THE APPLICATION OF OBJECT BASED ANALYSIS OF HIGH SPATIAL RESOLUTION IMAGERY FOR MAPPING LARGE CORAL REEF SYSTEMS IN THE WEST PACIFIC AT GEOMORPHIC AND BENTHIC COMMUNITY SPATIAL SCALES.

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ABSTRACT

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Coral reef habitat maps at various spatial scales and extent are needed for monitoring and management purposes in coral reef environments. This paper will demonstrate object based analysis for coral reef habitat mapping at reef type, geomorphic zone and benthic community spatial scales, on single reefs or reef systems in Western Pacific. For the study sites, archived high spatial resolution Quickbird and/or Ikonos imagery were acquired and radiometric and atmospheric corrected. Georeferenced benthic photos along transects were acquired for calibration and validation purposes. Hierarchical mapping from reef, to geomorphic zone, then community scales, was completed using object based segmentation and semi-automated *labeling* through membership rules using field data for calibration and validation. The resulting hierarchal maps for reef type, geomorphic zone and benthic community, had varying accuracies 60-80% for each spatial scale.

Index Terms— Object Based Image Analysis, high spatial resolution imagery, Habitat Mapping, Coral Reefs

1. INTRODUCTION

For monitoring, modeling and management, habitat maps at geomorphic and benthic community spatial scales and large spatial extent are needed [1, 2, 3]. High spatial resolution satellite imagery, with pixels < 5 m, integrated with field survey data can provide these maps through pixel [4] or object-based image analysis [5].

As coral reef systems can extend beyond the scene of a high spatial resolution image, they often require a mosaic of various images. The mosaics are in generally not seamless as each image was acquired under unique atmospheric and environmental (e.g. tidal range, water clarity) conditions. This is especially challenging for pixel based approaches as these mainly rely on the reflectance values of the individual pixel.

Object based analysis mapping approach on the other hand incorporates next to the pixel reflectance values, the texture, location and biophysical properties of groups of pixels (objects). This provides object based analysis approach with more options to differentiate mapping categories and to create habitat maps of the large coral reef systems, which has not been presented before.

This paper will demonstrate the application of object based analysis for coral reef habitat mapping at geomorphic and benthic community spatial scales, on single reefs or reef systems in Western Pacific.

2. METHODS

Initial research of the object based analysis approach presented in this paper, was applied on single reefs: Heron Reef on the Great Barrier Reef in Australia, Navakavu Reef in Fiji and Ngdarack Reef in Palau [6].

The lessons learned from these single reefs studies were then in this study implemented on larger reef systems: Great Astrolabe Reef and Kubulau Reef in Fiji, and Bikini Atoll in Marshall Islands. These reefs were representing a range of Indo-Pacific platform, fringing, barrier and atoll reef types at various spatial extends.

5.1. Image and Field Data Collection and Pre-Processing

For each case study, archived high spatial resolution Quickbird (2.4 m pixels) and/or Ikonos (4 m pixels) imagery were acquired. The various satellite image data sets were corrected for radiometric and atmospheric distortions to at-surface reflectance as in [6]. Mosaics of the satellite imagery were created for the Astrolabe Reef, Kubulau Reef and the Bikini Atoll sites. Some scenes were correct for sun-glint if required using existing approaches [7].

For all study sites, except Bikini Atoll, benthic field data was collected through georeferenced benthic photo transects after each photo was assigned a benthic community category [8].

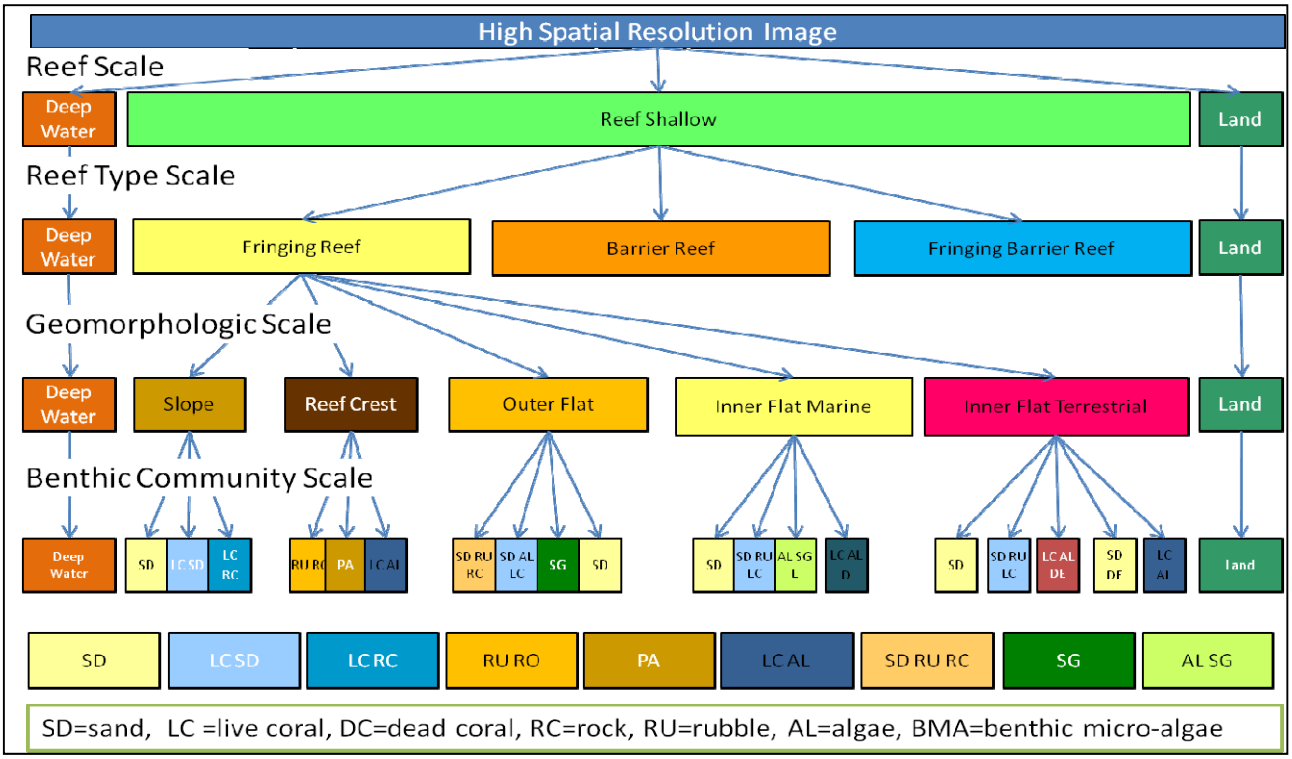

Figure 1: Hierarchical class structure diagram of mapping categories at four different spatial scales: 1) Reef, 2) Reef Type, 3) Geomorphic Zone, and 4) Benthic Community.

5.2. Object Based Image Classification

For each individual study site four hierarchical spatial scales of habitat maps were subsequently created based on object based image analysis using Definiens Developer 7.0. These four hierarchical spatial map scales were: 1) reef; 2) reef type; 3), geomorphic zone, and 4) benthic community (Figure 1).

The object based analysis consisted of two steps: image segmentation and segment classification [9]. The first step determined the segments for a required spatial scale depending on the colour and shape of groups of pixels, and the spatial resolution of features to be mapped. The segmentation step was applied initially on the whole image or image mosaic but then sub-segmentation was applied on the mapping categories of higher level map scale (Figure 1). The second step assigned automatically or manually mapping categories to the segments of the first step based on membership rules, which incorporate the segment: colour, shape, texture, position or biophysical properties. This process was repeated for each of the mapping scales.

The membership rules for each of the study sites were extracted from the previously developed rule sets [6] for a similar: reef type, geomorphic zone or benthic community mapping category and mostly required adjustments of thresholds. In some cases new membership rules were created to account for different mapping categories present in each study site. These membership rules could for example be determined by: NDVI value; brightness of Blue band; ratio blue and red band; standard deviation of blue band, location one mapping category to another, and distance to land.

The segmentation scales and the membership rule sets for the first three mapping scales were mostly driven by image interpretation and expert knowledge, where as for the benthic community scale it was mostly based on the field data.

5.3. Accuracy Assessment

To assess the accuracy of the habitat maps at geomorphic and benthic community scale, error matrixes were determined that are based on classified image and reference data for the individual maps. The error matrixes were used to calculate commonly used: map accuracies, Overall and Kappa; and the mapping category accuracies, user and producer [10]. The geomorphic reference dataset was extracted by manually assigning a geomorphic mapping category to randomly distributed points within each geomorphic zone based on expert knowledge. The benthic community reference data was derived from field data set not used for calibration by comparing the field data with the underlying segment from the benthic community scale map.

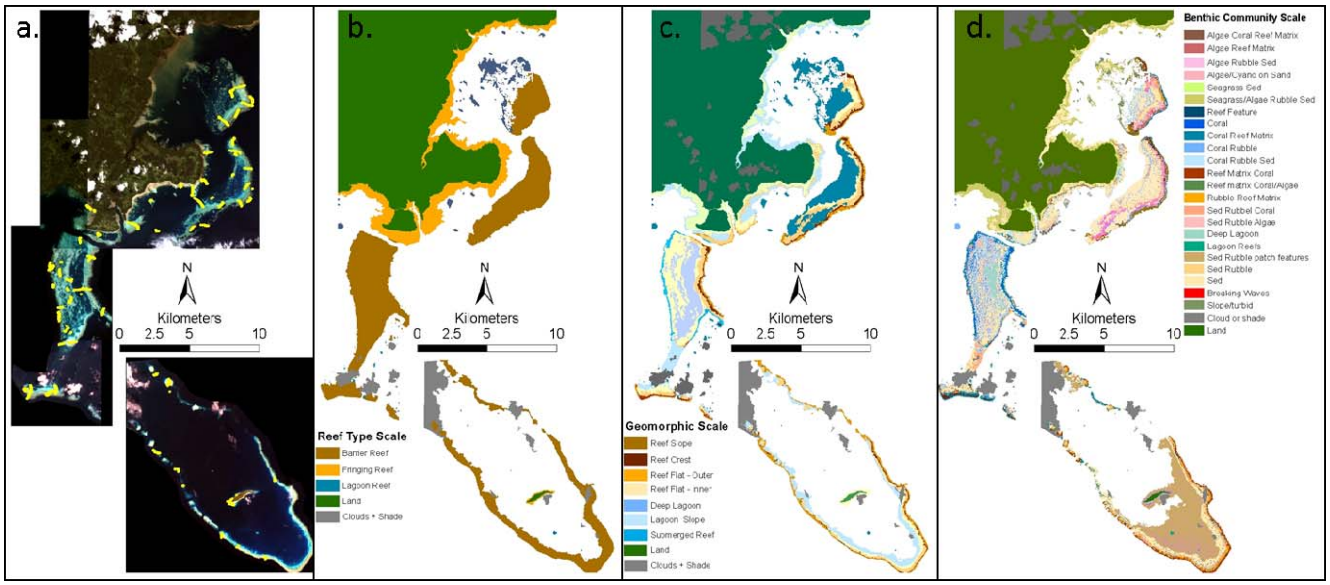

Figure 2: Kubulau Reef, Fiji of mosaic of Quickbird and Ikonos imagery with in yellow the field data points (a), and hierarchical mapping categories at three different spatial scales: Reef Type (b), Geomorphic Zone (c), and Benthic Community(d).

3. RESULTS AND DISCUSSION

The object based Image Analysis applied on the Kubulau reef system (Figure 2) resulted for the Geomorphic zone map in an Overall accuracy of 82.1 % and a kappa accuracy of 80.1 %, for the benthic community map these accuracies were respectively 66.6 % and 62.9 %. These results were in the same range compared to previous work in coral reefs using object based image analysis [6]. It is therefore expected that similar values could be expected for the Kadavu reef system which still need to be determined.

The object based approach showed that rule set that were not solely based on pixel value for one band proved to work cross study sites and scenes (e.g. band ratios, standard deviation, distance to other category) whereas rule sets based on the pixel value only (e.g. blue band value) could rightly assign a map category to segments in one scene in comparison to segments in adjacent scene. The rule sets developed for one site could be implemented on other reefs that had similar characteristics after adjusting the thresholds for some of the mapping categories.

Object based analysis showed to be effective in using the information of multiple images of the same area to improve the classification. For instance, in one image lagoon reefs were not visible due to turbid water, where as in another image the water was clearer revealing the lagoon reefs, both images were therefore used in the image segmentation.

A similar example where two images were used was in the case of presents of sun-glint corrected and not corrected image. As a result of applying sun-glint correction the NIR band was lost which was no problem for deep reef as the NIR band is not penetrating sufficiently but a los for very shallow and exposed reef. By including un-corrected and corrected image in the segmentation process, the first image was used to extract shallow/exposed reef mapping categories and the second image to extract deep reef categories.

4. CONCLUSIONS

This study demonstrates that object based image analysis is robust approach that can be applied on a variety of reef systems to create habitat maps at different spatial scales:1) reef, 2) reef type; 3), geomorphic zone, and 4) benthic community. Future research will focus on two fields: firstly, creating libraries of membership rules sets for specific reef types, reef zones and benthic community categories; and secondly determining the cost effectiveness of this approach for coral reef monitoring, modeling and management.

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6. REFERENCES

[1] Mumby, P.J., W. Skirving, A.E. Strong, J.T. Hardy, E. LeDrew, E.J. Hochberg, R.P. Stumpf, and L.T. David, "Remote sensing of coral reefs and their physical environment", *Mar. Pollut.* Bull. 48(3-4): p. 219-228. (2004),

[2] Andréfouët, S., "Coral reef habitat mapping using remote sensing: A user vs producer perspective. Implications for research, management and capacity building", *Journal of Spatial Science*. 53(1): p. 113-129. (2008),

[3] Green, E.P., P.J. Mumby, A.J. Edwards, and C.D. Clark, *Remote sensing handbook for tropical coastal management.* 1(Paris: UNESCO: p. 316.(2000),

[4] Andréfouët, S., P. Kramer, D. Torres-Pulliza, K.E. Joyce, E.J. Hochberg, R. Garza-Perez, P.J. Mumby, B. Riegl, H. Yamano, W.H. White, M. Zubia, J.C. Brock, S.R. Phinn, A. Naseer, B.G. Hatcher, and F.E. Muller-Karger, "Multi-site evaluation of IKONOS data for classification of tropical coral reef environments", *Remote Sens. Environ*. 88(1-2): p. 128-143. (2003).

[5] Benfield, S.L., H.M. Guzman, J.M. Mair, and J.A.T. Young, "Mapping the distribution of coral reefs and associated sublittoral habitats in Pacific Panama: a comparison of optical satellite sensors and classification methodologies", *Int. J. Remote Sens*. 28(22): p. 5047-5070. (2007).

[6] Phinn, S.R., C.M. Roelfsema, and P.J. Mumby, "Multi-scale image segmentation for mapping coral reef geomorphic and benthic community zone", *Int. J. Remote Sens*. (in press),

[7] Hedley, J.D., A.R. Harborne, and P.J. Mumby, "Simple and robust removal of sun glint for mapping shallow-water benthos", Int. J. Remote Sens. 26(10): p. 2107-2112. (2005),

[8] C.M. Roelfsema and S.R. Phinn, "Calibration and Validation of Coral Reef Benthic Community Maps Derived from High Spatial Resolution Satellite Imagery", Journal of Applied Remote Sensing, Vol. 4, 043527 (2010)

[9] Blaschke, T. "Object based image analysis for remote sensing", Journal of Photogrammetry and Remote Sensing. (2010),

[10] Congalton, R. G. and K. Green (1999). *Assessing the accuracy of remotely sensed data: principles and practices.* Boca Rotan FL, Lewis Publishers: 137.