Mapping habitats and biodiversity of Ningaloo Reef lagoon using hyperspectral remote sensing data

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This project is part of the CSIRO Flagship Wealth from Oceans, Ningaloo Cluster: "Reef use, biodiversity and socio economics for integrated management strategy evaluation of Ningaloo". This project is run from Murdoch University in collaboration with Curtin and Queensland Universities. Airborne hyperspectral data have been acquired by HyVista through the efforts of AIMS and sponsored by BHP Billiton.

The project is focusing on the mapping of habitats and biodiversity of the Ningaloo Marine Park. This is being achieved through a combination of state-of-the-art hyperspectral remote sensing techniques, coupled with biodiversity field surveys of the area.

Specific aims are to:

1. Use the hyperspectral data to create a bathymetry data set and broad-scale classification of the lagoon habitats over the extent of the Marine Park (Curtin University).
2. Develop a radiation transfer model and optimisation code that can be used by researchers on a number of different systems to reprocess atmospherically corrected reflectance data (Curtin University).
3. Develop a high-resolution characterisation of the reef and shallow water habitats of the Ningaloo Marine Park that will provide the basis for future multiple use management and planning of the area.
4. Develop a high resolution characterisation of terrestrial land use and distribution in relationship to marine habitats.
5. Qualitatively and quantitatively describe the biodiversity values of selected areas of the reef in relationship to the bio-physical environment, patterns of reef use and access from land, linking these with physical and/or biological surrogates to enable specific biodiversity values to be applied across the entire Ningaloo Marine Park.
6. Identify biodiversity hotspots and develop an understanding of the environmental and habitat factors that explain the distribution of these hotspots.

Airborne hyperspectral data were collected by HyVista in April 2006 over 3500 km2 covering the whole Ningaloo Marine Park. This is the largest hyperspectral coral reef survey to date in the world and provides images at 3.5m spatial resolution for a 1km wide terrestrial coastal strip and out to 20m depth over lagoon areas. Hyperspectral remote sensing data are corrected for atmospheric, air water interface and water column effects. This, physics-based approach, promotes automatisation and the removal of subjectivity from the classification process, allowing improved transferability to additional sampling locations and extension of the monitoring to other seasons.

Optical remote sensing techniques, especially hyperspectral sensors can provide an efficient and cost-effective approach to mapping and monitoring the condition of reefs over large areas because of their capability to identify individual reef components on the basis of their detailed spectral response. The aim of this study is to develop a reliable and repeatable procedure for mapping submerged coral reefs using airborne hyperspectral data.

Spectral data collection

Spectral reflectance of corals, macroalgae and sediment from several habitats at different locations were measured underwater in the field with an OceanOptics2000 hyperspectral spectroradiometer. Field samples were collected during airborne remote sensing data acquisition in April 2006 (2 weeks), April 2007 (2 weeks), September/October 2007 (1 week) and December 2007 (2 weeks).

Spectral reflectance from different substrate types including sand, coral and brown algae were collected in situ to assess the range of spectral variability that may be found in each cover type. Benthic group code for survey of sessile benthic communities were adopted from AIMS (Page et al., 2001). A sampling strategy was used to measure the spectral reflectance of as many homogenous substrates as possible to characterise the spectral signatures of each species. Data collection was performed following the methods described in Hochberg and Atkinson (2000,2003).

These underwater spectra were used for development of algorithms for automated applications to image classification. A genetic algorithm technique was used to determine optimal waveband combinations ideal for identification of substrate types by remote sensing.

Initial results show that in situ reflectance spectra of coral reef substrates were significantly different for various spectral wavelengths. Based on a linear discriminant analysis, the in situ spectra of six benthic groups (branching Acropora, digitate Acropora, tabulate Acropora, massive corals (e.g.

Porites), submassive corals (e.g. Pocillopora) and macroalgae) could be classified to 90 % accuracy using as few as six optimally-positioned bands in the visible wavelengths. Statistical tests such as unsupervised classification (Principal Component Analysis) and a distance measure index (Jeffries-Matusita) were used to confirm species separation and indicated that hyperspectral remote sensing techniques offer great potential in mapping coral reef habitats. A preliminary classification of major habitat groups was applied to airborne hyperspectral remote sensing data from HyMap acquired in November 2005 and April 2006 over the Yardie Creek area and Coral Bay. The images were corrected for atmospheric, air-water interface, and water column effects using the physics-based Modular Inversion & Processing System. This has the advantage of removing subjectivity from the classification process, approaching an automated classification which allows improved transferability to other sampling locations and monitoring applications. The retrieved bottom albedo image was then used to classify the benthos, generating a detailed map of benthic habitats, followed by accuracy assessment.

The outputs of multitemporal image analysis allowed us to create quantitative maps of selected substrate cover types. These have now been partly validated using our own data and data from 17 sites monitored by DEC (Dr Suzanne Long) over the past 10 years.

Comparison of the preliminary marine habitat maps with the field results of description and cover is very encouraging. The results indicate that the spectral response of corals can be determined up to a depth of 10 m and show that hyperspectral remote sensing techniques provide an opportunity for developing baseline mapping and monitoring programs for coastal and coral reef ecosystem health indicators.

Terrestrial data processing is focusing on mapping tracks, invasive grass species (buffel grass) and mapping broad coastal vegetation communities.

The following landforms components have been identified for mapping:

- foredunes, relic foredunes, relic foredunes plain, parabolic dunes, active parabolic dunes,
- coastal storm surge flats, inlet splits (relic), interdune depression/flat, aeolian flat/ridge,
- deflation basin, saline flat/salt pan, hypersaline pools, calcarenite rocks and sand plains.

Vegetation components are assessed through vegetation indices as well and spectral mixture mapping techniques. The following vegetation components have been identified as "mappable" using hyperspectral data: trees (Eucalyptus, acacias, Casuarina, Tamarisk (non native), palms); shrubs (ficus, halophytes, coastal shrubs, mangroves; grasses (buffel (non native), green grass in settlements) and coastal/dune complex plants (spinifex, saltbush, acacia).

Data layers generated from marine and terrestrial data processing will comprise thematic maps of cover type showing habitat distribution as well as probability maps for each of the habitat components. These data will assist in current and future management of activities in the park as well as future planing and monitoring programs.

References

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