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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1 INTRODUCTION:

Coral reef habitat maps at geomorphic and benthic community spatial scales are needed for monitoring, modelling and management of reefs [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 over 5 – 75's km in length, they require a mosaic of images to produce a map. Large area reef mosaics are not seamless, as each image is acquired under unique atmospheric and environmental, e.g. tidal range, water clarity, water roughness, conditions. Significant scene to scene variation still exists after atmospheric correction and mosaicking, causing significant problems for per-pixel based mapping approaches. Mapping based on object based image analysis, is a potential solution to mapping in this context, as it uses reflectance values, texture, location and biophysical properties of groups of pixels, or objects. This approach provides a more robust solution to mapping coral reef geomorphic and habitat zones across multiple satellite image scenes. This work demonstrates the application of object based analysis for coral reef habitat mapping at four different mapping levels: reef/non-reef, reef type, geomorphic and benthic community, on single reefs or reef systems in Western Pacific.

2 METHODS

2.1 Study Sites, Image and Field Data

The object based analysis approach presented in this paper, was initially applied to 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 applied to several larger reef systems: Great Astrolabe Reef and Kubulau Reef in Fiji, and Bikini Atoll in Marshall Islands. These reefs represent a range of Indo-Pacific platform, fringing, barrier and atoll reef types at various spatial extents, from 15 to 1000 km^2.

For each reef mapped, archived high spatial resolution Quickbird imagery (2.4 m pixels) and/or Ikonos imagery (4 m pixels) were acquired. These 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 corrected for sun-glint if required using existing approaches [7]. For all study sites, except Bikini Atoll, benthic field data were collected through georeferenced benthic photo transects. Each photo was manually assigned a benthic community mapping category using Coral Point Count Excel extension [8, 9].

2.2 Object Based Analysis

For each individual study site, four hierarchical spatial scales of habitat maps were 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).

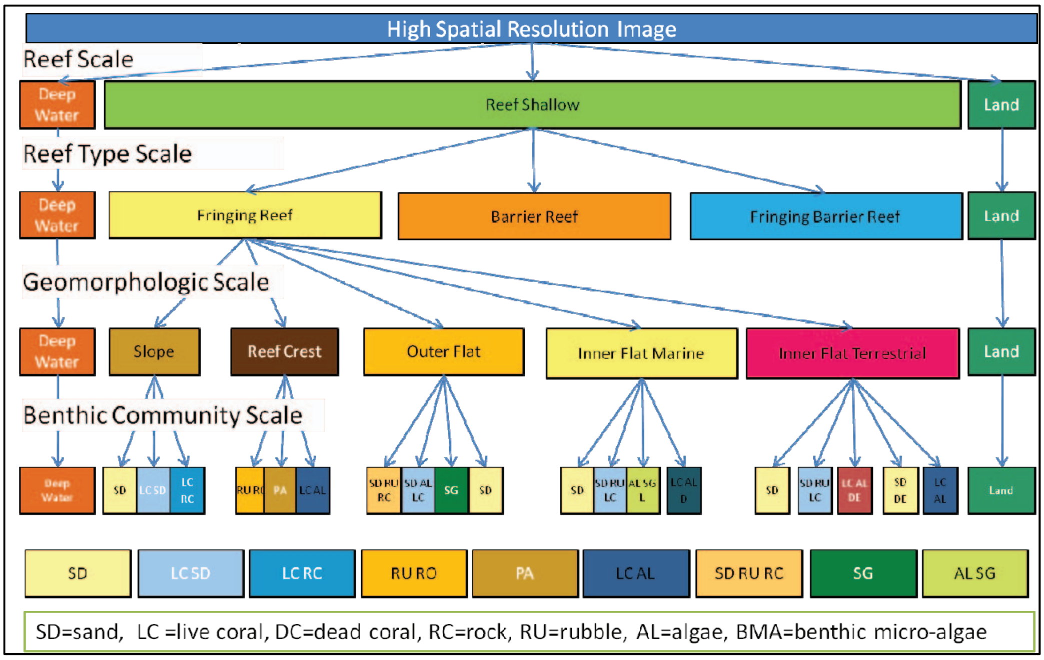

Figure 1: Example of a hierarchical class structure diagram of mapping categories at four different spatial scales: 1) Reef, 2) Reef Type, 3) Geomorphic Zone, and 4) Benthic Community.

The object based analysis consisted of two steps, image segmentation, followed by segment classification [10]. 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 the features to be mapped. The segmentation step was applied initially to the whole image or image mosaic, and then sub-segmentation was applied to the individual mapping categories of higher level map scale (Figure 1). The second step assigned, automatically or manually, map categories to the segments that were created in the first step using membership rules. These rules 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, reef type, geomorphic zone or benthic community mapping category. Although the class membership rules for individual mapping categories did not have to be changed from reef to reef, the thresholds used in the rules had to be modified as the same type of reef feature could have differing image pixel values due to differences, in water clarity, water surface and/ atmospheric conditions. In some cases, new membership rules were created to account for different mapping categories present at each study site. For example, the membership rules were defined by : pixel value; overall pixel brightness; ratio of blue to red band; vegetation index band value, standard deviation of blue band; object shape, location of one object relative to another object; and/or distance to land. The segmentation scales and the membership rule sets for the first three mapping scales, 1) reef; 2) reef type; 3), geomorphic zone, were driven by image interpretation and expert knowledge, whereas the benthic community scale was mostly based on the field data. An error matrix was determined for each map based on independent validation data set and was used to calculate accuracy statistics (Overall accuracy, user producer, Kappa and Tau) for each map in each study site[11, 12].

3 RESULTS

The object based analysis produced maps of the reef at four hierarchical mapping levels: reef; reef type; geomorphic, and benthic community (Figure 2).

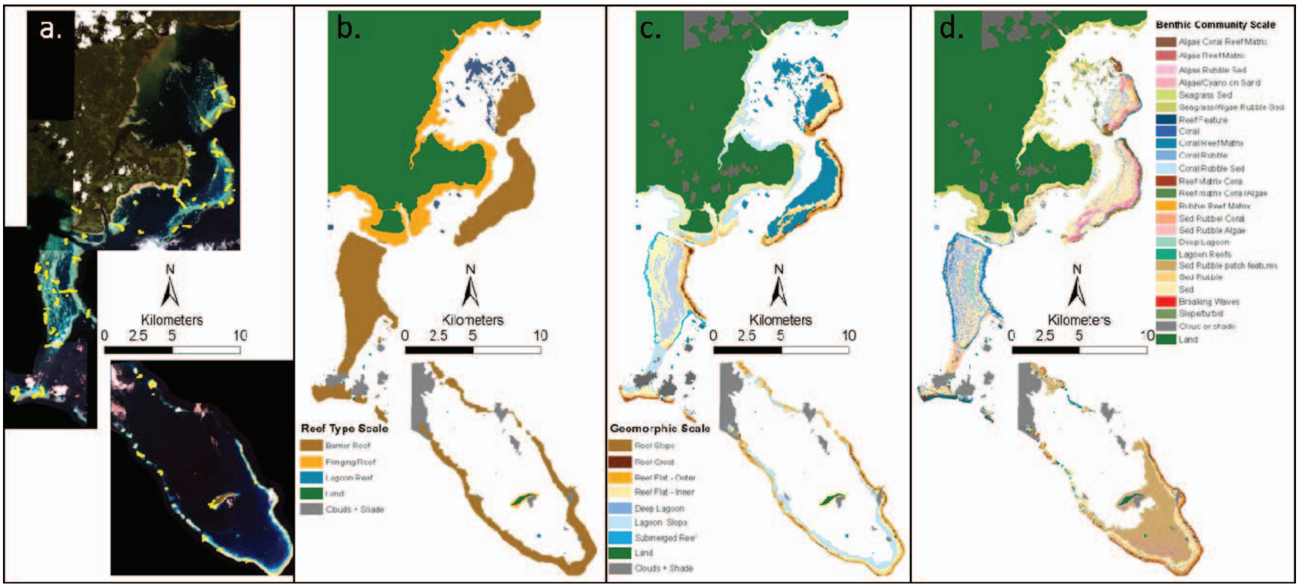

Figure 2: Kubulau Reef in Fiji, from acquisition dates in the period 2006-2007, showing from left to right: (a) Mosaic of three Quickbird and two Ikonos image scenes, yellow = calibration and validation sites; (b) reef type map, (c) geomorphic zones map; and (d) benthic community map. Geomorphic zones map had 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 %.

For the study sites examined, the number of mapping categories varied between each of the four map levels, where the reef map had only three to four categories and benthic community scale map had up to 30 categories. As each category requires a membership rule, the rule set for benthic community based maps were more complex, as they required more rules, had most adjustment to thresholds, and needed additional rules. Overall and Kappa accuracies for each level of map were calculated and varied between 50-85 %, where maps with fewer categories had higher accuracies.

4 CONCLUSIONS & FUTURE WORK

This study showed that object based analysis applied to mosaics of high spatial resolution, multi-spectral imagery, when combined with field data, for single reefs or larger reef systems, can be used can produce maps at four hierarchical mapping levels: reef, reef type, geomorphic, and benthic community. The membership rules sets which were developed for the mapping categories of a specific mapping level and reef type, formed the basis for implementing the same rule set on other reefs which had similar characteristics. As a result of this, the development of the initial rule sets took more time then the adjustment of that same rule set when applied on another reef, making it an effective approach for application on a variety of individual reefs or large reef systems. The consistent use of the same hierarchical structure for the four spatial map levels, made the results for the single reef or reef systems comparable with each other, which was considered beneficial for monitoring and management purposes. Object based analysis could therefore potentially be and effective approach for mapping reefs at a variety of spatial scales and environments, once a library of membership rule sets is created for various representative reef types. Future research will therefore 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, modelling and management.

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