

Relationships between seagrass communities and sediment properties along the Queensland coast

Progress Report

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Acronyms Used In This Report

CERF	Commonwealth Environment Research Facilities
DEW	Commonwealth Department of the Environment and Water Resources
GBR	Great Barrier Reef
MTSRF	Marine and Tropical Sciences Research Facility
RRRC	Reef and Rainforest Research Centre Limited
WTWHA	Wet Tropics World Heritage Area
Reef Plan MMP	Great Barrier Reef Water Quality Protection Plan Marine Monitoring Program

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Executive Summary

This Progress Report summarises baseline data and research results aimed at developing indicators for seagrass condition in response to contrasting sediment properties.

This first year focused on preliminary analysis of the relationships between sediment properties and seagrass community properties (esp. species composition and epiphyte loads) based on existing Seagrass-Watch data, to identify parameters that most predictably change in response to changing sediment and water quality.

Progress to date includes a detailed description of the datasets used and their manipulation to ensure they are suitable for further analysis. The Seagrass-Watch program provides a comprehensive dataset covering nearly 2000 km of the Queensland coastline, which is suitable for the investigation of relationships between seagrass, sediments and epiphytic algae. The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments.

Due to the size of the datasets (over 42000 samples), and the time required to validate and manipulate, the time frame of the project was not adequate to statistically analyse relationships. Due to time constraints only preliminary exploration of the dataset was completed.

Preliminary results of relationships between seagrass communities and sediment properties along the Queensland coast are explored. Preliminary findings are that coastal sediments differ in the north of the state compared to the south, with greater composition of finer sediments in the south. This appears correlated with the predominance of the structurally larger *Zostera capricorni* dominated meadows in the south.

The roles of different seagrass species in their communities are discussed as they can vary depending on their stature and life history. The role of disturbance and meadow succession are also discussed and a conceptualised model of the relationship between seagrass and sediments is proposed.

Introduction

The coastal zone of the Great Barrier Reef shelf receives an average annual input of sediment on the order of 14-28 Mty⁻¹, an estimated increase by at least four times compared to estimates from before 1850 (Schaffelke *et al.* 2005; Alongi and McKinnon 2005). Most sediments are deposited within the first few kilometres of river mouths (Larcombe and Woolfe 1999; Wolanski 1994), however fine sediment particles can travel large distances (Wolanski *et al.* 1981; 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 are most likely to be found (Lee Long *et al.* 2003; Wolanski *et al.* 2005). Thus coastal seagrass habitats are vulnerable to changes in water quality as they are directly exposed to increased sediment loads.

Seagrass meadows are considered important for sediment trapping and sediment stabilisation. Seagrasses, especially structurally large species, affect coastal and reefal water quality by absorbing nutrients and trapping sediments acting as a buffer between catchment inputs and reef communities. Seagrass meadows have the ability to modify the energy regimes of their environments (Keulen and Borowitzka, 2003), and help stabilise sediment by trapping and binding the sediment (Gacia *et al.* 2003). Seagrasses are able to do this as they have a vast root mat that can take up nutrients from the sand (Fonesca 1989). However, the trapping ability of seagrass is in reality equilibrium established between deposition / sedimentation and erosion/resuspension (Koch 1999).

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. Research to date in the GBR region has shown that nutrients do not appear to be having a negative effect on seagrass growth and distribution (Mellors *et al.* 2005). However, a broad spatial survey revealed substantial heterogeneity in sediment nutrients and seagrass biomass even within species (Mellors *et al.* 2005). This heterogeneity indicates the significance of local site history: the geographic setting of a location dictating its sediment regime, while the frequency of disturbance dictates the structure of the meadow. In turn, differences in sediment mineralogy and grain size influence the nutrient regime at specific locations (Mellors *et al.* 2007).

Seagrasses are sensitive to the deposition of sediments directly on top of them. Where sediment deposition is greater than the ability of the seagrass beneath it to grow through the sediments, plants will die. Anecdotally seagrass meadows in the GBR are regularly lost due to the deposition of sediments over them such as the result of flooding of the Bohle River, north of Townsville, where intertidal meadows of *Halodule* and *Halophila* were completely covered (J. Mellors, DPI&F, Pers. Comm.) or in Sarina Inlet near Mackay where there was an observed loss of seagrass due to sediment related smothering (Personal Observations). No data on the specific sensitivity of seagrasses to burial in the GBR is available although it is intuitive that larger more robust species such as *Zostera capricorni* are more likely to survive than smaller ephemeral species. In addition to the action of sediment deposition river flood plumes are often associated with strong currents during their movement from the river, out to sea.

Studies have shown that sediment characteristics are important in determining seagrass growth, germination, survival, and distribution (Short, 1987; Barko *et al.* 1991; Terrados *et al.* 1997; Halun *et al.* 2002; Bradley and Stolt 2005; van Katwijk and Wijgergangs 2004). Sediment texture, in particular, affects diffusion of oxygen, rhizome elongation, and levels of nutrients and phytotoxins, such as sulfides (Chambers *et al.* 1994; Fonseca *et al.* 1998). Sandy-textured sediments tend to diffuse oxygen more readily, obstruct rhizome elongation,

and have lower fertility (Thayer *et al.* 1984; Fonseca *et al.* 1998; Koch *et al.* 2000). Conversely, finer-textured sediments will tend to have higher fertility, allow rhizome elongation, and will tend to have greater levels of anoxia as pore water will have less interaction with the overlying water column (Koch *et al.* 2000). The effects of anoxia on seagrass are complex as anaerobic conditions may stimulate germination in some species (Moore *et al.* 1993); but also result in elevated sulfide levels, an inhibitor to leaf biomass production in more mature plants (Terrados *et al.* 1999; Koch *et al.* 2007), and a known toxin to seedlings of some species (Goodman *et al.* 1995). While there have been a few studies describing the sediment characteristics of seagrass meadows, what is presently known is “not sufficient to establish the ‘best’ sediment types for submerged aquatic vegetation growth at this time” (Koch *et al.* 2000).

One of the most extensive datasets which includes both measures of seagrass (abundance and species) and sediment characteristics (visual/tactile estimation of grain size composition) along the Queensland coastline is from Seagrass-Watch. The Seagrass-Watch monitoring program was established in 1998 as an initiative of the Queensland Department of Primary Industries and Fisheries (QDPI&F). This program monitors the seasonal dynamics of seagrass meadows, the relationships between seagrass condition and climate change and the loss and recovery of seagrass meadows and provides an early warning of change of the intertidal seagrasses of the GBRWHA. It involves supervised monitoring at predominately intertidal sites (including sites monitored for the Reef Plan MMP). Local community volunteers are trained by QDPI&F in the application of methods for scientifically rigorous assessment of seagrass resources. Independent analysis of the data collected indicated that the Seagrass-Watch monitoring methods are appropriate to detect change of intertidal seagrass communities on various scales (De’ath 2005). Seagrass-Watch monitoring currently occurs at sixty-five locations (across fifteen regions) in Queensland (Figure 1): twenty-nine of which are within the GBRMPWHA. Seagrass-Watch is an ongoing program and current updates and information are available on www.seagrasswatch.org.

Visual/tactile descriptions of wet surficial marine sediments, as used in the Seagrass-Watch program, have previously been shown to be extremely useful (Hamilton 1999). For example, the visual descriptions made in the field from the northern Great Barrier Reef lagoon by the Royal Australian Navy Hydrographic Office formed a consistent and reliable dataset at regional and smaller scales (Hamilton 1999). In this study, the sediment descriptions from the Seagrass-Watch program are used to explore seagrass and sediment relationships at both spatial and temporal scales.

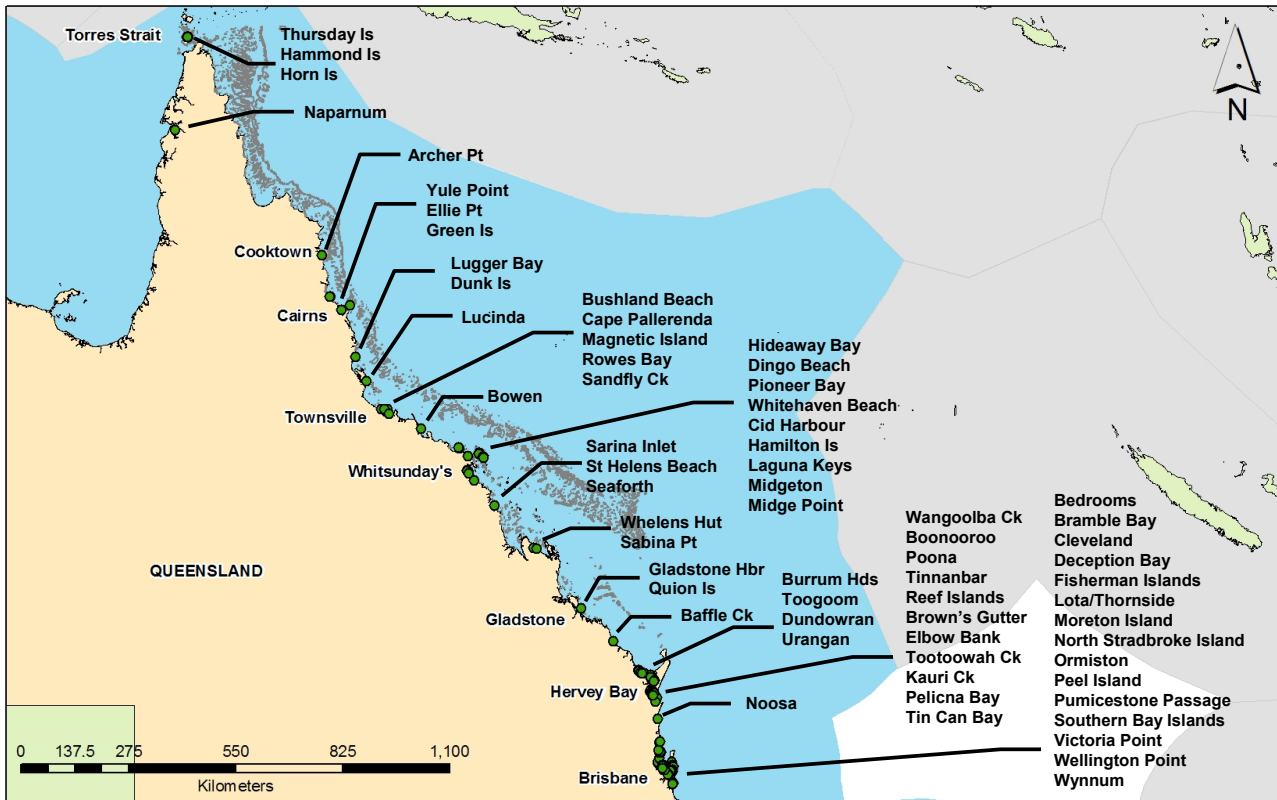


Figure 1: Distribution of Seagrass-Watch monitoring locations in Queensland (April 2007).

Methodology

Visual / tactile estimates of grain size scheme

Methodology and terminology of the visual/tactile description scheme are prescribed in McKenzie *et al.* (2003). Field descriptions of sediment type collected 0-2cm below the sediment/water interface were determined by visual and tactile inspection of (wet) samples and constituents (primary descriptors) differentiated according to the Udden-Wentworth grade scale (Wentworth 1922; Udden 1914): shell, rock and gravel ($>2000\mu\text{m}$); coarse sand ($>500\mu\text{m}$); sand ($>250\mu\text{m}$); fine sand ($>63\mu\text{m}$); and mud ($<63\mu\text{m}$). The primary descriptors are written down from left to right in decreasing order of abundance: e.g. Mud/Sand is mud with sand, where mud is determined as the dominant constituent (by volume). Note that geological descriptions are usually written in reverse order to this (e.g. Folk's classification).

Data collection

Seagrass-Watch sites (50m x 50m) are placed within relatively homogeneous areas (low variability, even topography) of intertidal seagrass meadows representative of a location ($<10\text{km}$). The monitoring is conducted using a nested design at three scales: transect (metres), sites (hectares) and locations (kilometres). Monitoring sites are established in areas of a.) relatively high usage, b.) where usage may be high in the near future and c.) in comparable 'control' sites where current and predicted usage is low and likely to remain low. Generally, three sites are established at each location.

Seagrass abundance and habitat characteristics were monitored approximately quarterly at permanently marked sites, using the standard Seagrass-Watch rapid assessment technique, as described in McKenzie *et al.* (2003). Within each site, three replicate transects were laid parallel to each other, and 25m apart. Along each transect, observers recorded seagrass habitat characteristics (including percent seagrass cover, seagrass species composition, canopy height, epiphyte cover, algae cover, algae composition, sediment type and associated fauna) within a 0.25m² quadrat (50cm x 50cm) at five-metre intervals (11 quadrats per transect, 33 quadrats per site). Percent cover of seagrass within the quadrat was visually estimated with photographic cards as a guide following McKenzie *et al.* (2003) (see www.seagrasswatch.org). Seagrass species within the quadrat were identified and the percent contribution of each species to the total cover determined. Seagrass species were identified according to Waycott *et al.* (2004). Canopy height of the dominant strap leaved species in the seagrass community was measured (from the sediment to the leaf tip) using a ruler. The method used was to ignore the tallest twenty percent of leaves of the dominant species and to haphazardly select three to five leaf blades from the remainder. The cover of epiphytes was recorded by estimating the percent of the total leaf surface area covered by epiphytes. Percent cover of non-epiphytic algae in each quadrat was estimated using the same visual technique used for seagrass cover.

Pseudo-geological classes

To convert the qualitative visual/tactile descriptions to quantitative values (percentage composition by weight), the 265 unique description categories defined in the Seagrass-Watch dataset were first collapsed to 86 pseudo-geological generic classifications involving the five descriptors mud, fine sand, sand, coarse sand and gravel. Twenty-six of the descriptions occurred only once or twice in the 42,000 samples (e.g. Mud / Coarse sand / Gravel), whereas nine descriptions comprised 88% of all data: these were sand/mud, mud/sand, sand, fine sand, mud, sand/gravel, fine sand/mud, mud/fine sand, sand/mud/gravel. The components of each category were then scored from 3 to 1 based on their order of dominance. The fourth or higher components of a description were considered insignificant and scored 0. From the scored values, the percent composition of each grain size was calculated. This scoring scheme was loosely based on Folk's classification (Figure 2); however the compositions were more conservative. For example, if the visual/tactile estimation from Seagrass-Watch was *mud/sand*, Folk's classification *sM* would result in compositions of 10-50% sand, 50-90% mud, whereas the classification here would be 60% mud, 40% sand.

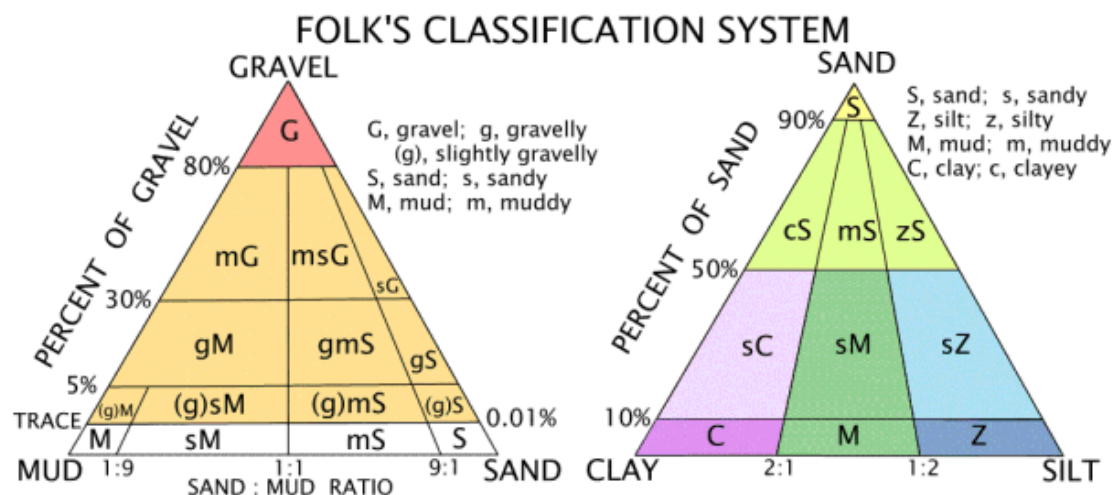


Figure 2: Sediment classification scheme modified from Folk (1954, 1974).

For analysis, grain size was differentiated into larger fractions according to the Udden – Wentworth grade scale: gravel-sized particles have a nominal diameter of 2.0mm; sand-sized particles have nominal diameters from <2.0mm to >63 μm ; mud (including silt and clay) -sized particles have nominal diameter <63 μm (Table 1).

Table 1: Grain size classes used, based on the Udden-Wentworth grade scale of Wentworth (1922).

0 – 0.002 mm	Fine-medium Clay	Mud
0.0021 – 0.004 mm	Coarse Clay	
0.0041– 0.008 mm	Very Fine Silt	
0.0081 – 0.016 mm	Fine Silt	
0.0161 – 0.031 mm	Medium Silt	
0.0311 – 0.063 mm	Coarse Silt	
0.0631 – 0.125 mm	Very Fine Sand	Sand
0.1251 – 0.250 mm	Fine Sand	
0.2501 – 0.500 mm	Medium Sand	
0.5001 – 1.000 mm	Coarse Sand	
1.0001 – 2.000 mm	Very Coarse Sand	
2.0001 – 4.000 mm	Granules	Gravel
>4.0001 mm	Pebbles and larger	

Validation of the visual / tactile estimation of grain size

Validation of the tactile estimation of grain size was conducted by examining samples where size of sediment particles was measured by both visual/tactile (descriptive) estimation and by wet sieving. The dataset used for validation was from the DPI&F/CRC Reef GBR Seabed Expeditions (1994 to 1999). These expeditions were conducted to examine the presence, abundance and distribution of seagrasses between 15m and 90m deep in the GBR. Because of the extent of the region covered, sampling was conducted over multiple years (1994 to 1999) with a section of the GBR sampled in each year. The sampling area included the inter-reef and lagoon waters (from the 15m contour seaward to the outer barrier reefs, or to the inner edge of the Ribbon Reefs in the northern section). Sampling included the GBR from the tip of Cape York Peninsula (10°S) to Hervey Bay (25°S) approximately one thousand nautical miles of coastline and extending just below the GBR in the south. At each sampling site, a real time video (remote camera slaved to an onboard monitor) was used to record bottom habitat characteristics. Data on seagrass, macro-algae, benthos and sediment composition was obtained from video images. In conjunction with the camera tow, a 0.0625m² van Veen Grab sample of the sediment was collected providing a qualitative benthic sample to confirm sediment characterisation inferred from the video. Before sediment samples were catalogued, a “deck description” was conducted by visual and tactile inspection of (wet) samples. This deck description was conducted using the same methodology as employed by the Seagrass-Watch program. Post expedition, sediment samples were wet sieved into seven fractions according to the Wentworth (1922) scale: shell/gravel (>2000 μm), coarse sand (<2000-1000 μm), medium sand (<1000-500 μm), sand (<500-250 μm), fine sand (<250-125 μm), very fine sand (<125-63 μm) and mud (<63 μm). This data has also been incorporated into the National Marine Sediments Database (Passlow *et al.* 2005; <http://www.ga.gov.au/oracle/mars/>).

The DPI&F/CRC Reef GBR Seabed Expeditions (1994 to 1999) dataset was interrogated to obtain data which was of the same categories as the Seagrass-Watch coastal dataset. Sediment samples which included *Halimeda* and foraminifera sands were removed as these are not found in the coastal dataset. A total of 1,203 sediment samples from a possible 1,426 were used for further analysis.

To compare the descriptive and sieve derived datasets from the DPI&F/CRC Reef GBR Seabed Expeditions (1994 to 1999), the mean grain size was calculated using the method of moments as outlined by Lindholm (1987). First, grain sizes (D) were transformed to the Krumbein phi (ϕ) scale (Krumbein and Sloss 1963), via Equation 1.

Equation 1: $\phi = -\log_2 D$

Where D = is the diameter of the particle, in millimetres.

The mean gain size (M) was then calculated for each of the datasets (descriptive and sieve generated) via Equation 2.

Equation 2:
$$M = \frac{\sum fx}{n}$$

Where f = percent retained by the smaller of adjacent sieves.

x = the midpoint value in phi between adjacent sieves.

n = sum of the cumulative percent retained on the smallest sieve used.

This value will generally be less than 100%, as mud material passes through all the sieves.

To transform the mean gain size (M) phi value back to mm (D), Equation 3 was used.

Equation 3: $D = 2^{-\phi}$

The resulting mean grain sizes from each of the paired datasets, were then compared statistically using a Paired T-test.

The mean grain size of the descriptive and sieve derived datasets from the DPI&F/CRC Reef GBR Seabed Expeditions (1994 to 1999) were not significantly different (Paired T-test, $T = -0.51$, $df = 54$, $p = 0.6092$). Therefore, the visual/tactile estimations of grain size used in the Seagrass-Watch program could be converted to a quantitative estimate for further analysis.

Preliminary results

The Seagrass-Watch Queensland coast dataset extends from Cooktown to Moreton Bay (Figure 3) and covers a distance of approximately 2,000km. There are distinct latitudinal patterns in sediments. Sediment grain sizes were not normally distributed within habitats of regions sampled. Coastal seagrass habitats were generally composed of Sand/Mud in the north, and tended to more Mud/Sand south of the Whitsunday's (Figure 3). Coarser sediments are generally associated with reef platform seagrass habitats. Coastal seagrass meadows north of Whitsunday's were generally *H. uninervis* dominated, in comparison to south of Whitsunday's which were *Zostera capricorni* dominated (Figure 4). Most seagrass meadows to the south were also located within estuary habitats. No reef-platform seagrasses were monitored north of Mackay.

Sediment grain size composition also showed long-term trends at many of the locations examined along the coast (Figure 5). Closer examination of a couple of long-term monitoring sites revealed temporal patterns in seagrass cover, seagrass species composition and sediment grain size composition. For example, at Shelly Beach (Townsville), sediments have fluctuated from sand/mud to mud/sand over the six years of monitoring (Figure 6). These changes appear to be correlated with the total seagrass cover, although the relationship with species composition is less clear.

At another coastal site in the region (Bushland Beach), seagrass cover increased over the monitoring period however there was little change in species composition. At this site, increases in the sediment mud content appear to correlate with increased *Halodule uninervis* leaf height and epiphyte cover (Figure 7).

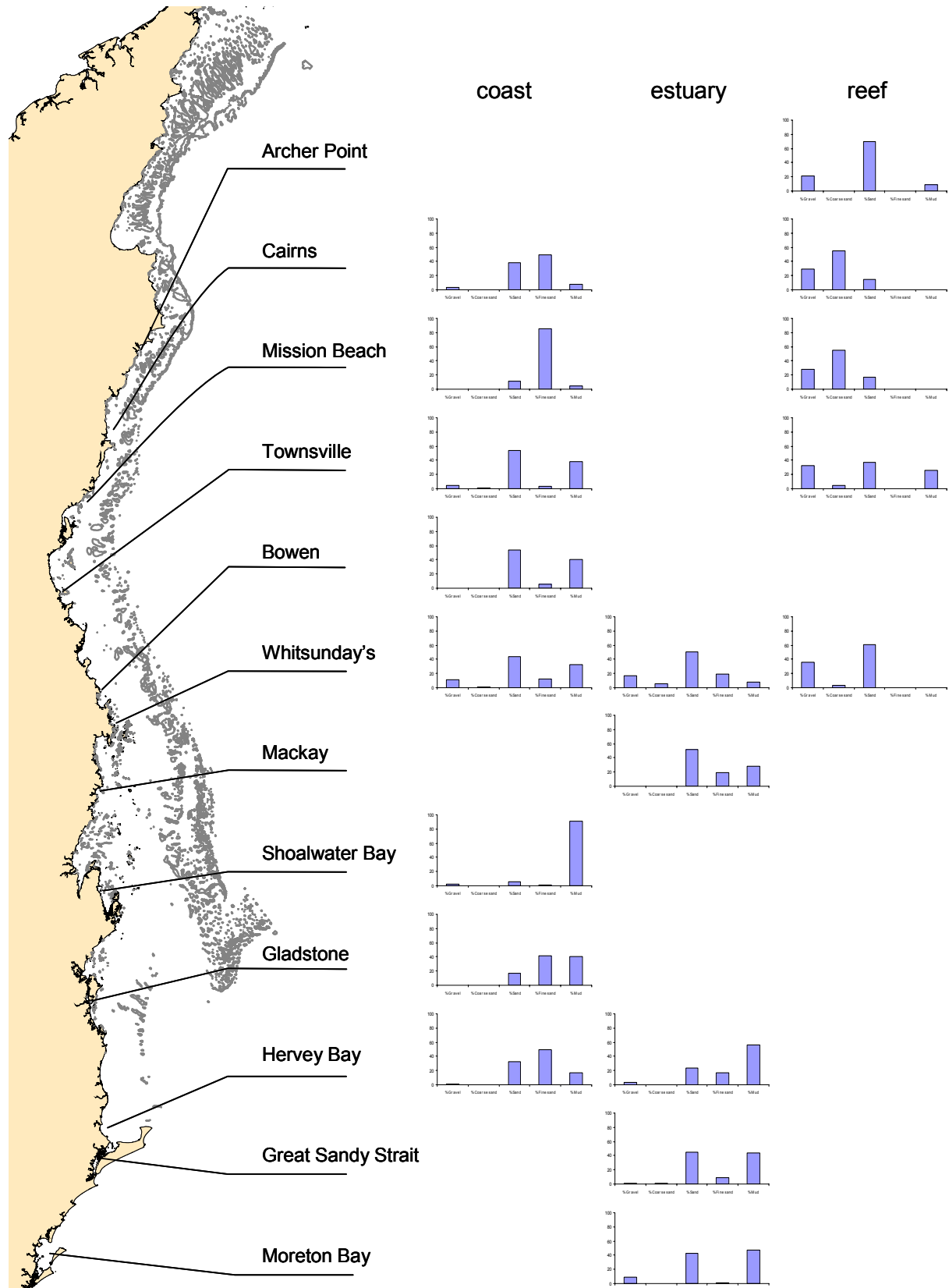


Figure 3: Mean composition of sediments for each seagrass habitat type in each Seagrass-Watch region along the east coast of Queensland. All sites pooled over monitoring period within habitat type across each region.

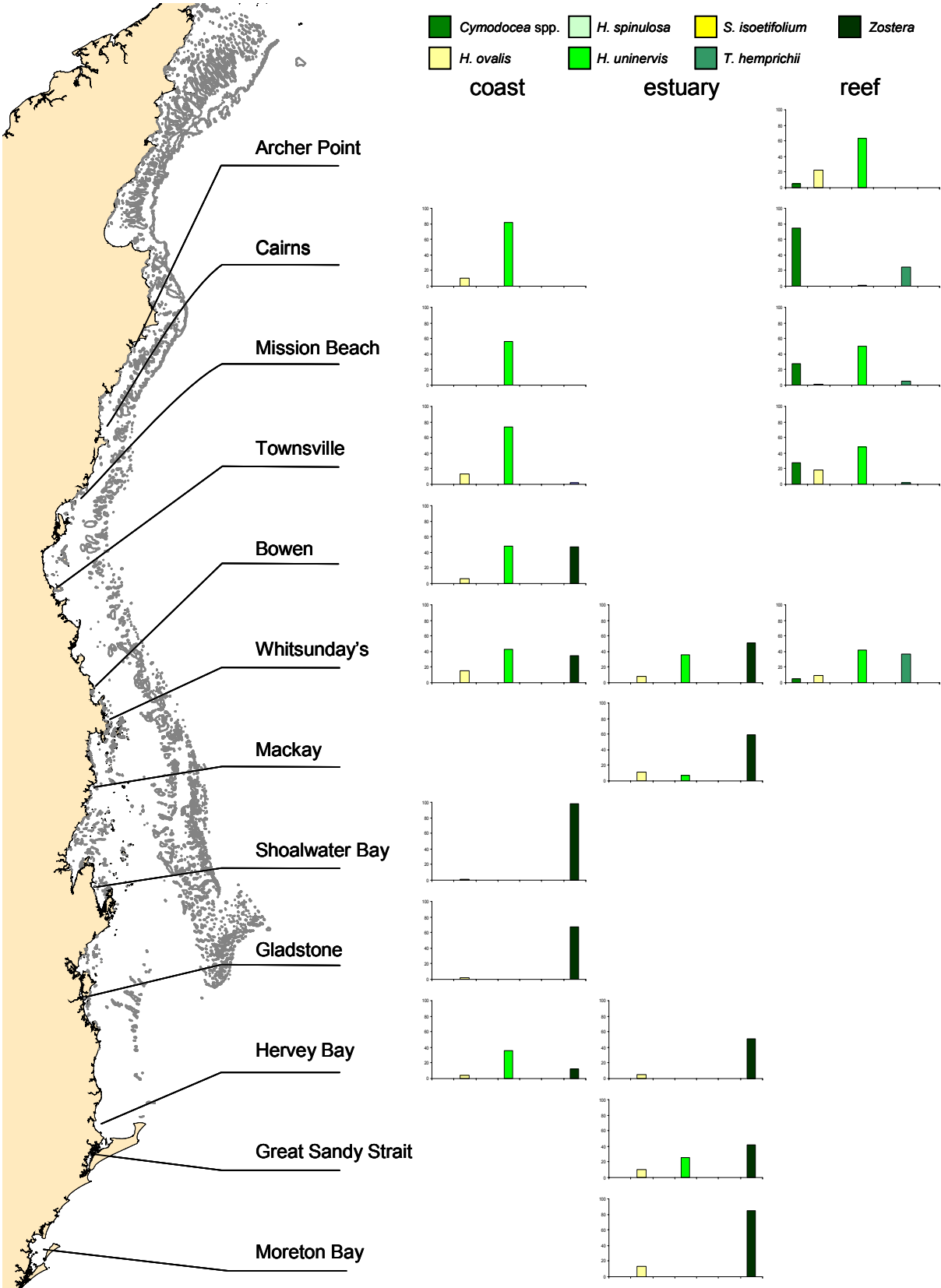


Figure 4: Mean seagrass composition for each seagrass habitat type in each Seagrass-Watch region along the east coast of Queensland. All sites pooled over monitoring period within habitat type and across each region.

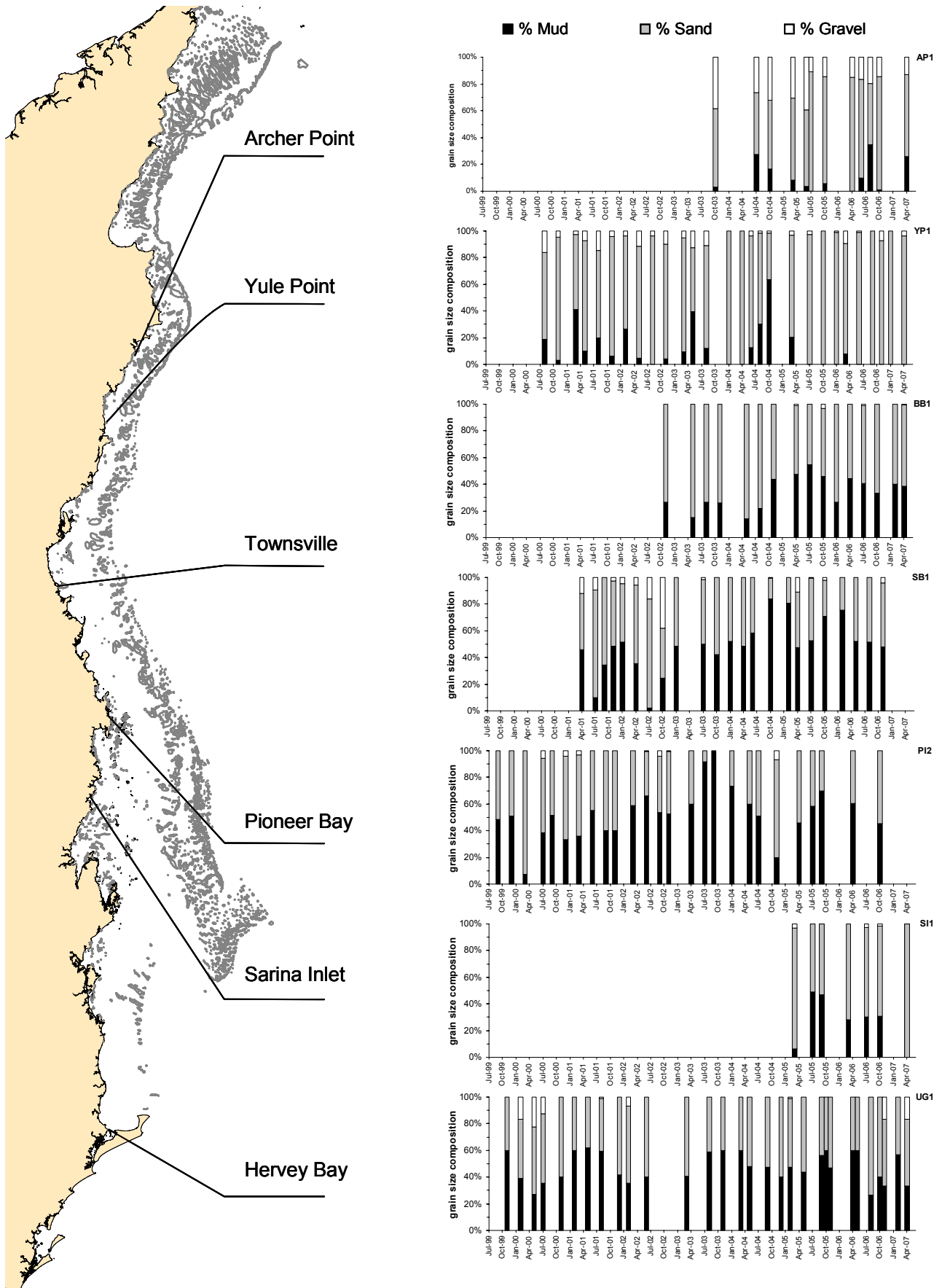


Figure 5: Temporal changes in sediment grain size composition for selected sites along the east coast of Queensland.

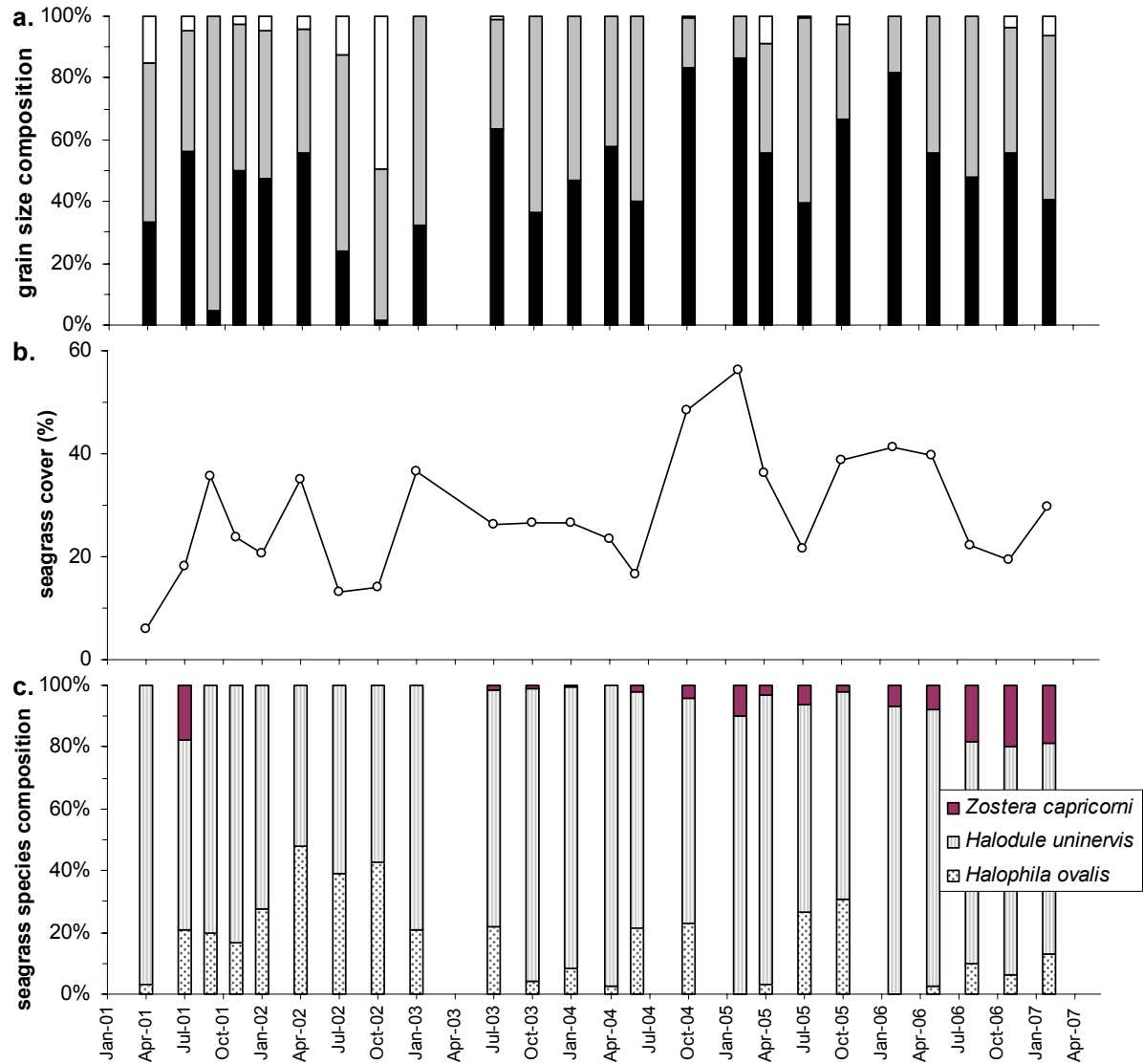


Figure 6: Changes in sediment grain size composition (a), seagrass total cover (b) and seagrass species composition (c) at Shelly Beach (SB2) (Townsville) from April 2001 to February 2007.

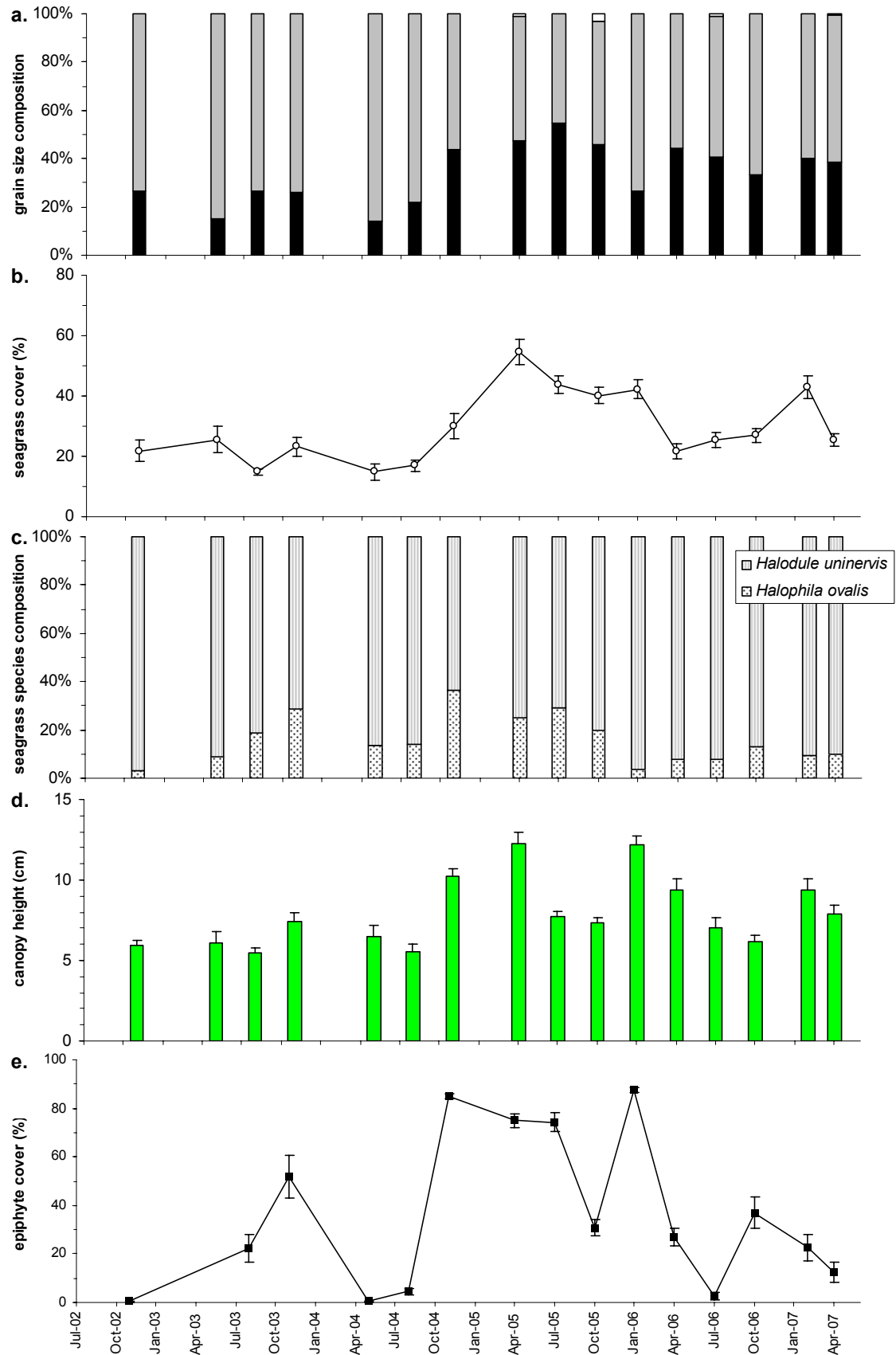


Figure 7: Changes in sediment grain size composition (a), seagrass total cover (b), seagrass species composition (c), canopy height (d) and epiphyte cover (e) at Bushland Beach (Townsville) from November 2002 to April 2007.

Discussion

The Seagrass-Watch program provides a comprehensive dataset covering nearly 2,000 km of the Queensland coastline, which is suitable for the investigation of relationships between seagrass, sediments and epiphytic algae. The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments.

Coastal sediments differ in the north of the state compared to the south, with greater composition of finer sediments in the south. This also appears correlated with the predominance of *Zostera capricorni* dominated meadows in the south. The roles of different seagrass species in their communities vary depending on their stature and life history. The often sparse meadows typical of the central and northern GBR coast, are probably less important for sediment trapping than in other regions due to their smaller size (Mellors *et al.* 2002, Koch *et al.* 2007) often being less than ten centimetres in height (Coles *et al.* 1987, McKenzie 1994). This is possibly a consequence of disturbance, as meadows which are highly disturbed (due to wave action and associated sediment movement) are usually composed of structurally smaller species such as *Halophila ovalis* and *Halodule uninervis* (narrow leaved).

However, seagrass meadows can be successional in nature. In terrestrial plant communities, succession not only changes in species composition and abundance, but also changes in the environmental conditions such as soil structure, organic matter and nitrogen in the soil (Begon *et al.* 1996). Seagrass meadow development is generally viewed as a successional process: a directional and continuous pattern of colonisation and extinction of species at a site over time (Begon *et al.* 1996). Along the Queensland coast, the structurally small seagrass species *H. ovalis* and *Halodule* spp. generally colonise bare intertidal substrate first, followed by the structurally larger *Z. capricorni* which becomes the dominant species, with a reduction in the relative abundance of the original two colonising species (e.g. Birch and Birch 1984; Poiner 1984). The rate of succession can be influenced by environmental conditions such as sediment type (Harper 1977). For example, coarse, sandy sediments tend to have low nutrients (Udy and Dennison 1996; Mellors *et al.* 2005), limiting plant growth and slowing the rate of succession (Begon *et al.* 1996). However, changes in sediment type have not been documented during succession in seagrass meadows; although Birch and Birch (1984) recorded net accretion of sediment during the ten year succession of an intertidal meadow.

Although some seagrass meadows along the coast have not changed species (e.g., Bushland Beach), increased sedimentation appears to have increased with increase in canopy height. Sedimentation and resuspension of particles is not only a function of the hydrodynamic conditions in the seagrass meadow but also depends on the percentage of the water column which is occupied by the vertical distribution of seagrass leaves (Koch 1999). When seagrass occupy the entire water column, current velocities are reduced (Ward *et al.* 1984; Fonseca and Fisher 1986) and sediments tend to accumulate (Fonseca 1996). In contrast, when the water depth is larger than the maximum meadow height, wave attenuation is less efficient, and sediment is deposited as well as resuspended (Ward *et al.* 1984). Resuspension not only changes the meadow geomorphology but affects other environmental factors essential for the survival of the plants such as: increasing total suspended solids (TSS) in the water column which results in reduced light availability (Dennison *et al.* 1993); or enhancing the flux of nutrients from the sediment into the water column to fuel eutrophication in shallow waters (Duarte 1995). In such instances, the abundance of epiphytes increases which also trap finer sediment particles, further reducing light available to seagrass. Eventually this will begin to cause seagrass loss.

Increased development and changes in land use patterns in the coastal zone have resulted in increased sediment loading and eutrophication, which has led to extensive degradation and loss of seagrasses (Short and Burdick 1996; Short and Wyllie-Echeverria 1996). This increase in siltation of the sediments promotes changes in the sediment conditions by increasing the concentration of silt, organic matter, and nutrients (Kamp-Nielsen *et al.* 2001) causing the light penetration to be reduced (Bach *et al.* 1998). This ultimately affects seagrass in a negative way (Terrados *et al.* 1998).

Nutrient loading is increased in coastal areas due to runoff, stormwater input and various types of litter. While nitrogen and phosphorous play an important role in the growth of seagrass meadows, an excess of these can have deleterious effects. Macroscopic and microscopic algae can grow in large amounts and become abundant as attached epiphytes or free floating forms, reducing light penetration in the water column. Increased epiphytic growth can result in shading of seagrass leaves by up to 65%, reducing photosynthetic rate and leaf densities of the seagrasses (Touchette, 2000; Walker and McComb 1992). As a result of these factors, seagrass decline is on the rise in many coastal areas worldwide (Orth *et al.* 2006).

Based on the findings from this project and information from the scientific literature on the effects of sedimentation and related nutrients on seagrasses, a conceptualised model is proposed (Figure 8).

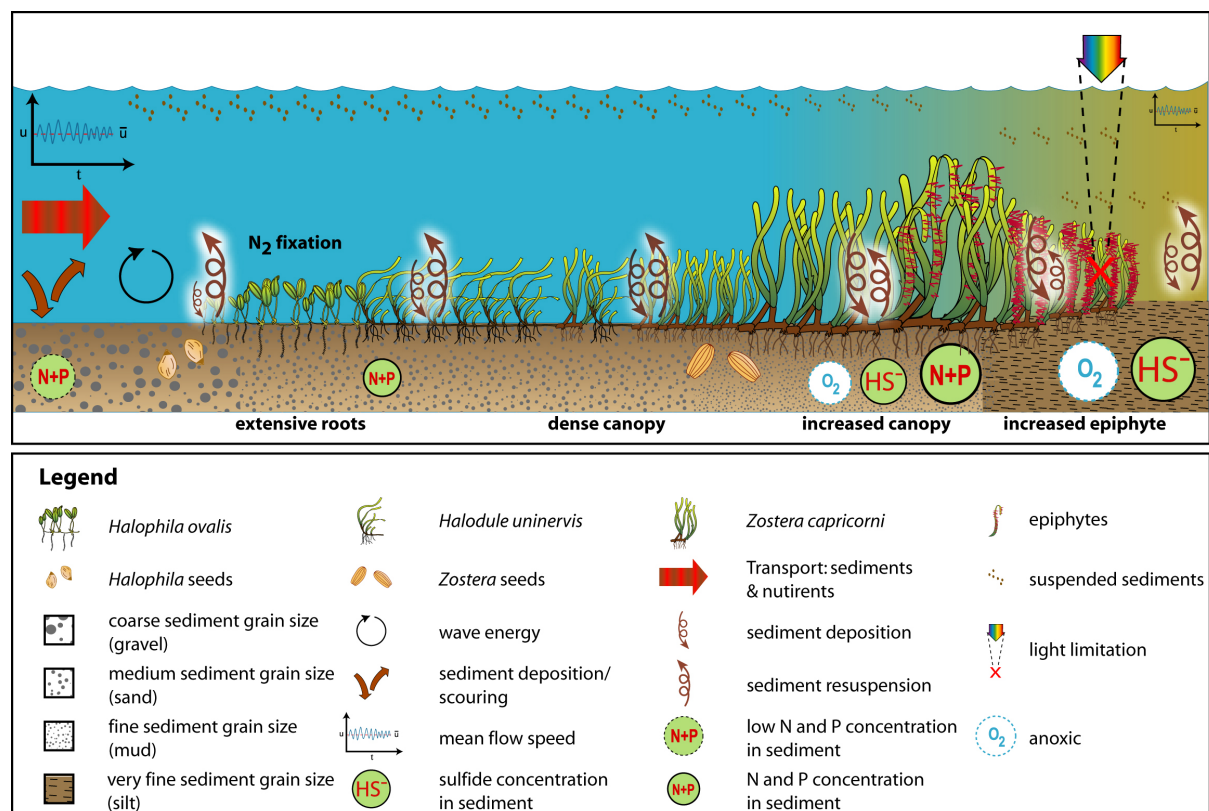


Figure 8: Conceptual diagram of the relationships between sedimentation and seagrass (abundance, species composition, canopy height and epiphytes) in successional seagrass meadow.

A preliminary/graphical examination of dataset has revealed interesting relationships worthy of further detailed statistical investigation. Unfortunately this was not possible within the time

and resources available, and is planned for the near future in consultation with the Australian Institute of Marine Science.

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