OPTIMIZING CLASSIFICATION ACCURACY OF ESTUARINE MACROPHYTES:
COMBINING SPATIAL AND PHYSICS-BASED IMAGE ANALYSIS

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INTRODUCTION

As a consequence of climate change, environmental managers face challenges in decision making particularly in Australian coastal areas [1]. Combined anthropogenic pressure and rising sea level may significantly alter estuarine ecology. Estuarine macrophytes, including seagrass, mangrove and saltmarsh are an important resource as they provide fish habitat, contribute to food chains, enhance water clarity and reduce erosion. The forecast rise in sea level may significantly alter the distribution of estuarine macrophytes, modifying coastal ecologies as well as economies [1]. There is consequently an increasing need to obtain regular, accurate and up-to-date information on the extent of estuarine resources.

Baseline data on the extent of estuarine macrophyte cover was produced for the whole of the New South Wales (NSW), Australia, coast in the early 1980s [2]. Maps were produced from aerial photographic interpretation (API) using the *camera lucida* technique, an analogue exercise that took at least 10 person-years to complete. While the methodology was a standard approach for its time, it had systemic operational errors that reduced its accuracy [3].

A study assessing change in the subtidal habitat in Wallis Lake over a 14 year period using historical Landsat satellite multispectral imagery from 1988 - 2002 [4] proved that retrospective change analysis is possible. Key recommendations from [4] were to investigate the use of higher resolution imagery and alternative image interpretation techniques, for improved classification accuracy.

Traditionally, interpretation of remote sensing data has been image-based, and thus empirical. However, empirical approaches are not easily transferrable across study areas or data types [5]. Object oriented analysis (eg, image segmentation) can increase classification accuracy by integrating additional (non spectral) information, such as texture and pattern, where the potential for spectral confusion exists [6]. Recently physics-based classification approaches have evolved to utilize semi-analytical (bio-optical) models that can incorporate water column properties and benthic substratum composition [7, 8]. These models allow us to accurately simulate the response of airborne- or spaceborne sensors for various benthic substrates (forward modelling).

While the non-linear optimization of these models (inverse modelling) can be implemented to simultaneously derive water depth, water column properties and substratum composition from spectral data.

METHODOLOGY

Wallis Lake is an immature barrier estuary with extensive areas of estuarine macrophytes [2, 9], located on the central coast of NSW. Due to the lake's variable water quality and substratum complexity, it poses a challenging target for developing an objective remote sensing monitoring method.

A field campaign was conducted at representative sites around the lake in May and September 2008. *In situ* data was collected for both model parameterisation and validation of the results. The aim was to characterise the optical properties of the water column, variations in optical properties of the benthos and collect geo-located validation data of benthos type, distribution and bathymetry.

In situ optical properties of benthos and water constituents were used to create a representative library of the environmental spectral responses. In order to visualise the relationship between water constituents (concentrations and optical properties) and the remotely observable reflectance, a forward simulation approach was implemented. This approach was used in the sensitivity analysis of the benthic spectral library and validation of the atmospheric correction.

To select the appropriate spectra for input into the physics-based processing pathway, the spectral separability (in the QuickBird/Landsat spectral range) of the field spectra was determined. This required simulating the behaviour of each benthic spectrum at increasing water depth in the water type defined for this study. Benthos that were spectrally distinct at depth were selected for the spectral library.

Landsat (30m pixels) and QuickBird (2.6m pixels) satellite imagery of Wallis Lake was acquired in September 2008. Image pre-processing (co-registration, atmospheric correction, segmentation) was deemed important because it allowed for a standardized repeatable processing pathway required for any comparisons between satellite data. Ensuring each pixel represents the same area in each image, it was essential to co-register the images, using the QuickBird (with the higher spatial resolution) as the base image.

A standardised atmospheric and air/water interface correction [10] was applied to the images to retrieve subsurface irradiance reflectance R(0-). In general, the validation of atmospheric correction is performed by comparison between concurrent *in situ* and satellite water reflectance spectra over the same targets. However, collecting such *in situ* data is often not feasible, as was the case with this project. Therefore, simulated spectra were compared to the satellite-derived water reflectance. The simulated spectra were computed with the water column properties and benthic spectral library collected during the field experiments.

Spatially relevant validation data for satellite image based classifications require a spatially dense sampling design. By utilising image segmentation, point observations can be converted to polygons by taking advantage of the homogeneity of benthos in the vicinity of the geo-located point observations [11]. Additionally, image segmentation can be implemented to reduce data complexity by introducing additional information such as pattern, texture and depth zonation. This generally improves the fine scale separability of some seagrass species which may be spectrally indistinct from each other at depth.

Image Analysis

Similar to the approach outlined by [8], SAMBUCA, an enhanced implementation of the inversion/optimization approach by [7] was applied to the satellite imagery. Estimates were produced of bathymetry, benthic composition, concentrations of the optically active constituents of the water column, including chlorophyll-a, coloured dissolved organic matter (CDOM) and non algal particulate matter (NAP).

Output from SAMBUCA also estimates the accuracy between the modelled spectra and the image spectra. This estimation can therefore be an indication of the reliability, or confidence in, the SAMBUCA bathymetry and substratum estimates. A more detailed description of the data retrieval and error assessment procedure used in the SAMBUCA model can be found in [8]. To validate model accuracy, SAMBUCA bathymetry estimates were compared with *in situ* depth measurements collected during the field campaign. Substratum type for each image pixel is output from the SAMBUCA model as a percentage of two substratum types. Classification accuracy of substratum maps was assessed with standard post-classification statistical analysis tools using a validation dataset of georeferenced *in situ* observations collected during the field campaign.

DISCUSSION

This presentation will discuss the processing output in terms of:

- The in-built SAMBUCA quality control measures that lead to the exclusion of suboptimal data from the comparison, increasing confidence in the output
- Assessing the field-validated model output accuracy as a function of spatial resolution
- Comparing the modelled output with the traditionally produced API maps.
- The potential development of a more consistent trend assessment processing pathway.

Using this standardized approach, it is evident that satellite remote sensing can support management decisions by improving the effectiveness of monitoring programs. Furthermore, when this approach is used to detect change it becomes a cost-effective source of information because it can be applied on historical, current and future images. Future advances in satellite sensor technology will result in higher spectral resolution image data. This will increase the number of benthic types that can be distinguished using the same physics-based approach implementing the existing spectral libraries.

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