of extreme events such as storms and cyclones will reduce light availability and are expected to negatively impact seagrasses
- Cool-temperate seagrasses in southern Australian waters are expected to be more vulnerable to rising temperatures then tropical species
- Shallow sub-tidal species are more vulnerable to warming temperatures and extreme events then deeper-living seagrasses

Update on First Report Card

Scientists are on the cusp of substantially improved predictions of climate impacts on seagrass in Australia. This work is developing rapidly. Some very encouraging preliminary results have been presented at recent national and international science conferences.

Quantitative modelling of the effects of SLR on seagrass are being undertaken by Megan Saunders at University of Queensland. The effects of SLR on seagrass in subtropical Moreton Bay, southeast Queensland, have been modelled by overlaying predicted values for SLR onto stylized seabed bathymetry, to estimate likely shifts and changes in total area available as potential habitat for shallow and intertidal seagrass (M. Saunders 2011 AMSA presentation, Perth WA). At this stage, predictions are not modelled dynamically with likely responses of seagrass to other climate variables such as temperature, but modelling of such interactions is planned.

Another useful advance is the modelling of likely shifts in distributions of different species of seagrass to SLR, based on known light requirements, in a spatially explicit fashion at local scales (tens to hundreds of metres) in tropical seagrass meadows in an exemplar section of the GBR (M. Saunders 2012 ECSA presentation, Venice Italy).

Such models should become more realistic quite quickly with the addition of the more detailed environmental drivers being determined by long term (Rasheed and Unsworth 2011) or spatially-intense measurements (C. Collier 2012 ICRS presentation, Cairns, QLD).

Confidence Assessment: Observed and Expected Impacts

Confidence in observations is little changed since the first report card. Some further work has been undertaken, for example to test multi-year (16 years) seagrass data against climate variables, but while this helps build our understanding of environmental influences on seagrass, the records are not over long enough periods to be observations of long term change due to climate.

Confidence in expected changes has improved slightly since the first report card because a little more data exists on the relationship between seagrass and climate variables, and because preliminary modelling is beginning to quantify changes in seagrass with sea level rise. Confidence will rise again once these works are published and available and become more widespread.

Table 1. Summary of observed and projected changes in Australian seagrass habitat and confidence levels about those changes

	Amount of evidence	Degree of consensus	Confidence level
Observed changes			
1. Seagrass loss over 13,000 ha area due to heat stress in single incident in southern Australia.	Low	High	Low
2. Range extension of tropical species (*Halophila minor*) into subtropical waters (300 km shift).	Low	High	Low
Expected changes			
1. Decreased productivity generally. Potentially enhanced productivity due to increased dissolved CO_2 and warmer water overridden by increased water depth, and pulsed turbidity from more extreme rainfall and thus river plumes. Local exceptions in clear, still water (where CO_2 is currently limiting).	Low	Medium	Low
2. Local (to large) scale loss due to decreased light (increased water depth, turbidity, storm intensity), increased storm intensity and water temperature. Shallow water seagrass extremely vulnerable.	Medium	High	Medium
3. Seagrass community change to heat tolerant species (and/or species favouring CO_2 uptake).	Medium	Medium	Medium
4. Long-term decline of seagrass health and extent in some places, species changes in other places.	Low	High	Low
5. Distribution changes to seagrass species. Recolonisation higher on shore, and southward shift (where not prevented by physical barriers or unsuitability of substrate), and especially favouring species with seed dispersal. Diminished range in some species, or lost altogether, especially with synergistic effects of other, non-climate stressors.	Medium	High	Low
6. Reduction or loss of ecosystem services provided by seagrass, such as support of dugong and turtle populations, and fisheries productivity reliant on seagrass (and attached algae) either as nursery habitat or for nutrition in adjacent habitats.	**Medium**	**Medium**	**Medium**

Summary of Confidence Assessments for Observed and Future Changes in Australian Waters

	Observed Changes	Future Changes
Amount of Evidence	Low	Low-Medium
Degree of Consensus	High	Medium-High
Confidence Level	Low	Low-Medium

Current and planned research effort

There has been a pronounced shift in research direction since the first report card. The role of coastal habitats in global carbon sequestration has come sharply into focus – the phenomenon now known as Blue Carbon (see < http://bluecarbonportal.org/>. Two attributes of seagrass have been discussed in this context.

First, genetic analysis of the Mediterranean seagrass *Posidonia oceanica* demonstrated that seagrasses can have great longevity. The modular growth form of seagrass means that an individual plant (technically known as a genet – all parts of the plant deriving from a single seed, whether retaining physical connections via rhizomes or not) potentially can be spread over a wide area. Genetic analysis showed that an individual *P. oceanica* plant could be spread over several kilometres, and might be as old as hundreds or even many thousands of years (Arnaud-Haond et al. 2012).

Second, global analysis of rates of sequestration of carbon into coastal sediments showed that seagrass might be locking dissolved (and thus ultimately atmospheric) carbon away at a very fast rate (Irving et al. 2011). And just as importantly, healthy seagrass meadows appear to lock that carbon in the sediment for long periods (hundreds or perhaps thousands of years). The role of seagrass in Blue Carbon has quickly become a very active area of research (Fourqurean et al. 2012), both from an Australian and global perspective.

Knowledge Gaps

The key knowledge gaps that need addressing remain similar to those listed in the first report card:

- Better defined thermal tolerances for Australian seagrass species
- Informative modelling of changes in coastal catchment runoff at a local scale under climate change
- Dispersal and recolonisation information for seagrasses and their associated fauna – how will seagrass communities respond to a higher rate of habitat fragmentation?

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