Relationships between seagrass communities and sediment properties along the Queensland coast

Progress Report

Len McKenzie

Queensland Department of Primary Industries and Fisheries
Northern Fisheries Centre, Cairns

Queensland Government
Department of Primary Industries and Fisheries

Australian Government
Department of the Environment and Water Resources

Funded through the Australian Government's
Marine and Tropical Sciences Research Facility
Project 3.7.1(c) Marine and estuarine indicators and thresholds of concern

© Queensland Department of Primary Industries and Fisheries

This report should be cited as:
McKenzie, L. J. (2007) Relationships between seagrass communities and sediment properties along the Queensland coast. Progress report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Ltd, Cairns (25pp.).

Made available online by the Reef and Rainforest Research Centre Ltd on behalf of the Australian Government's Marine and Tropical Sciences Research Facility.

The Marine and Tropical Sciences Research Facility (MTSRF) is part of the Australian Government's Commonwealth Environment Research Facilities programme. The MTSRF is represented in North Queensland by the Reef and Rainforest Research Centre Limited (RRRC). The aim of the MTSRF is to ensure the health of North Queensland's public environmental assets – particularly the Great Barrier Reef and its catchments, tropical rainforests including the Wet Tropics World Heritage Area, and the Torres Strait – through the generation and transfer of world class research and knowledge sharing.

This publication is copyright. The Copyright Act 1968 permits fair dealing for study, research, information or educational purposes subject to inclusion of a sufficient acknowledgement of the source.

The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the Australian Government or the Minister for the Environment and Water Resources.

While reasonable effort has been made to ensure that the contents of this publication are factually correct, the Commonwealth does not accept responsibility for the accuracy or completeness of the contents, and shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on, the contents of this publication.

This report is available for download from the
Reef and Rainforest Research Centre Limited website:
http://www.rrrc.org.au/mtsrf/theme_3/project_3_7_1.html

Reef & Rainforest RESEARCH CENTRE

June 2007

Contents

List of Figures

List of Tables

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

Acknowledgements

The datasets used within this report are the result of many people's efforts over the past eight years. I thank the past and present members of Seagrass-Watch HQ (DPI&F): Jane Mellors, Rob Coles, Naomi Smith, Stuart Campbell, Warren Lee Long, Chantal Roder, Juanita Bité, Karen Vidler, Michael Baer and Cameron Miller. I also thank the hundreds of Seagrass-Watch volunteers for their continued support and for giving their valuable time collecting field data, including: Margaret Parr, Trichelle Lowry, Lux Foot, Don Kinsey, Posa Skelton, Sue Mulvany, Jerry Comans, Matt Bloor, Paul Finn, Tom Collis, Gordon Cottle, Christina Howley, Wendy Jones, Karen Kirk, Maree Cliff, Peter Stratford, Kelly Jacobs, Alice Kay, Rhonda Kohler, Greg Lynch, Maren Mathews, Gary Neilsen, Jacquie Shiels, Elmer ten Haken, Paul Wenzler, Steve Winderlich, Tony Fontes, Leah Arnold, Larry Arnold, Sue Arnold, Tania Ashworth, Ron Baker, Becky Bowie, Rob Buck, Geoff Bunn, Valerie Bunn, Sarah Castine, Chris Chandler, Lynn Child, Beth Clouston, Susan Crocetti, Sally Cowan, Stephen Cox, Kathryn Crouch, Lauren Curry, Ian Curtis, Linda Davis, Sarah De Ghen, Helen Debnam, Gemma Cathy Dexter, Donahay, Di-anne Duffield, Deb Duggun, Stephanie Esentrager, Danielle Ewington, Katie Ewington, Eileen Finglas, Andrew Finglas, Sean Galvin, Don Gilmour, Natalie Gleeson, Stephanie Goldston, Sunnee Goudy, Meredith Hall, Dinah Hall, Matthew Hamilton, Sandra Hardy, Paul Hatherell, Jamie Havighurst, Maureen Hickling, Jen Holt, Beryl House, Alec Hughes, Jean Hughes, Heather Hyde, Graeme Hyde, Vanessa Jamieson, Barry Johns, Michelle Jones, Bill Kane, Noel Kane, Barbara Kinsey, Hugh Kirkman, David Kohler, Hana Larsson, Wayne Lawler, Alderd Lenting, Eileen Lewis, WJ Literacy, Kellie Lobb, Peter Lusk, Kathy Maskey, Chris Matthews, Steve McGuire, Ian McLaren, Debbie McManus, Robina Mealey, Evelyn Michell, Deidre Morrow, Shenade Muller, Michael Murphy, Bob Newell, Steve Nicol, Joyce Paptullo, Amanda Parr, Topa Petit, Horst Pfaller, Richie Pigeon, David Reid, John Roberts, John Ryder, Michael Salini, Robin Salmon, John Schmidt, Alisha Stewart, Paul Sysum, Sharon Taylor, Jenny Tenney, John Thornely, Jason Vains, Hans VanRoey, Jason Walker, Catherine Walsh, Michelle Waycott, Carla Wegscheidi, Dez Wells, Jean Wells, Wenzler family, Dick Wickenden, Brett Williams, Dell Williams, John Williams, Carolyn Williams, Betty Wilson, Blair Wilson, Denise Wilson, Iony Woolaghan, Alice Yeates, Masao Yoshida, Nicollete Yoshida, Venoma Yoshida.

The conceptual diagram symbols are courtesy of the Integration and Application Network (ian.umces.edu/symbols/), University of Maryland Center for Environmental Science.

This project and subsequent progress report was partially funded by the Australian Government's Marine and Tropical Sciences Research Facility represented in North Queensland by the Reef and Rainforest Research Centre.

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 growth 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 that 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 inhibiter 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.

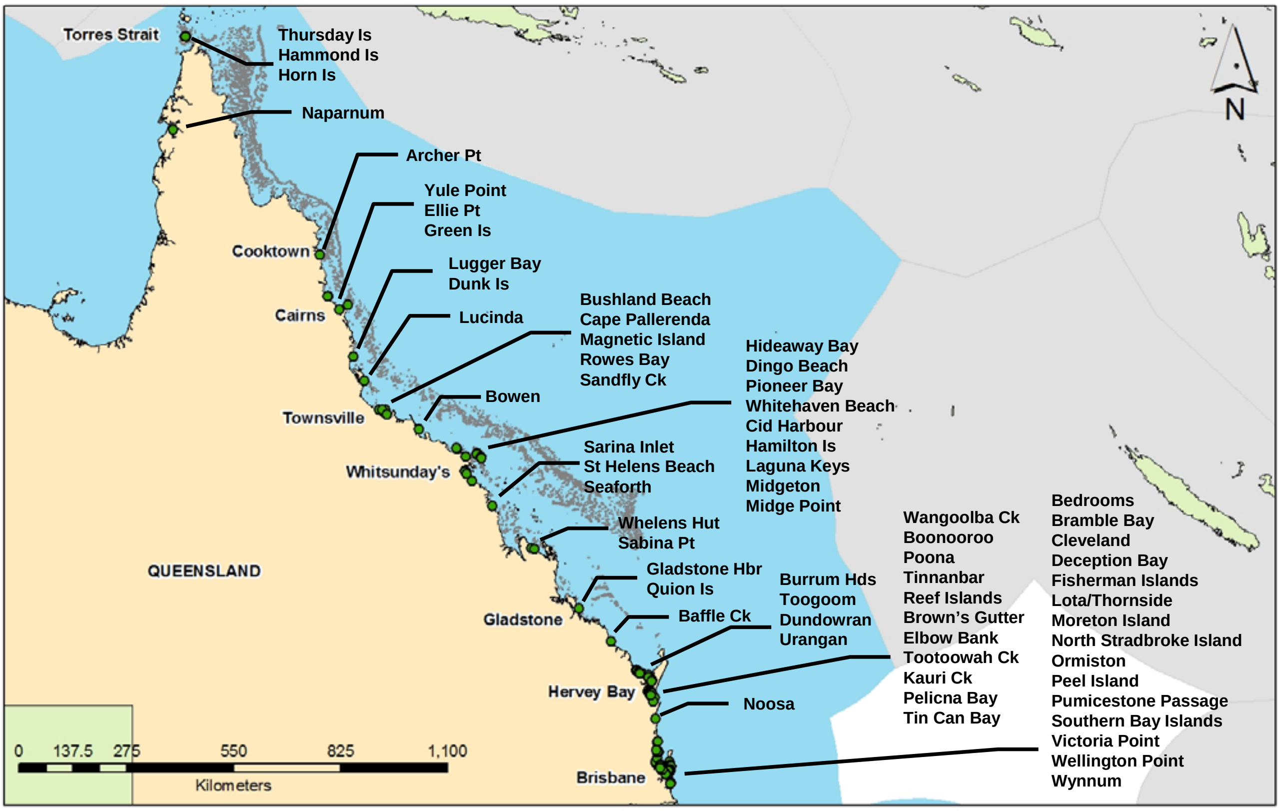

Figure 1: Distribution of Seagrass-Watch monitoring locations in Queensland (April 2007).

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 (>2000µm); coarse sand (>500 µm); sand (>250 µm); fine sand (>63 µm); and mud (<63 µm). 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 (<10km). 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 $0.25m^2$ 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.

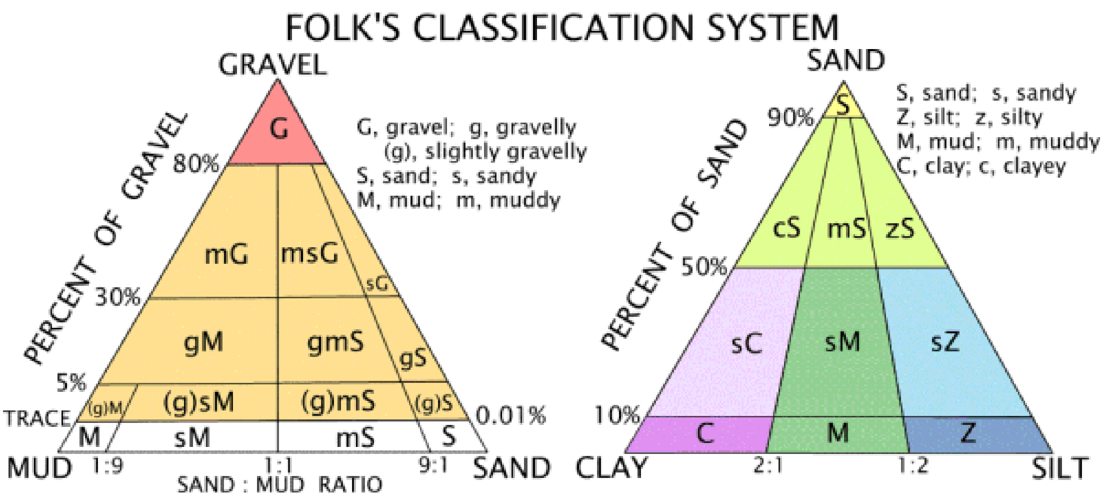

Figure 2: Sediment classification scheme modified from Folk (1954, 1974).

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 0.0625m^2 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 (<2000-1000µm), medium sand (<1000-500µm), sand (<500-250µm), fine sand (<250-125µm), very fine sand (<125-63µm) and mud (<63µm). 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: $$\varphi = -\log_2 D$$

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: $$\mathrm{M} = \frac{\sum fx}{n}$$

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: $$D = 2^{-\varphi}$$

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).

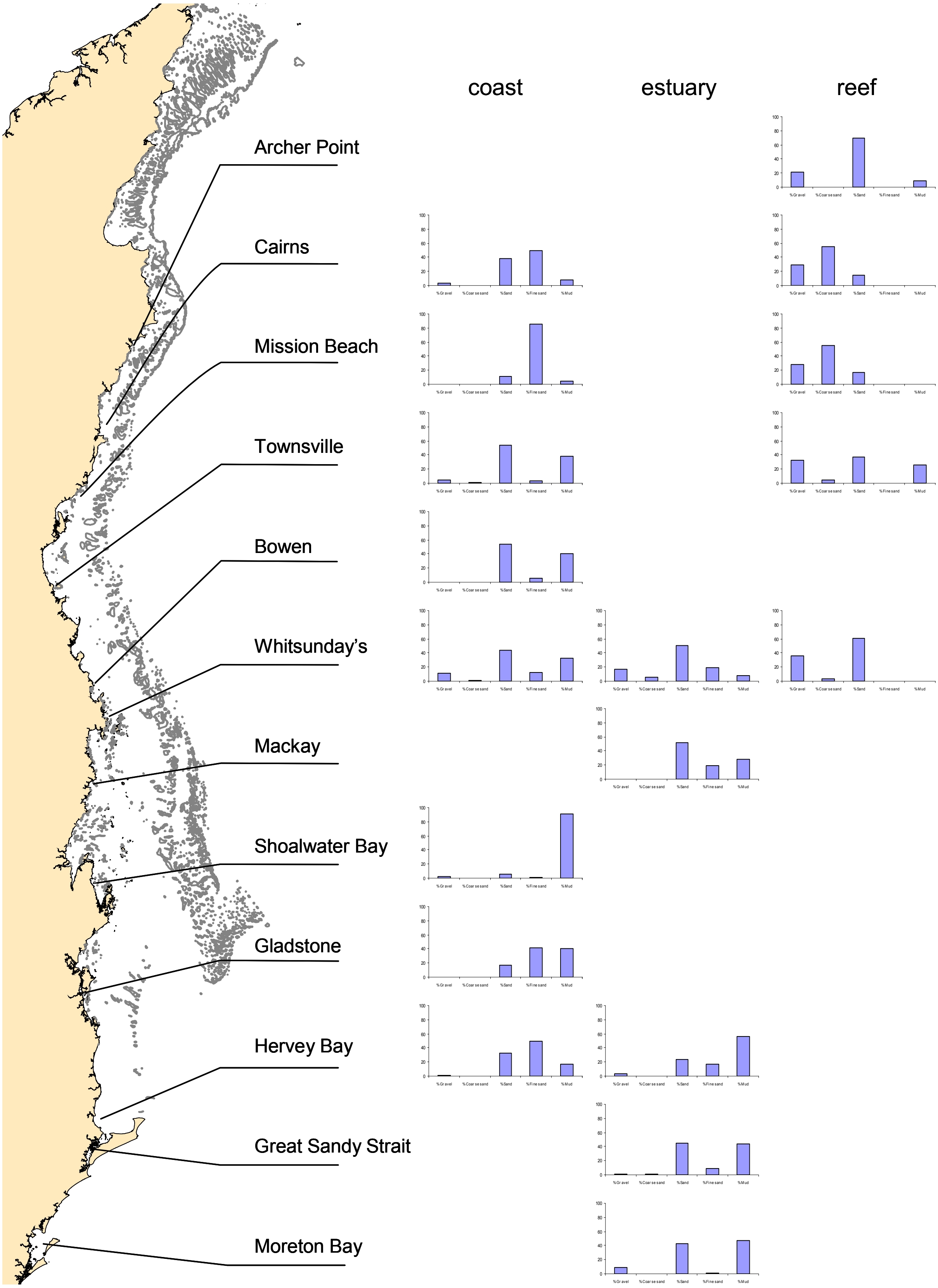

Figure 3: Mean composition of sediments for each seagrass habitat type in each Seagrass-Watch region along the east coast of Queensland. All sites pooled over monitoring period within habitat type across each region.

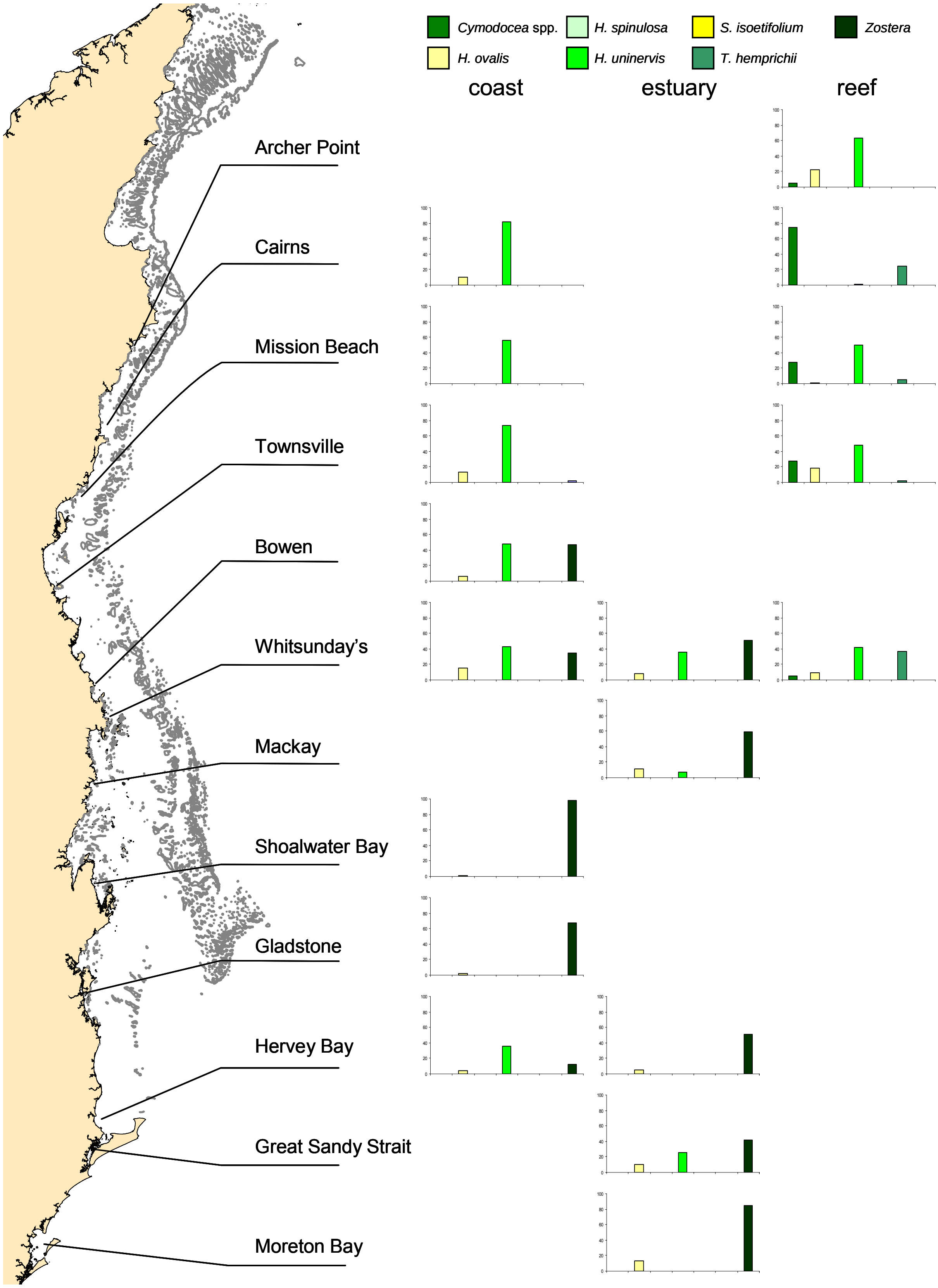

Figure 4: Mean seagrass composition for each seagrass habitat type in each Seagrass-Watch region along the east coast of Queensland. All sites pooled over monitoring period within habitat type and across each region.

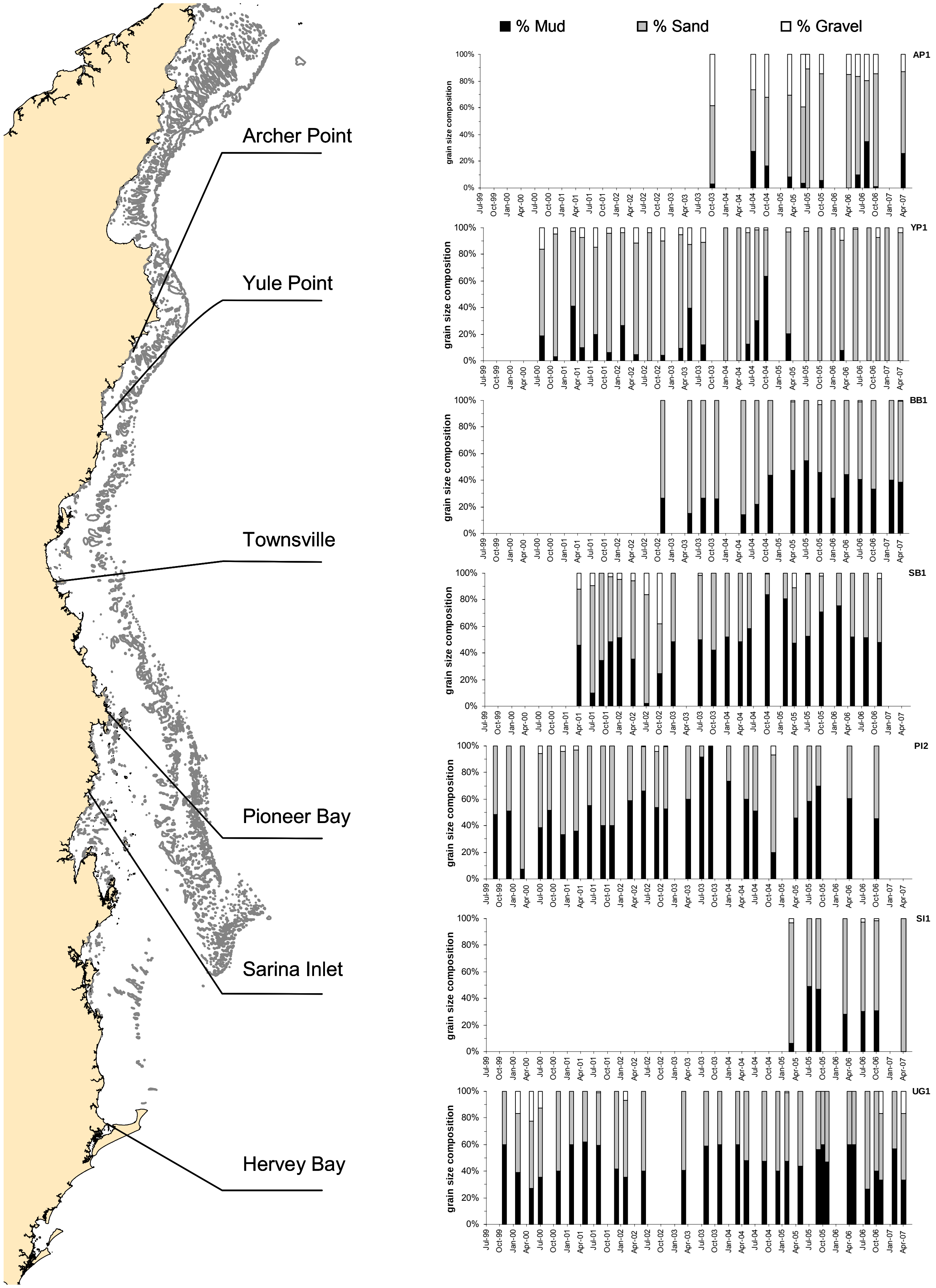

Figure 5: Temporal changes in sediment grain size composition for selected sites along the east coast of Queensland.

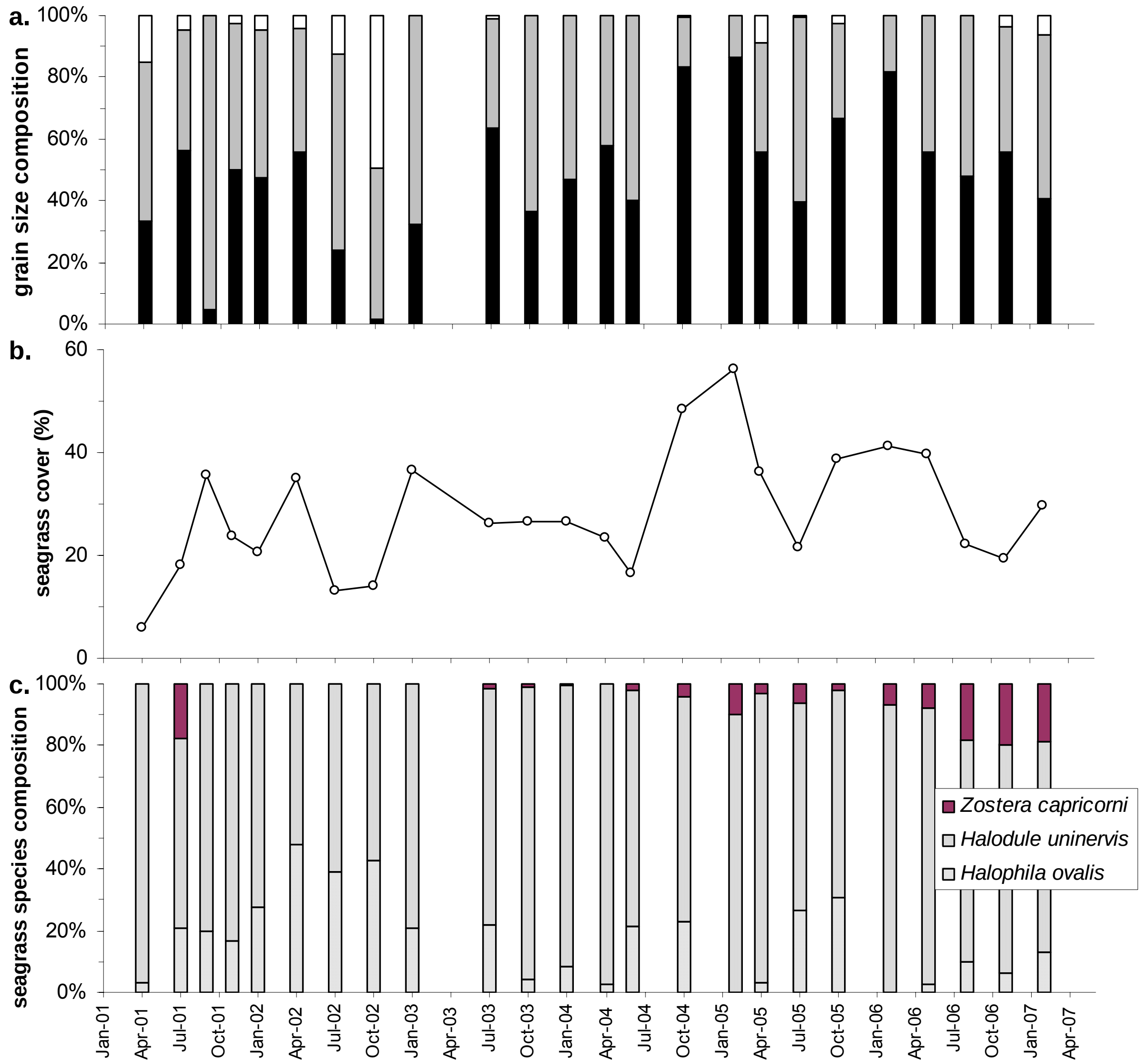

Figure 6: Changes in sediment grain size composition (a), seagrass total cover (b) and seagrass species composition (c) at Shelly Beach (SB2) (Townsville) from April 2001 to February 2007.

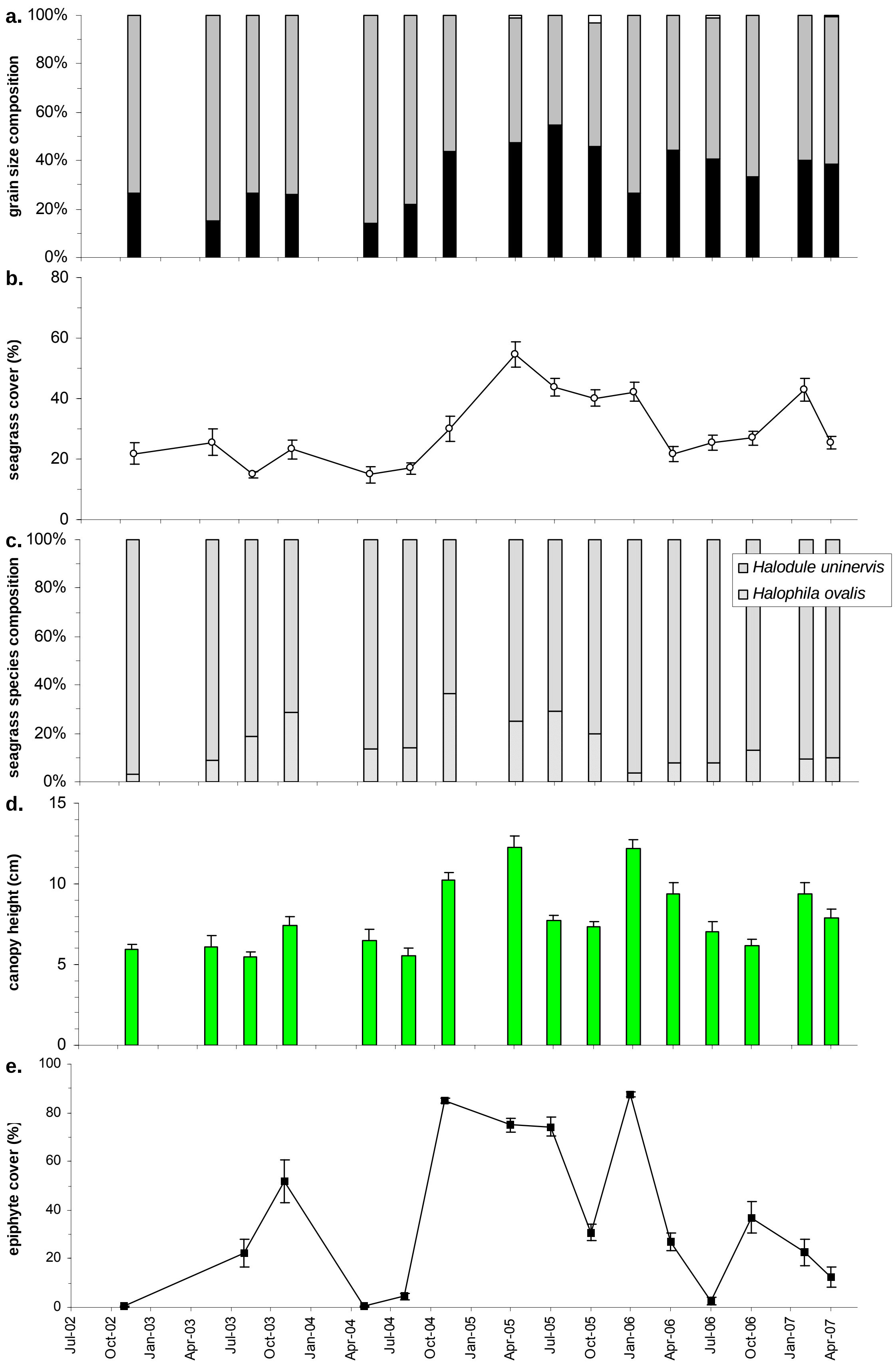

Figure 7: Changes in sediment grain size composition (a), seagrass total cover (b), seagrass species composition (c), canopy height (d) and epiphyte cover (e) at Bushland Beach (Townsville) from November 2002 to April 2007.

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 is also appears correlated with the predominace 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 v 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 lead to extensive degradation and loss of seagrasses (Short and Burdick 1996; Short and Wyllieecheverrria 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).

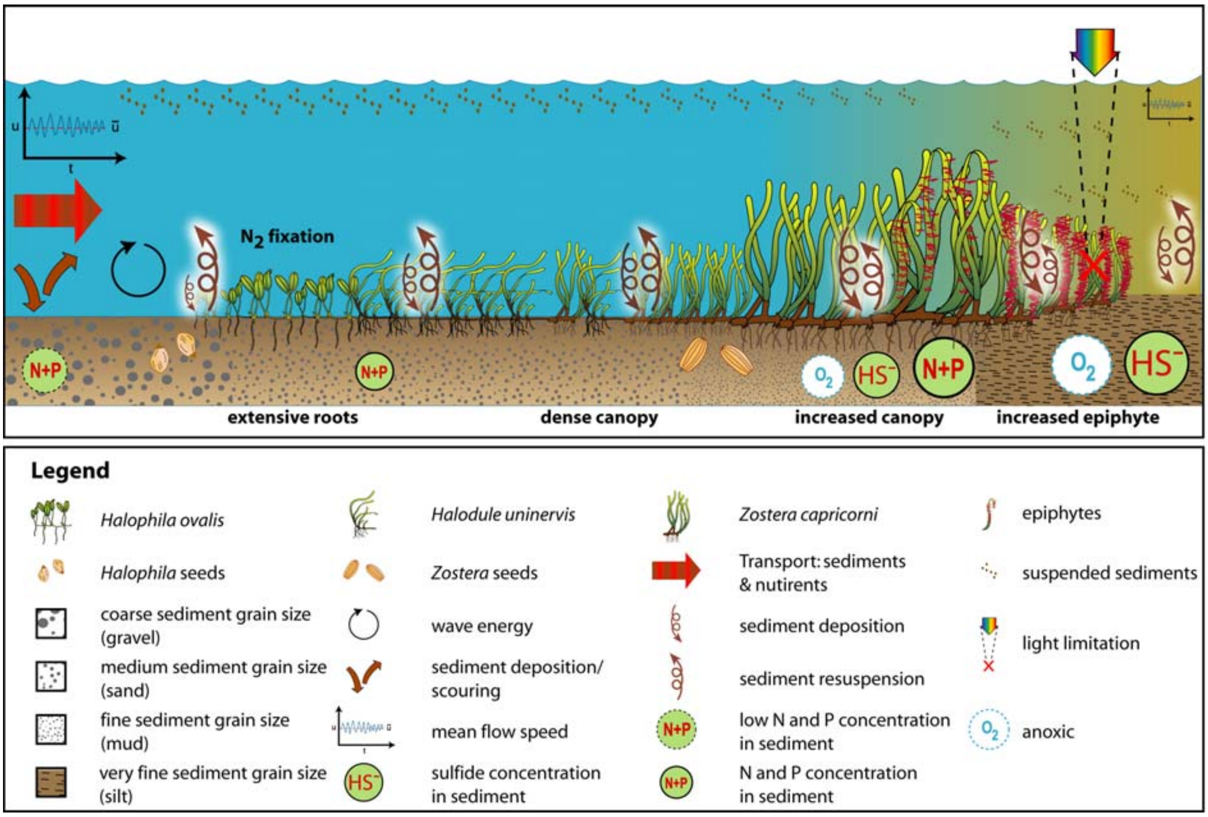

Figure 8: Conceptual diagram of the relationships between sedimentation and seagrass (abundance, species composition, canopy height and epiphytes) in successional seagrass meadow.

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.

References

Abal, E.G. and Dennison, W.C. (1996). Seagrass depth range and water quality in southern Moreton Bay, Queensland, Australia. *Marine and Freshwater Research* **47**: 763-771.

Alongi, D.M. and McKinnon, A.D. (2005). The cycling and fate of terrestrially-derived sediments and nutrients in the coastal zone of the Great Barrier Reef shelf. *Marine Pollution Bulletin* **51**: 239-252.

Bach, S.S., Borum, J., Fortes, M.D. and Duarte, C.M. (2002). Species composition and plant performance of mixed seagrass beds along a siltation gradient at Cape Bolinao, The Philippines. *Marine Ecology Progress Series* **174**: 247-256.

Barko, J.W., Gunnison, D. and Carpenter, S.R. (1991). Sediment interactions with submersed macrophyte growth and community dynamics. *Aquatic Botany* **41**: 41-65.

Begon, M., Harper, J.L. and Townsend, C.R. (1996). Ecology: individuals, populations and communities. Blackwell Science, Oxford, 1068 pp.

Birch, W.R. and Birch, M. (1984). Succession and pattern of tropical intertidal seagrasses in Cockle Bay, Queensland, Australia: A decade of observations. *Aquatic Botany* **19**: 343-367.

Bradley, M.P. and Stolt, M.H. (2005) Landscape-level seagrass–sediment relations in a coastal lagoon. *Aquatic Botany* **84**: 121-28.

Chambers, R.M., Hollibaugh, J.T. and Vink, S.M. (1994). Sulfate reduction and sediment metabolism in Tomales Bay, CA. *Biogeochemistry* **25**: 1-18.

Coles, R.G., Lee Long, W.J., Squire, B., Squire, L.C. and Bibby, J.M. (1987). Distribution of seagrasses and associated juvenile commercial penaeid prawns in north-eastern Queensland waters. *Australian Journal of Marine and Freshwater Research* **38**: 103-119.

De'ath, G. (2005). Water Quality Monitoring from River to Reef. A report to the GBRMPA. Unpublished Report, Australian Institute of Marine Science, Townsville.

Dennison, W.C., Orth, R.J., Moore, K.A., Stevenson, J.C., Carter, V., Koller, S., Bergstrom, P.W. and Batuik, R.A. (1993). Assessing water quality with submersed aquatic vegetation: Habitat requirements as barometers of Chesapeake Bay Health. *Bioscience* **43**(2): 86-94.

Devlin, M.J. and Brodie, J. (2005). Terrestrial discharge into the Great Barrier Reef Lagoon: nutrient behavior in coastal waters. *Marine Pollution Bulletin* **51**: 9-22.

Duarte, C.M. (1995). Submerged aquatic vegetation in relation to different nutrient regimes. *Ophelia* **41**: 87-112.

Folk, R.L., (1954). The distinction between grain size and mineral composition in sedimentary rock nomenclature. *Journal of Geology* **62**(4): 344-359.

Folk, R.L. (1974). Petrology of Sedimentary Rocks (Hemphill Publishing Co: Texas).

Fonesca, M.S. (1989). Sediment stabilization by *Halophila decipiens* in comparison to other seagrasses. *Estuarine, Coastal and Shelf Science* **29**: 501-507

Fonseca, M.S. and Fisher, J.S. (1986). A comparison of canopy friction and sediment movement between four species of seagrass with references to ecology and restoration. *Marine Ecological Progress Series* **29**: 15-22.

Fonseca, M. (1996). The role of seagrasses in nearshore sedimentary processes: a review. In: Nordstrom, K., Roman, C.T. (Eds.), Estuarine Shores: Evolution, Environments and Human Alterations, Wiley, London, pp. 261-286.

Fonseca, M.S, Kenworthy, W.J. and Thayer, G.W. (1998). Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters. NOAA Coastal Ocean Program Decision Analysis, Series No. 12. NOAA Coastal Ocean Office, Silver Spring, MD.

Gacia, E., Duarte, C.M., Marba, N., Terrados, J., Kennedy, H., Fortes, M.D. & Tri, N.H. (2003). Sediment deposition and production in SE-Asia seagrass meadows. *Estuarine, Coastal and Shelf Science* **56**: 909-919.

Goodman, J.L., Moore, K.A. and Dennison, W.C. (1995). Photosynthetic responses of eelgrass (*Zostera marina* L.) to light and sediment sulfide in a shallow barrier island lagoon. *Aquatic Botany* **50**: 37-47.

Halun, Z., Terrados, J., Borum, J., Kamp-Nielsen, L., Carlos, M.D. and Miguel, D.F. (2002). Experimental evaluation of the effects of siltation-derived changes in sediment conditions on the Philippine seagrass *Cymodocea rotundata*. *Journal of Experimental Marine Biology and Ecology* **279**: 73-87.

Hamilton, L.J. (1999). Classification, grainsize relations and sediment distributions inferred from visual sediment descriptions on RAN Hydrographic Office bathymetry charts of the northern Great Barrier Reef lagoon. *Australian Journal of Earth Sciences* **46**(4): 501-514.

Harper, J.L. (1977). Population biology of plants. Academic Press, London, 892 pp.

Kamp-Nielsen, L., Vermaat, J., Wesseling, I., Borum, J. and Geertz-Hansen, O. (2001). Sediment properties along gradients of siltation in South-east Asia. *Estuarine, Coastal and Shelf Science* **56**:127-137.

Koch, E.W. (1999). Sediment resuspension in a shallow Thalassia testudinum banks ex König bed. *Aquatic Botany* **65**: 269-280.

Koch, E., Ailstock, S. and Stevenson, J.C. (2000). Beyond light: physical and geochemical and chemical habitat requirements. Chesapeake Bay Submerged Aquatic Vegetation Water Quality Requirements and Restoration Targets: A Second Technical Synthesis. USEPA, Chesapeake Bay Program, Annapolis, MA, pp. 71-93.

Koch, M.S., Schopmeyer, S., Kyhn-Hansen, C. and Madden, C.J. (2007). Synergistic effects of high temperature and sulfide on tropical seagrass. *Journal of Experimental Marine Biology and Ecology* **341** (1): 91-101.

Krumbein W C and Sloss L L (1963) Stratigraphy and Sedimentation, 2nd edition (Freeman, San Francisco).

Keulen, M. and Borowitzka, M.A. (2003). Seasonal variability in sediment distribution along an exposure gradient in a seagrass meadow in Shoalwater Bay, Western Australia. *Estuarine, Coastal and Shelf Science* **57**: 587-592.

Larcombe, P. and Woolfe, K.J. (1999). Increased sediment supply to the Great Barrier Reef will not increase sediment accumulation at most coral reefs. *Coral Reefs* **18**: 163-169.

Lee Long, W.J., Mellors, J.E. and Coles, R.G. (1993). Seagrasses between Cape York and Hervey Bay, Queensland, Australia. *Australian Journal of Marine and Freshwater Research* **44**(1): 19-33.

Lindholm, R. (1987). A practical approach to sedimentology. Allen and Unwin, Inc.

McKenzie, L.J. (1994). Seasonal changes in biomass and shoot characteristics of a *Zostera capricorni* Ashers. dominant meadow in Cairns harbour, northern Queensland. *Australian Journal of Marine and Freshwater Research* **45**: 1337-1352.

McKenzie, L.J., Campbell, S.J. and Roder, C.A. (2003). Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources by Community (citizen) volunteers. 2nd Edition. (QFS, NFC, Cairns) 100pp.

Mellors, J., Marsh, H., Carruthers, T.J.B. and Waycott, M. (2002). Testing the sediment-trapping paradigm of seagrass: do seagrasses influence nutrient status and sediment structure in tropical intertidal environments? *Bulletin of Marine Science* **71**(3): 1215-1226.

Mellors, J. E., Waycott, M. and Marsh, H. (2005). Variation in biogeochemical parameters across intertidal seagrass meadows in the central Great Barrier Reef region. *Marine Pollution Bulletin* **51**: 335-342

Mellors, J., Fabricius, K. and De'ath, G. (2007). Seasonal variation in biomass and tissue nutrients of intertidal seagrasses (*Halophila ovalis* and *Halodule uninervis*) in relation to sediment nutrient contents in North Queensland. Chapter 9. In Fabricius, K., Uthicke, S., Cooper, T., Humphrey, C., De'ath, G. and Mellors, J. Candidate bioindicator measures to monitor exposure to changing water quality on the Great Barrier Reef: Interim report. pp. 179-193.

Moore, K.A., Orth, R.J. and Nowak, J.F. (1993). Environmental regulation of seed germination in Zostera marina L. (eelgrass) in Chesapeake Bay: effects of light, oxygen and sediment burial. *Aquatic Botany* **45**: 79-91.

Orth, R.J., Carruthers, T.J.B., Dennison, W.C., Duarte, C.M., Fourqurean, J.W., Heck Jr., K.L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Olyarnik, S., Short, F.T., Waycott, M. and Williams, S.L. (2006). A Global Crisis for Seagrass Ecosystems. *BioScience* **56** (12): 987-996.

Passlow, V., Rogis, J., Hancock, A., Hemer, M., Glenn, K and Habib, A. (2005). Final Report, National Marine Sediments Database and Seafloor Characteristics Project. Geoscience Australia, Record 2005/08. 120pp.

Poiner, I.R. (1984). A re-examination of the seagrass communities of North Stradbroke Island, with an evaluation of their long-term stability. In: Coleman, R. J., Covacevich, J., Davie, P. (Eds.), Focus on Stradbroke Island: new information on North Stradbroke Island and surrounding areas, 1974-1984. Booralong Publications, Brisbane, pp. 228-237.

Schaffelke, B., Mellors, J. and Duke, N.C. (2005). Water quality in the Great Barrier Reef region: responses of mangrove, seagrass and macroalgal communities. *Marine Pollution Bulletin* **51**: 279-296.

Short, F.T. (1987). Effects of sediment nutrients on seagrasses: literature review and mesocosm experiment. *Aquatic Botany* **27**: 41-57.

Short, F.T. and Burdick, D.M. (1996). Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. *Estuaries* **19**:730-739.

Short, F.T. and Wyllieecheverria, S. (1996). Natural and human-induced disturbance of seagrasses. *Environmental. Conservation* **23**:17-27.

Terrados, J., Duarte, C.M., Fortes, M.D., Borum, J., Agawin, N.S.R., Bach, S., Thampanya, U., Kamp-Nielsen, L., Kenworthy, W.J., Geertz-Hansen, O., & Vermaat, J.E. (1998). Changes in community structure and biomass of seagrass communities along gradients of siltation in SE Asia. *Estuarine, Coastal and Shelf Science* **46**:757–768.

Terrados J, Duarte C.M, Kamp-Nielsen L, Agawin N.S.R, Gacia E, Lacap D, Fortes M.D, Borum J, Lubanski M. and Greve T. (1999). Are seagrass growth and survival constrained by the reducing conditions of the sediment? *Aquatic Botany* **65**:175-197

Thayer, G., Bjorndal, K.A., Ogden, J.C., Williams, S.L. and Zieman, J.C. (1984). Role of the large herbivores in seagrass communities. *Estuaries* **7**: 351-376.

Touchette, B.W. (2000). Review of nitrogen and phosphorous metabolism in seagrasses. *Journal of Experimental Marine Biology and Ecology* **250**:133-167.

Udden, J.A. (1914). Mechanical composition of clastic sediments. *Bulletin of the Geological Society of America* **25**: 655-744.

Udy, J.W. and Dennison, W.C. (1996). Estimating nutrient availability in seagrass sediments. In: Kuo, J., Phillips, R. C., Walker, D. I., Kirkman, H. (Eds.), Seagrass Biology: proceedings of an International Workshop. UWA, Perth, pp. 163-172.

van Katwijk, M.M. and Wijgergangs, L.J.M. (2004). Effects of locally varying exposure, sediment type and low-tide water cover on *Zostera marina* recruitment from seed. *Aquatic Botany* **80**: 1-12.

Walker, D.I. and McComb, A.J. (1992). Seagrass degradation in Australian coastal waters. *Marine Pollution Bulletin* **25**:191-195.

Ward, L.G., Kemp, W.M. and Boynton, W.R. (1984). The influence of waves and seagrass communities on suspended particulates in an estuarine embayment. *Marine Geology* **59**: 85-103.

Wentworth, C. K. (1922). A scale of grade and class terms for clastic sediments. *J. Geology V.* **30**: 377-392.

Wolanski, E., Fabricius, K., Spagnol, S. and Brinkman, R. (2005). Fine sediment budget on an inner-shelf coral-fringed island, Great Barrier Reef of Australia. *Estuarine, Coastal and Shelf Science* **65**: 153-158.

Wolanski, E., Jones, M. and Willia, W.T. (1981). Physical properties of Great Barrier Reef lagoon waters near Townsville, II. Seasonal fluctuations. *Australian Journal of Marine and Freshwater Research* **32**: 321-334.

Wolanski, E. (1994) Physical oceanographic processes of the Great Barrier Reef. CRC Press, Inc., Florida. 194pp.