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15B Seagrasses and seagrass ecosystems

Monitoring inshore seagrasses of the GBR and responses to water quality

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Abstract. Seagrass are sensitive to environmental changes and can be monitored to detect human influences to coastal ecosystems. Measurable changes in seagrass abundance, distribution and condition provide resource managers with advance signs of deteriorating ecological conditions caused by poor water quality. For this reason, seagrasses are considered biological sentinels.
The Great Barrier Reef's (GBR) inshore seagrasses are being monitored as part of the Reef Rescue Marine Monitoring Programme (MMP). Information from the program is being used to assess the long-term effectiveness of management actions in reversing decline in water quality of the GBR Marine Park. Since 2005, inshore seagrasses have been monitored across the six Natural Resource Management regions (NRMs) adjacent to the GBR World Heritage Area, south of Cooktown. Inshore seagrasses are currently monitored sub-regionally (habitats) at 30 sites using Seagrass-Watch as the basis. Results from the monitoring report annually on seagrass status and are incorporated into a report card for the health of the GBR. Seagrass community status is assessed using measures of seagrass abundance and reproductive effort, while epiphyte abundance and seagrass leaf tissue C:N:P elemental ratios (atomic) indicate the WQ environment. Modifiers such as edge mapping, *in situ* canopy temperature and *in situ* light are also used to interpret the data. The environmental status indicates progressive degraded water quality where plants were growing in low light environments, with relatively large phosphorus pool and excessive nitrogen pool. Further refinement of the indicators will enable greater use of these metrics for water quality management of the GBR.

Key words: seagrass; monitoring; water quality; Seagrass-Watch; Reef Rescue; Great Barrier Reef.

Introduction

Seagrass are considered coastal canaries or coastal sentinels that can be monitored to detect human influences on coastal ecosystems (Orth et al. 2006). Since 1990, seagrasses globally have been declining at a rate of 7% per year (Waycott et al. 2009). Multiple stressors are the cause of this decline, the most significant being degraded water quality. In seagrass ecosystems, nutrients and light are the most common limiting factors that control abundance (Waycott and McKenzie 2010). Indeed, the various threats to seagrass ecosystems along the coast of the GBR (from cyclones to agricultural/urban/industrial runoff and urban/port developments) cause a variety of impacts to seagrass growth (Grech et al. 2011).

Approximately 3,063 square kilometres of coastal seagrass meadows has been mapped in Great Barrier Reef World Heritage Area (GBRWHA) waters shallower than 15m, and in locations that can potentially be influenced by adjacent land use practices (McKenzie et al. 2010). An additional 31,778 square kilometres of the sea floor within the GBRWHA has some seagrass present (Coles et al. 2009). This represents more than 50% of the total recorded area of seagrass in Australia (Green and Short 2003) and between 6% and 12% globally (Duarte et al. 2005) making the Great Barrier Reef's seagrass resources globally significant.

Healthy seagrass meadows in the GBR act as important resources as the primary food for dugong, green turtles, numerous commercially important fish species and as habitat for large number of invertebrates, fish and algal species. Much of the connectivity in reef ecosystems depends on intact and healthy non-reef habitats, such as seagrass meadows.

Monitoring the major marine ecosystem types most at risk from land based sources of pollutants ensures that any change in their status is identified. As seagrasses are well recognised as integrators of environmental stressors, monitoring their status and trend also provides insight into the status of the surrounding environment.

Observations such as seagrass abundance and reproductive health provide a measure of status and resilience, whereas leaf tissue C:N:P ratios provide insight into the responses of seagrass to nutrient regimes and may be advantageous for the early detection of environmental change.

The requirements for formation of healthy seagrass meadows are relatively clear as they require adequate light, nutrients, carbon dioxide, suitable substrate for anchoring along with tolerable salinity, temperature and *p*H (Waycott and McKenzie 2010). Indicators and thresholds have been established for some GBR seagrass communities, and are monitored as part of the Reef Rescue MMP.

Material and Methods

The sampling design was selected for the detection of change in inshore seagrass meadows in response to improvements in water quality parameters associated with specific catchments.

Inshore seagrass meadows representing three of the four major seagrass habitat types across the GBR were monitored along the urban coast south of Cooktown: estuary/inlet, coastal, and reef (Fig. 1). To account for spatial heterogeneity within habitats, two sites were selected at each location.

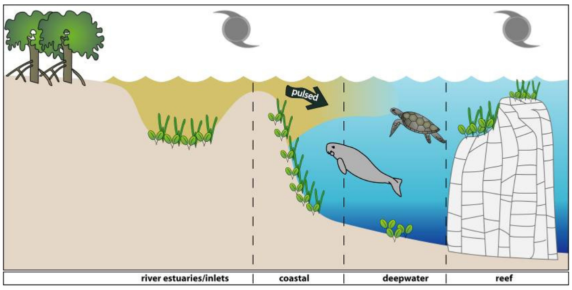

Figure 1: General conceptual model of the four major seagrass habitats in north east Australia (from Carruthers et al. 2002).

Monitoring occurred at 15 locations from Archer Point in the north to Urangan, just south of the marine park boundary (Fig. 2). Meadows chosen for monitoring were lower littoral (rarely not inundated) and sub littoral (permanently covered with water at least ankle deep), but have been classified as intertidal for this assessment. As the major period of runoff from catchments and agricultural lands was the tropical wet (monsoon), monitoring was focused on the late dry season and late wet season to capture the status of seagrass prior and post wet.

Field survey methodology followed Seagrass-Watch standard protocols (McKenzie et al. 2007; www.seagrasswatch.org). Intertidal sites were a 50m x 50m area within a relatively homogenous section of a representative seagrass meadow (McKenzie et al. 2000). Sites were monitored for seagrass cover and species composition. Additional information collected included canopy height, macro-algae cover and epiphyte cover. Seagrass reproductive health was assessed by per area estimates of the number of reproductive structures (spathes, fruits, flowers) by any seagrass species during the late dry season (October). In late dry season, leaf tissue nutrient samples were also collected for the foundation seagrass species to determine the availability of nutrients for growth.

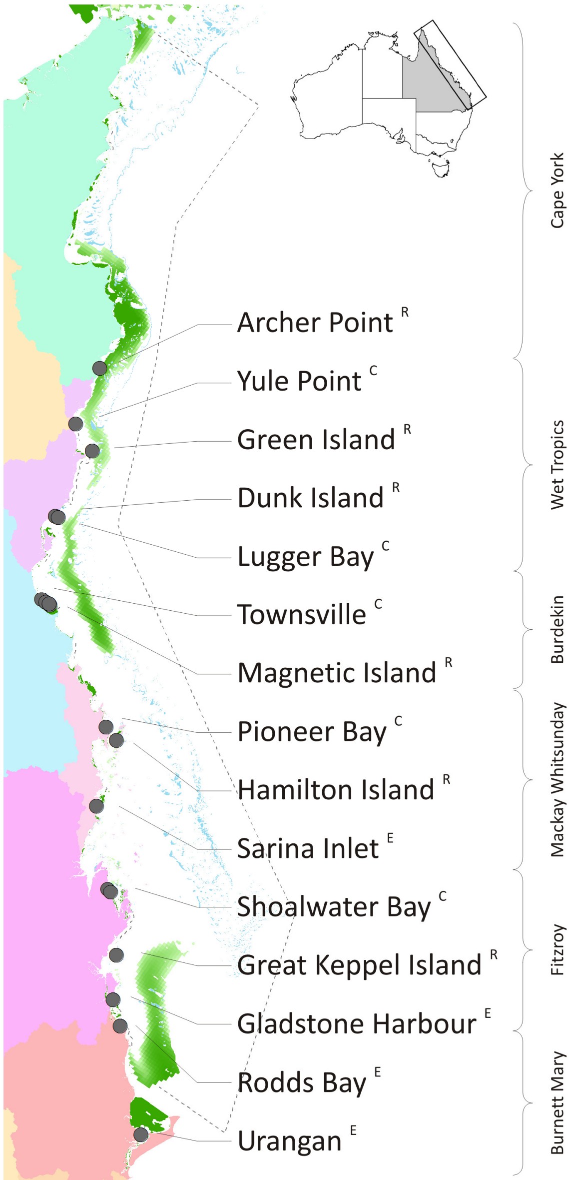

Figure 2: Seagrass distribution and Reef Rescue MMP long-term seagrass monitoring locations within the GBR World Heritage Area and each NRM. Seagrass habitat identified as: C, coastal; E, estuarine; R, reef. Seagrass distribution from McKenzie et al. 2010, is composite of all maps pooled; deepwater meadows (>15m) are modelled probabilities (>50%, pixel size of $2km^2$) from ground truth points.

Results

Seagrass species richness differed between habitats across the inshore GBR, with higher number of species at reef than coastal or estuarine habitats. Reef habitats were dominated by *Halodule uninervis, Thalassia hemprichii, Cymodocea* spp. and *Halophila ovalis*, coastal were dominated by *H. uninervis* and *H. ovalis*, and estuary dominated by *Zostera muelleri* subsp. *capricorni*.

The patterns of seagrass abundance also differed between habitat types since long-term monitoring was established (Fig. 3).

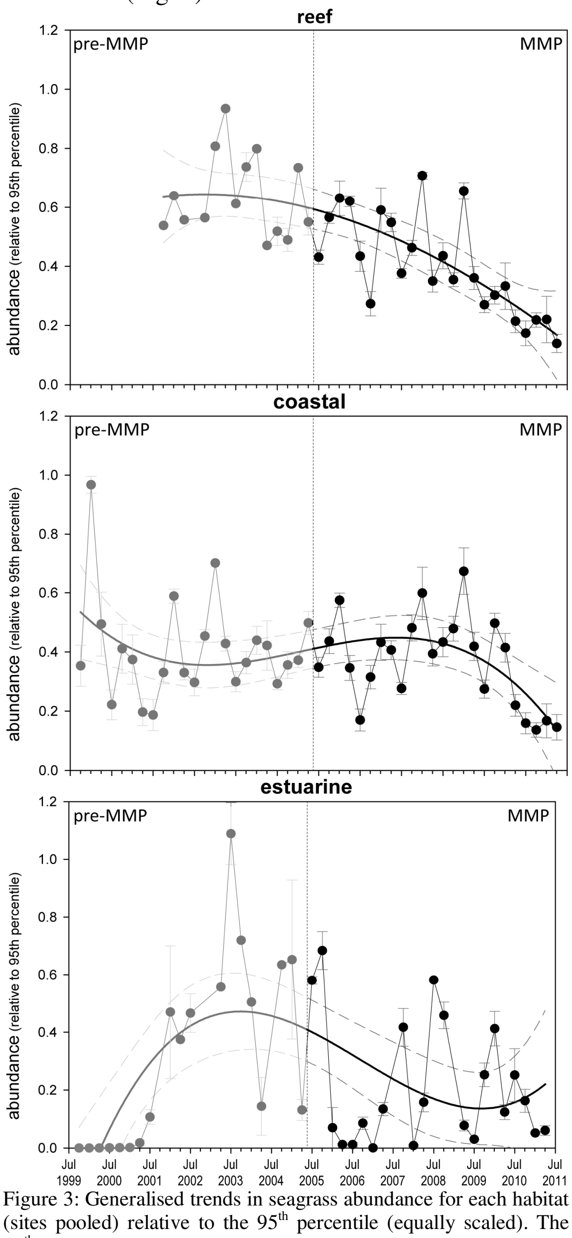

Figure 3: Generalised trends in seagrass abundance for each habitat (sites pooled) relative to the 95th percentile (equally scaled). The 95th percentile is calculated for each site across all data. Data prior and post implementation of the RRMMP (July 2005) displayed. Trendline is 3rd order polynomial, 95% confidence intervals displayed, reef r^2 =0.606, coastal r^2 = 0.218, estuary r^2 = 0.337.

The average seagrass percent cover (over the past 12 years) at each of the inshore GBR habitats were 13% for estuarine, 16% for coastal, and 22% for reef. Seagrass abundance has fluctuated greatly in estuarine habitats; most often as a response to climate (eg rainfall, temperature and desiccation) and at smaller localized scales there have been some acute event related changes. However both reef and coastal seagrass have been declining since 2009 (Fig. 3).

Of the 30 sites examined across the GBR south of Cooktown in 2010/11, 17% were classified as poor and 77% were classified as very poor in abundance in late monsoon 2011. Seagrass abundance declined across five of the six NRM regions monitored. Seagrass abundance at locations in the Fitzroy or northern Wet Tropics regions were stable or increasing; however most locations across the GBR have been declining since 2009. On top of this, significant losses occurred in early 2011 as a result of the highest floods in over 30 years impacting three-quarters of the state, and one of the most powerful cyclones to affect Queensland since records commenced (TC Yasi) impacting the region between Cairns and Townsville.

Across the GBR as a whole, reproductive effort, was found to be greater in coastal and estuarine habitats by nearly 3 times that of reef habitats (Fig. 4).

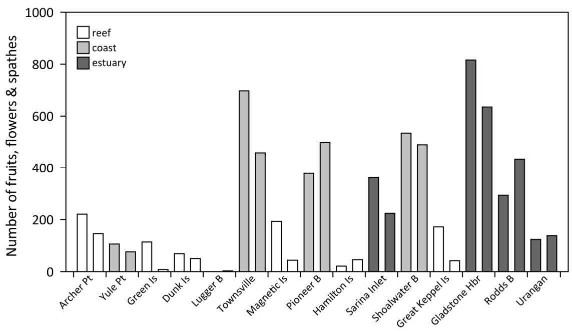

Figure 4: Total number of reproductive structures (fruits, flowers and spathes) produced by any seagrass species during the sampling period (all sampling events pooled) at each of the long-term monitoring sites (2005-2010).

Seagrass seed banks varied greatly between habitats, locations and years. Very large seed banks were found in the coastal habitats of the Burdekin region (Townsville), however seed banks have been near absent from coastal and reef sites in the southern Wet Tropics since monitoring was established.

Seagrass leaf tissue nutrient concentrations were variable between years, both across and within habitats between years. By pooling across species and habitat types, some trends are apparent.

Seagrass leaf tissue nutrient concentrations (%N, %P) appear to have increased since 2006 across all habitats (Fig. 5).

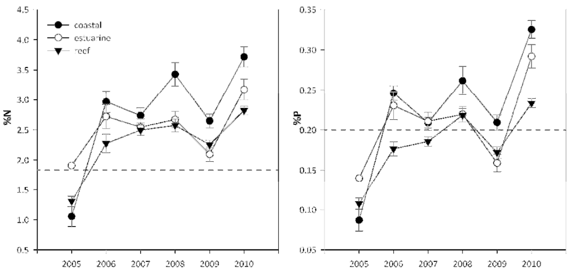

Figure 5: Mean seagrass leaf tissue nutrient concentrations (±SE) for each habitat type over the entire monitoring program. Dashed lines indicate global threshold values of 1.8% and 0.2% for tissue nitrogen and phosphorus, respectively (Duarte 1990).

Since 2005, tissue nitrogen concentrations for all habitats have exceeded the global threshold value of 1.8%. Mean tissue phosphorus concentrations for all habitats also exceeded the global threshold value of 0.2% in 2010 after concentrations in reef and estuarine habitats dropped below the global average in 2009. Duarte (1990) suggested tissue nutrient concentrations less that the global average implied nutrient limitation to seagrass growth. Although applicability of the global thresholds to the small, fast turnover species in the GBR is yet to be verified, nitrogen and phosphorus concentrations for all habitats reached their highest levels in 2010.

In 2010, all three habitat types (coast, reef and estuary) had C:N ratios <20; these levels have mostly declined since 2005. This decrease may be a consequence of N loading, however low C:N levels in 2010 could potentially indicate reduced light availability as an atomic C:N ratio <20 suggests reduced light availability (Abal et al. 1994; Grice et al. 1996).

In 2010, C:P and N:P ratios decreased across all habitats due to an increase in leaf tissue P. Reef and coastal habitats had N:P ratios between 25 and 30, indicating seagrass to be nutrient replete. In estuary habitats, N:P ratios declined below 25 for the first time since monitoring commenced, suggesting the plants have become N-limited.

Epiphyte abundance was found to be variable but increased slightly in estuarine and coastal meadows in 2010/11 and macro-algae abundance has remained low across all habitats.

Discussion

Seagrass form critical ecosystems in north eastern Australian coastal waters and deserve similar attention from management agencies, researchers and the public as other habitats, including coral reefs. The role of seagrass in fisheries production and sediment stabilisation is well known, but their role is much more diverse, spanning from directly providing food for endangered/ vulnerable species and filtering nutrients from the water, through to carbon sequestration.

Prior to the extreme weather events of early 2011 the seagrass meadows of the GBR were in a vulnerable condition with declining trajectories reported throughout much of the GBR (McKenzie et al. 2012). These impacts exacerbate the already stressed seagrass ecosystems. Overall there are indications that seagrass meadows along the GBR are continuing to decline and are now in a very poor state.

Water quality and ecological integrity of some coastal waters of the GBR are affected by material originating in adjacent catchments as a result of human activity, including primary industries and urban and industrial development. The coastal zone receives an average annual input of sediment in the order of 14 - 28 Mt y^{-1}; an estimated increase by at least four times compared to estimates from before the year 1850 (Schaffelke et al. 2005). Most sediments are deposited within the first few kilometres of river mouths (Larcombe and Woolfe 1999), however fine sediment particles can travel large distances (Devlin and Brodie 2005). These sediments settle out of the water column, particularly in the protected waters of estuaries, fringing reefs on the leeward margins of islands and coastal north-facing bays; areas where seagrasses grow.

Abal and Dennison (1996) predicted that detectable impacts on seagrass meadows may occur if higher sediment and associated nutrients were transported into the nearshore areas of the GBR region. While nitrogen and phosphorous play an important role in the growth of seagrass meadows, studies in the GBR in the early to mid 1990's reported that seagrass growth was generally limited by nitrogen (Udy et al. 1999; Mellors 2003). Results from the MMP now indicate that the levels of nitrogen have increased and inshore seagrasses across the GBR are either replete or predominately P-limited.

As bioindicators of the environmental status of the inshore GBR, seagrass at the inshore sites manifested a trend of nutrient enrichment with plants growing in reducing light levels (Collier et al. 2012). Elemental ratios of tissue nutrients indicate some sites in the coastal habitats of the northern Wet Tropics region are showing increasing signs of poor water quality conditions, as seagrass tissue indicates light limited, nutrient rich environments with elevated nitrogen levels. It is likely that future declines in abundance may be expected at this location in the near future.

As seagrass reproduction is positively correlated with nutrient saturation in some circumstances seagrasses experiencing low light and elevated nutrients may be expected to have increased reproductive effort – until light levels result in compromised survival due to respiration demands being greater than photosynthesis. The capacity of seagrass meadows to naturally recover community structure following disturbance will involve the interaction between light availability, nutrient loads and the availability of recruits, including seeds and remaining propagules, to form the foundation of new populations.

The regions of greatest concern for seagrass are the Burdekin, Mackay Whitsunday and Burnett Mary where not only has seagrass abundance declined, but very poor seed banks and reproductive effort have raised concerns about the ability of local seagrass meadows to recover from environmental disturbances. Complete seagrass recovery is expected to take several years (McKenzie et al. 2012; Birch and Birch 1984).

In their current state, seagrass meadows are declining along the agricultural and urban GBR coast, apparently as a result of river discharge water quality in flood plumes. Continued monitoring is important to measure if the trends abate and possibly reverse, which would indicate water quality and more generally that aquatic ecosystem health has improved.

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