MAPPING SEAGRASS EXTENT & COMPOSITION IN INTER- & SUB-TIDAL ENVIRONMENTS USING FIELD & REMOTE SENSING

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1. INTRODUCTION

Natural resource management agencies and communities in coastal areas around the world require information on the extent and composition of the resource base they are responsible for, in order to make effective decisions on how to sustainably manage them. Seagrass environments represent a unique challenge in this context [1]. Because they occur across a range of water depths, water clarities, and tidal regimes, the use of a single mapping approach is very difficult. Although remote sensing has been successfully applied to map submerged seagrass composition and biophysical properties in shallow and clear coastal environments [2], large areas of seagrass beds occur in shallow and turbid environments and cannot be mapped through the water column using optical or acoustic techniques [2]. This paper integrates and builds on the findings from three previous papers by the authors, to demonstrate how field survey and optical remote sensing data can be combined to map a variety of seagrass species and their properties, across a range of water depths, water clarities, and tidal regimes. In the first part of this work, results from [3] are presented to demonstrate which satellite sensors can discriminate seagrass from substrate, and between seagrass species, in highly turbid inter-tidal environments of north-eastern Australia. The findings from this work are used in the second stage, to evaluate a range of satellite and airborne sensors for mapping seagrass composition and cover in shallow clear waters [4]. An initial approach was then developed and applied for mapping across clear and turbid, sub- and inter-tidal environments in a coastal embayment in eastern Australia [5]. Based on the findings from each of these projects, a more robust method is proposed for using field-survey and high spatial resolution image data, with specific multi-spectral bands, for mapping and monitoring seagrass extent and composition, across the range of water depths and clarities found in coastal estuaries.

2. STUDY SITES

The sites used included: a sub-tropical coastal embayment in eastern Australia, Moreton Bay; and several sites in tropical north-eastern Australia. The north Queensland sites were shallow, inter-tidal and highly turbid, often with very low levels of seagrass cover. These sites were selected to cover a range of seagrass species, substrate colours and seagrass cover levels representative of the tropical coastline of northern

Australia. The species sampled were *Thalassia hemprichii, Halophila ovalis, Halodule uninerivs; Halodule pinifolia; Syringodium isoetifolium, Cymodocea serrulata,* and *Cymodoea rotundata.* The sub-tropical site, Moreton Bay, is a 1582 km^2, partially enclosed, shallow embayment, surrounded by several large sand islands, which receives run-off from five large rivers on its western side. The majority of the Bay is < 12 m deep, with some 30 m deep shipping channels, and a semi-diurnal tidal range (~ 1.7 m). Water clarities throughout the Bay are highly dynamic, changing on time-scales of hours to days, and with secchi depths ranging from 0.1 m in the turbid waters of the western Bay, to 15 m in the clearer waters of the eastern Bay. Seagrass species occurring in the Bay include, *Halophila ovalis, H. decipiens, H. spinulosa, Halodule uninervis, Zostera muelleri (previously Zostera capricorni), Cymodocea serrulata* and *Syringodium isoetifolium.* Extensive sub- and inter-tidal seagrass beds occur in the clear, tidally flushed areas of the eastern Bay, while inter-tidal seagrass dominate the more turbid areas in the west of the Bay.

3. DATA & METHODS

3.1 Mapping seagrass extent and composition in highly-turbid inter-tidal environments

Processing operations in this section focussed on (1) the minimum level of seagrass cover detectable from airborne and satellite imagery; (2) the minimum measurable differences in seagrass cover; and (3) discriminable versus non-discriminable species. High resolution in-situ spectral-reflectance data (2040 bands, 350 – 2500nm) were collected over 40cm diameter plots from 240 sites on Magnetic Island, Pallarenda Beach and Green Island in North Queensland at spring low tides in April 2006. Digital photos were used to derive seagrass species cover, epiphytic growth, micro- and macro-algal cover, and substrate colour. The field reflectance spectra were analysed to establish the minimum foliage projective cover for each seagrass species that was significantly different from substrate with algal cover. The spectral bands providing maximum discrimination and separation were also defined. This analysis was repeated with reflectance spectra resampled to the spectral bandpass functions of Quickbird-2, Ikonos, SPOT 5 and Landsat 7 ETM.

3.2 Mapping seagrass composition, cover and biomass in shallow and clear environments

Building on the findings from 3.1, this stage assessed the accuracy of airborne hyper-spectral and satellite multi-spectral image data sets for mapping several seagrass properties in an 80 km^2, clear, shallow water environment of eastern Moreton Bay[4]. Three types of image data were used: Quickbird-2 multi-spectral and Landsat-5 Thematic Mapper multi-spectral; and CASI-2 hyper-spectral. All images were captured in the July-August 2004 period, coincident with a field survey. The field survey collected 2500 georeferenced underwater digital photographs of 1.0 m^2 areas, captured at 2.0m intervals along 56, 100 m long transects, distributed across the Eastern Banks section of Moreton Bay. The percentage cover of substrate and seagrass and macro-algae species was identified for each photo. The field data were used to guide a supervised mapping approach at depths shallower than 3.0 m, to map: (1) sand and four seagrass cover classes (1–1 0%, 10–40%, 40–70% and 70–100%); and (2) seagrass species. This process was applied to the Quickbird-2, Landsat-5 TM and

CASI-2 images. Approximately half of the photo survey points from field-survey data set were used to train the supervised classification algorithms with the other half being used for validation of the seagrass cover and species maps. Accuracy assessments were conducted at pixel level for the seagrass cover and species maps, based on validation data from the field photo analyses.

3.3 Integrated field and image based seagrass mapping for a range of water clarities and depths

This stage of the project built on the findings from 3.1 and 3.2, to design and apply a suitable approach for mapping seagrass cover and composition across a coastal embayment with a range of water depths and water clarities, which encompassed the area used in section 3.2 [5]. Landsat 5 TM image and field survey data from the last section were used, along with 4578 additional spot check sites, with visual and drop camera observations covering deep, shallow and turbid sections of Moreton Bay. The image data were used to map seagrass cover in the exposed inter-tidal and clear shallow water areas to depths of 3.0 m. The field survey data were used to map deep (> 3 m) and turbid sub-tidal areas. The resulting maps were combined into a single layer, using the same seagrass cover class labels as existing mapping programs. Due to an absence of independent field data for accuracy assessment, a reliability assessment was conducted based on subjective assessments of the quality of spatial information used to derive the location and seagrass cover level for each polygon. This indicated that > 75 percent of the Bay was mapped with high categorical reliability.

4. FINDINGS & FUTURE WORK

The main findings for each of the three components of the project can be summarized as follows:

(1) Based on in-situ hyper-spectral data, minimum detectable cover levels range from 12 - 37%. Distinct effects of leaf and canopy structure and pigment levels were observed. Maximum discrimination between seagrass and substrate, and various seagrass cover levels was provided by the visible portion of the spectrum (400-650 nm). Re-sampling the field spectrometer signatures to the spectral bandwidths of commercially available sensors resulted in slightly lower levels of detectable cover for all species. This increased sensitivity may be attributed to the increased signal produced by wider bandwidths for the sensors used.

(2) For seagrass species and cover mapping on the shallow and clear Eastern Banks, airborne hyper-spectral data produced the highest overall accuracies (46%), followed by Quickbird-2 and then Landsat-5 Thematic Mapper. Low accuracy levels were attributed to difficulties in matching locations on image and field data sets.

(3) The final mapping approach integrated image and field data, provided a reliable means to map and monitor seagrass beds over Moreton Bay, across a full range of water depths and clarities. In contrast to previous mapping approaches, this work covered a “management area”, as most previous studies only covered areas < 400 km^2, using only a single data sets, and lacking error or reliability assessment. Similar distributions and cover levels were also presented in relation to recent maps of seagrass in Moreton Bay.

Although the progression of methods developed and applied in this work addressed a significant gap in seagrass mapping methods [6, 7] by providing an approach that worked across shallow and deep, clear and turbid water bodies, the final mapping approach was not sufficiently accurate, nor did it include all of Moreton Bay's seagrass. To address this limitation, the next version of our coastal seagrass mapping routine will use satellite image data with a pixel size < 5.0 m , a greater number of green and red spectral bands (e.g. Worldview 2) in shallow and clear areas, combined with spot checks for shallow turbid waters and drop camera in deep waters. The lessons learnt from this process, in terms of data selection and processing, now form the basis for an on-line educational tool (www.gpem.uq.edu.au/CRSSIS/tools/rstoolkit/default.html) to guide scientists and resource managers on selecting data to use and processing requirements for mapping and monitoring coastal environments.

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