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Mapping shallow water habitats of the Wallabi Group, Houtman Abrolhos Islands, using remote sensing techniques

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Contents

Abstract

The use of mapping techniques to identify and quantify habitats is becoming an increasingly important tool for the effective management of marine resources. With a multitude of techniques such as remote sensing, acoustic surveys and towed video all commonly used, the decision on the methodology to use depends on the resolution of output data required to answer the objectives of the survey, the spatial extent and location of survey site as well as the associated costs of surveying. For this study remote sensing technologies were used to assess the capacity to categorise, and potentially monitor, a large spatial area of shallow (< 20 m in depth) marine benthic habitats. The project was conducted at the Wallabi Group of the remote Houtman Abrolhos Islands, in Western Australia. Two satellite sensors (ALOS AVNIR-2 and Landsat 5 TM) where used to provide unsupervised classifications of the habitats. Extensive ground truthing of the study area was then conducted in March and April of 2010 to inform and refine the classifications. Initial habitat classification resulted in 21 habitat categories being developed, however due to the inability of the sensor to accurately discriminate that level of habitat classification, categories were merged into eight classes to improve classification success. The level of accuracy of the eight class habitat map is similar to other studies using this technique and consistent with the complexity of the benthic habitats of the Houtman Abrolhos Islands. Improvements and developments of sensors into the future should further assist in refining habitat discrimination further providing managers and researchers with an effective tool to categorise and monitor marine habitats.

1.0 Introduction

1.1 Background

The Houtman Abrolhos Islands (Abrolhos) are an archipelago of 122 small islands and associated coral reefs approximately 65 – 90 km offshore from Geraldton, in the Mid-West region of Western Australia (nominally 28°43’S 113°37E) (Wells 1997). The Abrolhos is divided into four island groups; North Island, Wallabi, Easter and Southern (Pelsaert) separated by deep (~ 40 m) channels (Figure 1). Situated near the edge of the continental shelf, the Abrolhos contains the southern most true coral reefs in the Indian Ocean with an extremely diverse coral community for the high latitude at which they occur (184 species in 42 genera) (Veron and Marsh 1988, Wells 1997). This diversity is primarily driven by the Leeuwin Current, a warm southward flowing current, which is strongest in autumn and winter (Feng et al. 2003) and surrounds the archipelago in tropical water. This warm water current, along with the islands southerly/temperate location, means that the marine environment of the Abrolhos are a unique blend of tropical and temperate species (Wells 1997). The uniqueness and ecological value of the Abrolhos resulted in their placement on the National Estate Register (under the Australian Heritage Act (1975)) and were gazetted as Western Australia’s first Fish Habitat Protection Area under the Fish Resources Management Act (1984) (Webster et al. 2002).

The Abrolhos Islands also have significant economic value, primarily due to commercial fisheries and aquaculture production. The most significant fishery is for western rock lobster (*Panulirus cyngus*). This fishery began in the 1940’s with the islands currently contributing approximately 20% (1103 tonnes in 2010/11) of the total Western Australian catch of western rock lobster (Department of Fisheries 2011). The Abrolhos is also a significant source of western rock lobster egg production, and provides a critical habitat for the continued sustainability of the fishery (Webster et al. 2002). The next important commercial fishery, in terms of economic value, is the highly variable saucer scallop (*Amusium balloti*) fishery, which landed 806t in 2010 (Department of Fisheries 2011). A significant component of west coast demersal scalefish fisheries for species such as the dhufish (*Glaucosoma hebraicum*), baldchin groper (*Choerdon rubescens*) and pink snapper (*Pagrus auratus*) are also commercially fished from the waters of the Abrolhos Islands (Department of Fisheries 2011). The dominant aquaculture sector at the Abrolhos is black-lipped pearl oyster (*Pinctada margaritifera*) production, with eight licenses currently being issued for production of these species. In addition, a license for a pilot sea cage finfish farm was issued in 2004. However to date the licensee has not used this license. There has also been interest in the production of live rock, sand and coral culture at the Abrolhos for the aquaria trade.

In recent years, there has also been an increase in tourism, driven by recreational fishers, divers and live-aboard ecotourism operators. Tourists are not currently permitted to stay on the islands, although a development group has proposed the establishment of a land-based facility in the Wallabi Group. The potential increase in these activities at the Abrolhos has raised concerns regarding the risk to the sustainability of the archipelago and highlighted the importance of good planning and management as identified in the Management of the Houtman Abrolhos System (Department of Fisheries, 2007). A critical first step in the process of implementing appropriate planning management strategies, is to identify and quantify the marine habitats of the Abrolhos and their sensitivity to human activities. As a result this project was initiated as an attempt to develop a better understanding of the marine habitats of the Abrolhos, particularly the Wallabi Group, to ensure ecologically sustainable multiple use of this unique area.

1.2 Habitat mapping

There is an increasing trend for the marine benthos to be used as a surrogate for ecosystem diversity (Ward et al. 1999, Eyre and Maher 2010) as well as a tool for the identification and monitoring of natural and anthropogenic impacts on habitats of high conservation or ecological value (Hochberg and Atkinson 2003, Kenny et al. 2003, Klemas 2011). Mapping of the benthic marine environment, although in its infancy in comparison with its terrestrial counterpart, is rapidly emerging as an essential tool for the effective management of marine environment resources (Jordan et al. 2005, Pandian et al. 2009, Hamel and Andréfouët 2010, Coggan and Diesing 2011). Our capacity to characterise marine habitats has also expanded rapidly over the last ten years (Eyre and Maher 2010, Harper et al. 2010, Valesini et al. 2010, Brown et al. 2011). Developments in the availability and reliability of remote sensing techniques (Bello et al. 2005, Rios-Lara 2007, Valesini et al. 2010), acoustic surveys (Jordan et al. 2005, Harper et al. 2010, Valesini et al. 2010, Brown et al. 2011), underwater vehicles (Laidig et al. 2009, Williams et al. 2010), towed underwater videos (Jordan et al. 2005, Bellchambers et al. 2010) and still photography (Waddington et al. 2010) have all enhanced our ability to characterise the seafloor and associated habitats. All of these techniques have varying levels of suitability in terms of the resolution of output data, spatial area of study, depth, requirements for specialised knowledge and equipment, expense and clarity of water column (Kenny et al. 2003, Diaz et al. 2004, Hamel and Andréfouët 2010). Therefore a key consideration is which technique is best suited to quantify the habitats of the proposed study site and to what resolution.

The spatial size and complexity of most coastal waters means that the use of satellites with a range of sensors is a cost-effective method for identifying and observing marine benthos

(Klemas 2011). The classification of multi spectral imagery to map benthic habitats is well known (Hochberg and Atkinson 2003, Mumby et al. 2004a and b, Pandian et al. 2009, Hamel and Andréfouët 2010, Klemas 2011). Recent studies also suggest that the use of sensors with 'high' resolution (i.e. between 0.6 and 10 m) in shallow (up to 30 m) coral reef communities, vastly improves the ability to discriminate the benthos into broad habitat classes (Hamel and Andréfouët 2010, Klemas 2011). The combined use of multi-spectral imagery and bathymetry data can also assist in increasing the accuracy of benthic habitat mapping (Mumby et al. 2004a).

1.3 Previous detailed habitat mapping studies at the Abrolhos

Hatcher et al. (1988) conducted the most comprehensive habitat mapping of the shallow-water regions (< 20 m) of the Abrolhos to date. The mapping was a 5-stage process of 1) preparing ortho-aerial photos of each reef group overlaid with depth contours, 2) designing a classification of ecological units, 3) identifying ecological units on the ortho-aerial photos and tracing them onto draft maps, 4) ground-truthing ambiguous units and 5) preparing final ecological base maps from the corrected draft maps. The resulting map categorised the marine environment into geomorphic units based on topography and composition of the substrate (Figure 2). The sensitivity of marine habitats to physical damage (e.g. storms and damage by pots) was also mapped.

As part of developing an Abrolhos Island Planning Strategy, Marine Science Associates (1998) did further habitat mapping in 1998. Satellite imagery (Landsat collected in 1989) was used to classify habitats by depth, slope, and cover type (plant, coral, sand and pavement) followed by ground truthing of selected areas. Subsequently Webster et al. (2002), conducted additional ground truthing of the geomorphic units identified by Hatcher et al. (1988) to identify a range of human use activities (fishing gear, anchor damage, divers etc.) and natural factors such as storm damage that could potentially physically impact the marine habitats at the Abrolhos.

Recently, in response to a potential tourist development at the Wallabi Group, benthic habitat mapping of the area around Long Island was undertaken (Oceanica 2006). Bathymetry was combined with digital charts and aerial images to determine the distribution of habitats at a coarse scale. The digital images were ground truthed using snorkelling surveys that recorded habitat type and biota. Short transects were also conducted using a chart plotter and underwater viewer to collect fine scale habitat data and define habitat boundaries (Oceanica 2006).

1.4 Project objectives

The aims of the study were;

1. To test the capacity of remote sensing techniques to measure and monitor benthic habitats in a shallow water temperate / tropical environment.

2. To develop a detailed habitat map of the shallow water (< 20 m) marine benthos of the Wallabi Group.

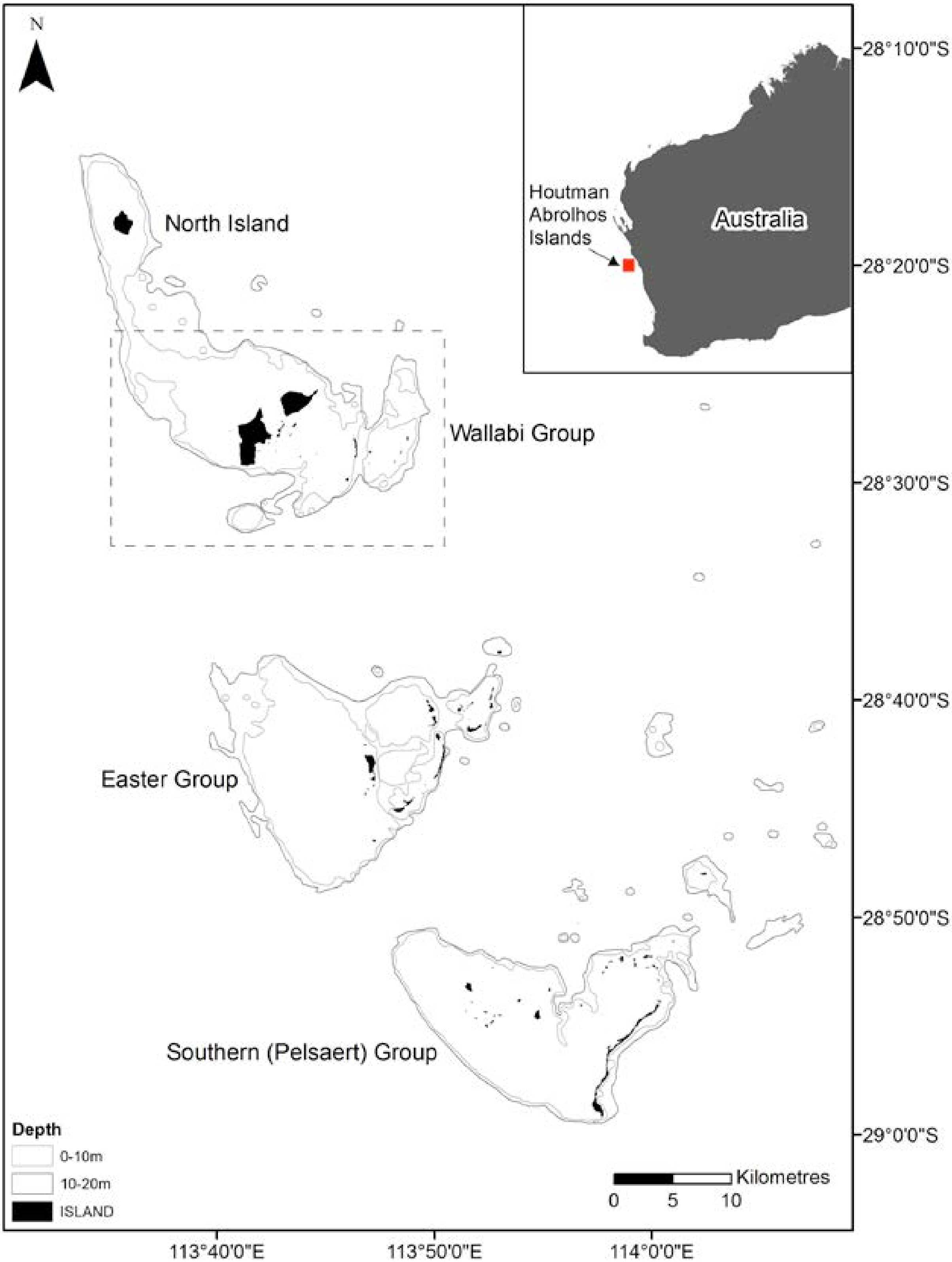

Figure 1. Map of Houtman Abrolhos Islands showing the study area (Wallabi Group) in the hatched box.

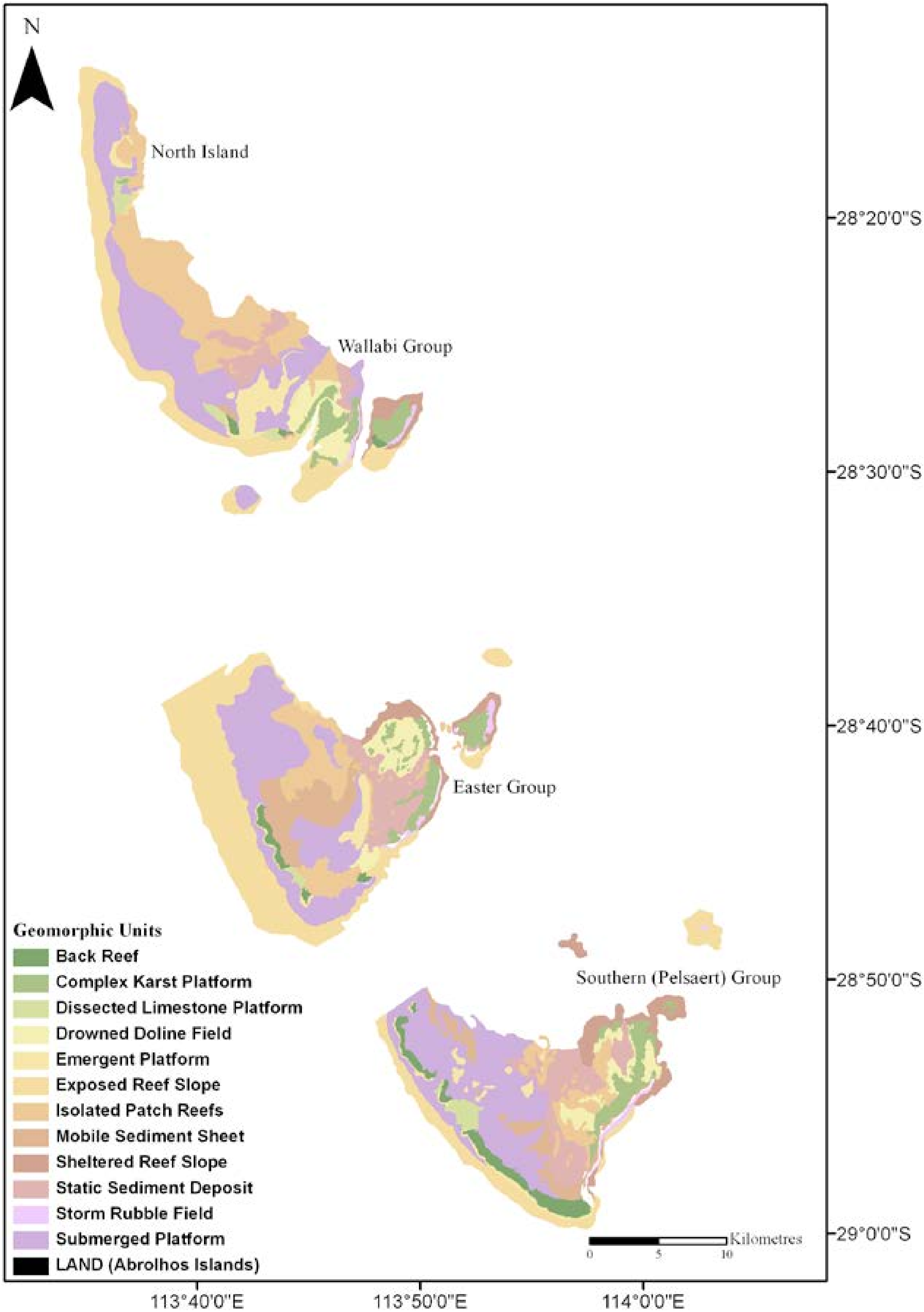

Figure 2. Geomorphic units mapped at North Island, Wallabi Group, Easter Group and at Southern (Pelsaert) Group (Source: Hatcher et al. 1988).

2.0 Methods

Two types of satellite sensors were used to map shallow water benthic habitats (Table 1). The images were selected based on the timing of capture and clarity of the image (i.e. relatively cloud and wind free). High-resolution ortho-aerial photography was also used to assist with the classification.

Table 1. Satellite sensors used to develop benthic habitat map.

Image	Date of Capture	Resolution	Source
ALOS AVNIR-2	25 May 2009	10 metres	Geoscience Australia
Landsat 5 TM	10 January 2009	25 metres	National Earth Observation Group
Ortho-aerial photos	October 2006	0.2 metres	Landgate

The process of assessing the ability of remote sensing techniques to classify benthic habitats was divided into three components;

- Unsupervised classification
- Field ground truthing
- Supervised classification

2.1 Unsupervised classification

The unsupervised classification was used to construct a first pass habitat map and to select ground truthing sites to be verified in the field. Ground truthing sites were areas that were considered to be spectrally homogeneous suggesting a uniform habitat. A number of techniques were used to ensure that the unsupervised classification was representative of benthic habitats (see Figure 3 for details of the process). Homogenous sites were used to define similar habitats and allow the collection of multiple field measurements within an area to obtain a 'best fit description' of the habitat for comparison with the satellite image data (pixel data representing an area), giving the field data a unit of measure (Human et al. 2010). A homogenous site was defined within a nine pixel ALOS AVNIR-2 square (3 x 3, 30 m x 30 m) and where this was not possible, homogenous sites were 2 x 3 pixels. A total of 166 homogenous sites were identified from this process for ground truthing (Figure 4).

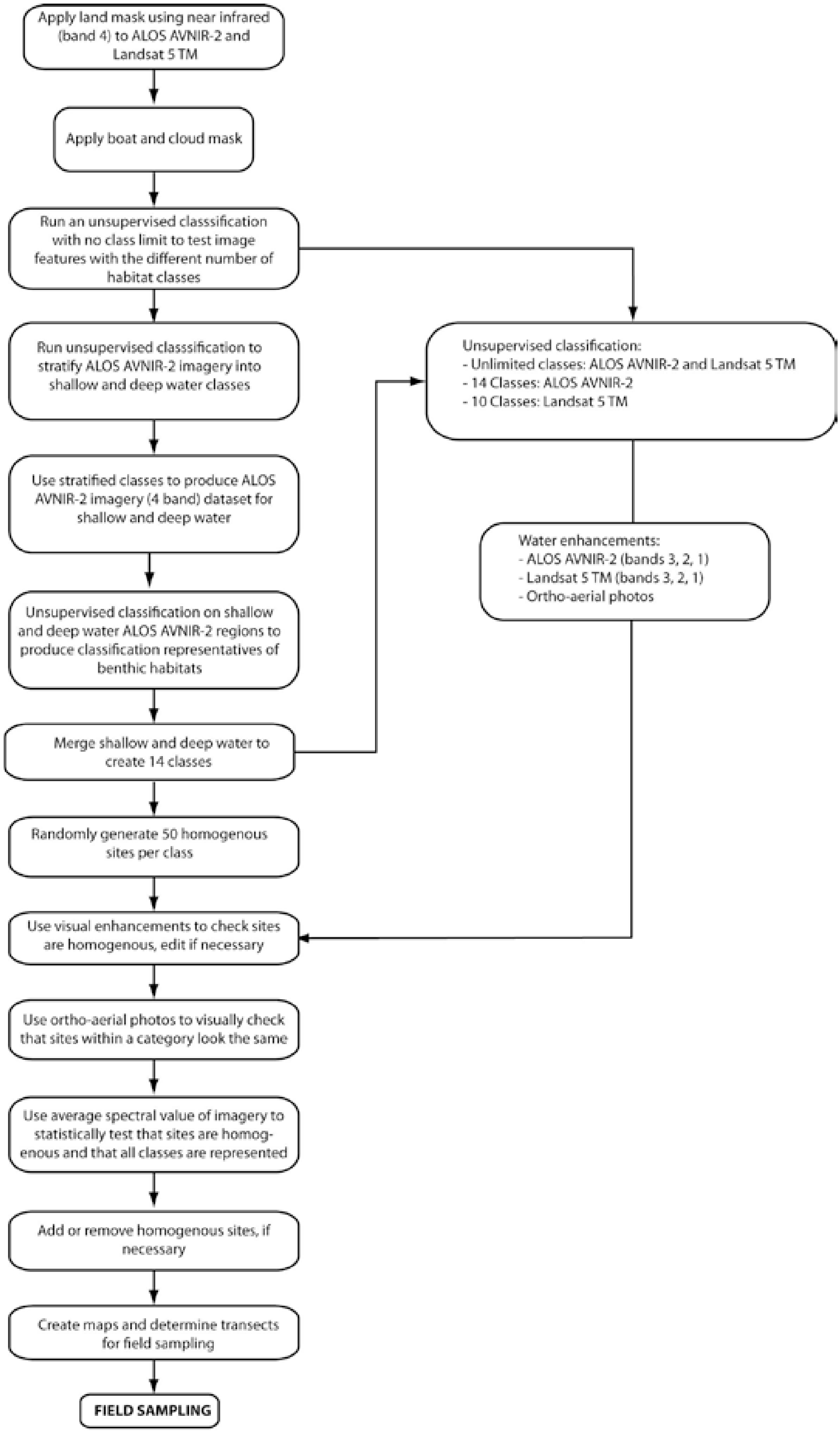

Figure 3. Flow chart of unsupervised classification of imagery and process undertaken to select field ground truthing sites.

2.2 Ground truthing of homogeneous squares

Field surveys were conducted between 20th March and 30th April, 2010. Of the 166 homogenous sites identified, 163 were surveyed. To increase the efficiency of field collection many of the homogenous squares were sampled by a single transect (Figure 4) using diver operated or towed underwater video.

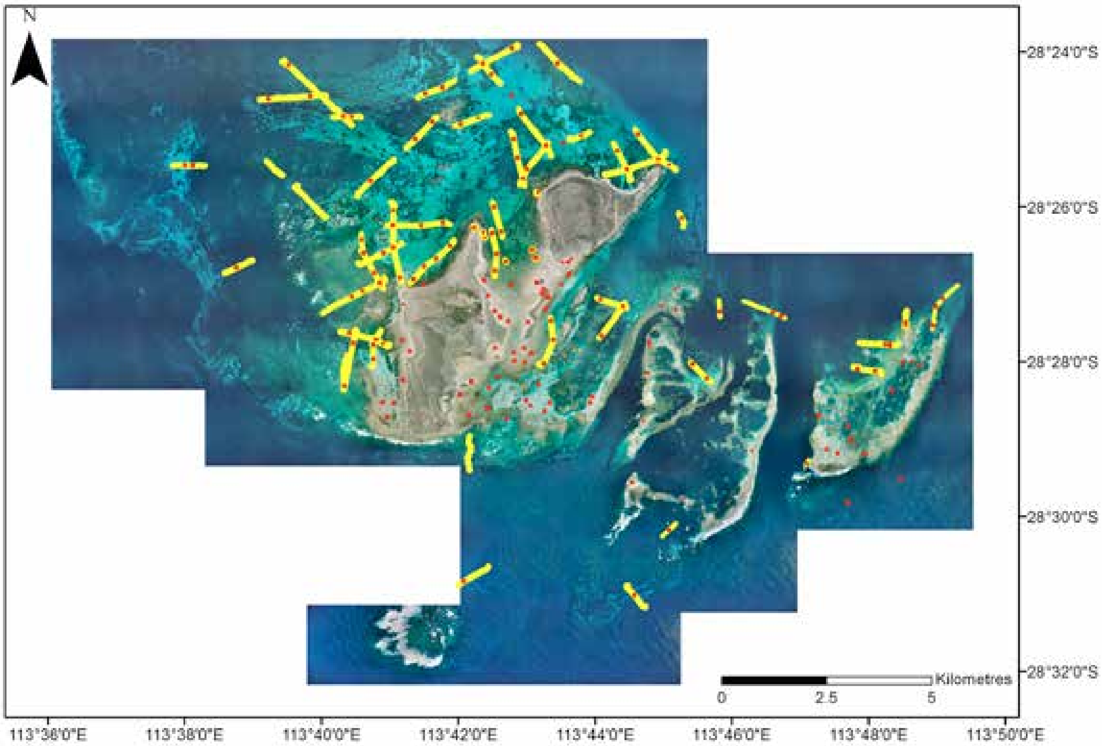

Figure 4. Ground truthing sites and transects at the Wallabi Group (yellow lines represent towed video transects, red dots represent homogenous sites).

The towed underwater video was a 'live feed' system consisting of a Dallmeier DF3000AS-DN HiRes UWDR Cam_inPix® colour box progressive scan camera with a F0.95/2.8-8.8mm lens in an underwater housing attached to towed vane. The system was connected to the vessel by 10 mm rope and a reinforced video umbilical cable. The live feed video, with GPS overlay, was recorded onto a Sony DCRHC21 Mini DV Progressive Scan HandyCam. The camera was towed at between one and two knots, approximately 0.5 m above the substrate. A total of 50 transects ranging in lengths from 100 m to 2400 m were surveyed using this method, incorporating 130 homogenous sites.

Side scan sonar was fitted to the vessel to record bathymetry and depth was recorded as a single point with time, date and location (latitude and longitude) recorded for each point. The data was adjusted to the tide state of the Wallabi Group to provide the depth at lowest astronomical tide (LAT) to be comparable to the bathymetry data derived from soundings also calculated to LAT.

For homogenous sites that were too shallow to be reached by vessel, diver operated video transects, using a Sony DCRHC21 Mini DV Progressive Scan HandyCam, were conducted. The benthos was recorded by snorkeling or wading, for at least two minutes, with the camera pointing at a 45°, 0.5 m above the substrate. Average water depth was also estimated and 33 homogenous sites were recorded using this method.

2.2.1 Data processing

Five stratified random points were analysed in each homogenous site. A ten second buffer of video from the start and end of the footage was allowed, to ensure that all analysed points fell within the homogenous site. Each transect within a homogenous site was then divided into five equal blocks. Each of the five blocks was then randomly assigned a point of latitude and longitude, using a Microsoft Excel randomizer, to be analysed for habitat.

The benthos was classified into six broad categories; coral, algae, seagrass, abiotic, other and unknown. Each category also had a number of subcategories;

- Coral – growth form or morphology (i.e. branching, plating, massive etc.)
- Algae – *Sargassum sp, Ecklonia sp*, brown, green, red, turf or coralline algae, and height from the benthos was estimated
- Seagrass – *Posidonia sp, Amphibiolous sp, Halophila sp* or other
- Abiotic – sand, rubble, silt or dead hard coral
- Other – sponges, wrack, rhotoliths
- Unknown – video was not clear enough to analyse

Percentage cover of each habitat type, latitude, longitude and depth were recorded at each of the five points in a homogenous site. For each homogeneous site the mean percentage of each habitat class was determined. This data was then square-root transformed and subjected to CLUSTER analysis with SIMPROF, using the PRIMER v6©. The SIMPROF test used a significance level of 1% to determine below which junctures of the dendrogram, statistical differences among samples could no longer be detected and therefore could be defined as homogenous habitat types. SIMPER identified 17 statistically different habitat categories, as well as an unknown category which provided the basis for the supervised classification.

2.3 Supervised classification

Before the supervised classification was run, environmental datasets were generated and Canonical Variate Analysis (CVA) conducted with habitat categories results and imagery (Figure 5).

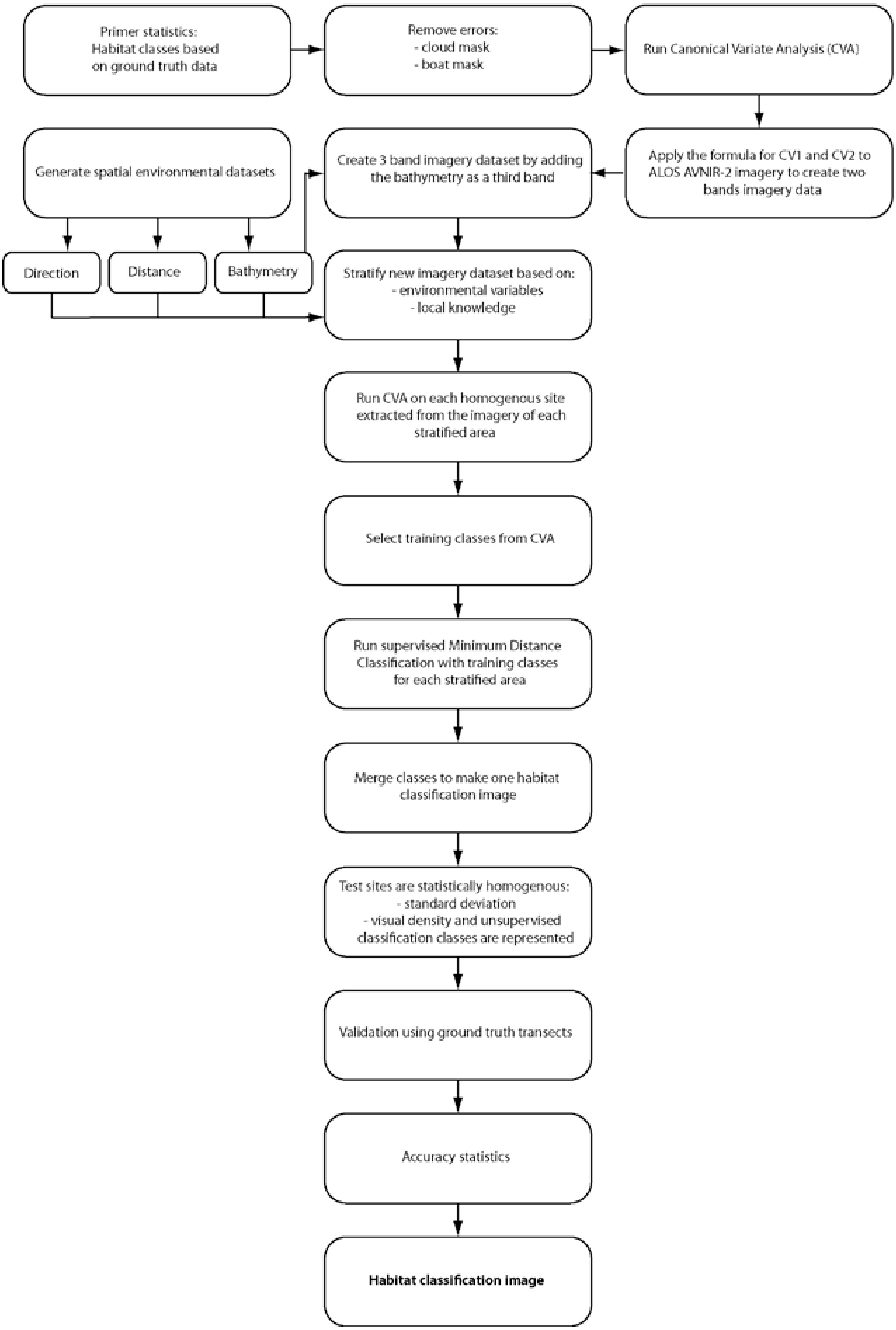

Figure 5. Flow chart of supervised classification of imagery.

2.3.1 Generating environmental variable datasets

The marine habitat is influenced by environmental variables such as wind (strength and direction), wave action, exposure and depth. Some of these variables are predictable and therefore, to an extent, can be modelled. Local knowledge can also provide information on sheltered areas with prevailing winds where habitat composition may change. Three environmental datasets (bathymetry, wind direction and distance from land) were generated to assist with understanding the environment around Wallabi Group.

A bathymetry dataset was created in ERMapper using the Gridding Wizard application (grid type – minimum curvature, resolution – 10 m). Several data sources were used to create the bathymetry dataset including;

- ALOS AVNIR-2 image thresholded to create a land boundary. The land boundary was buffered internally to create an inner land boundary and given an estimated height of zero metres, while the inner land boundary was estimated as one metre
- Department of Planning and Infrastructure (DPI) sonar soundings, corrected for tide height
- The 10, 20 and 50 metre contours from DPI (DPI, 1998)
- Single point sidescan sonar data, corrected for tide height, obtained during this field survey

Some areas lacked bathymetry data or created artefact values above zero and therefore manual interpretation was used to make an informed estimate of the actual bathymetry value. This was achieved by interpreting the aerial ortho photography i.e. DPI sonar soundings of nearby points and/or the height of similar features, errors that could not be fixed were recorded as null. Two additional datasets were created in ArcGIS©; Euclidean direction (a surrogate for wind direction/aspect) and Euclidean distance (a surrogate for wave action and open or protected waters). Both Euclidean direction and distance were calculated from the shoreline. These datasets also informed which areas might be impacted by wind/wave action and assisted with the stratification of the Wallabi Group.

2.3.2 Canonical Variate Analysis

Homogenous sites were attributed a habitat type from the ground truthing PRIMER analysis. The original homogenous site number was also added to the label. These labels were then added to the image with a vector to region conversion in ER Mapper. The spectral information from all the spectral bands of ALOS AVNIR-2 image was then extracted for each homogenous site and subject to a Canonical Variate Analysis (CVA) (Campbell and Atchley 1981).

The CVA of the image determined spectral variation between habitat classes and determined that the majority of information responsible for separating habitat classes was found in Canonical Variate (CV) 1 and CV2. Similarly, bands one, two and three of the ALOS AVNIR-2 image contributed the most information to CV1 and CV2. The contribution of each band determined the canonical vectors applied to the imagery, to create an imagery index for both CV1 and CV2. CV1 and CV2 were used as an index to remove noise in the image that was not contributing to the habitat classes. The distribution and variation in each canonical variate is evident in the Figures 6 and 7 where CV1 and CV2 have been applied to the ALOS AVNIR-2 image.

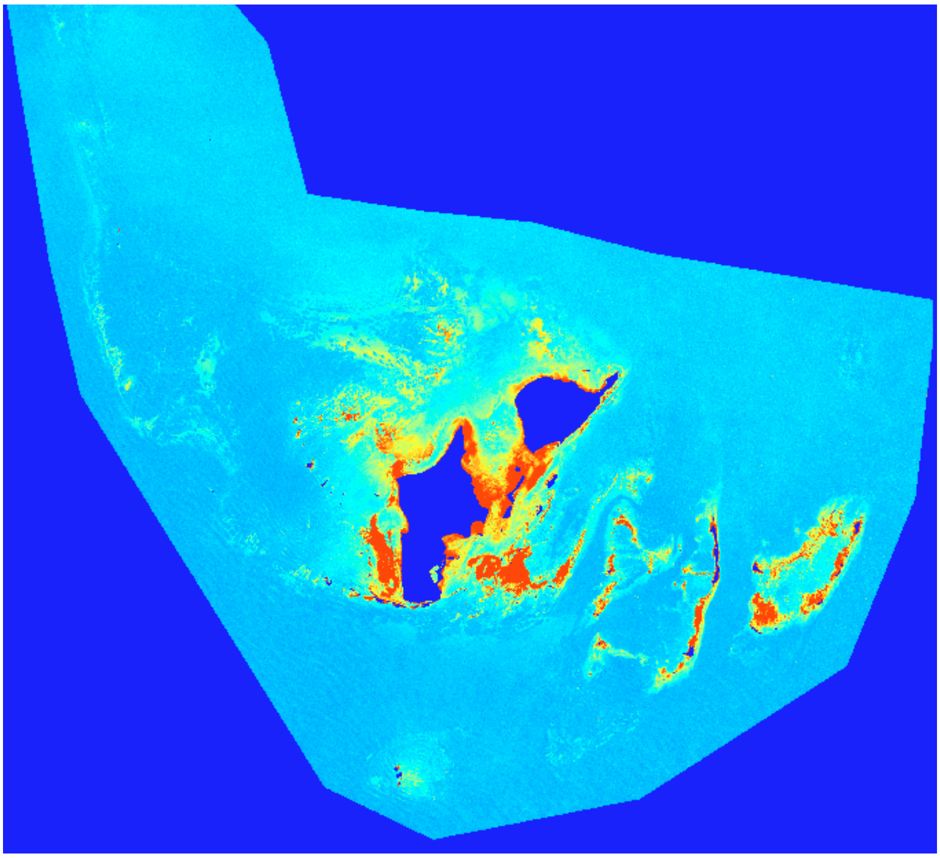

Figure 6. CV1 formula applied to the ALOS AVNIR-2 image.

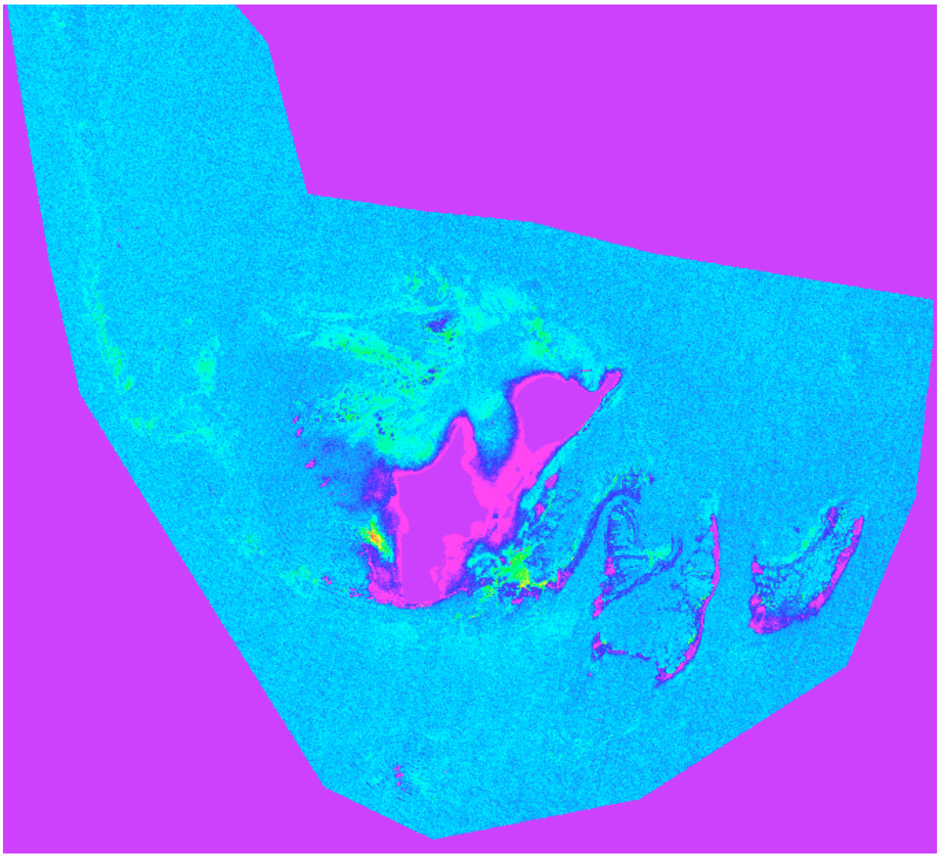

Figure 7. CV2 formula applied to the ALOS AVNIR-2 image.

A CVA with the additional environmental variables (bathymetry, Euclidean direction and Euclidean distance) was also applied to the ALOS ANVIR-2 image, however only bathymetry displayed a significant influence. A new three-band image was then created using CV1, CV2 and bathymetry. This image was stratified into three regions; all west, all east and all south using the environmental variables (distance, direction and bathymetry) previously derived. Areas of turbidity were removed from the image to avoid misleading the classification.

A CVA was run on each stratified image to determine the variation between habitat classes. Clusters of similar habitat classes that were distinct from other major habitat classes were then labelled to describe each cluster. Classes that could not be separated were labelled as a 'mixed class'. Only homogenous sites that were attributed to habitat classes were used as training sites for the supervised classification in ERMapper. The type of supervised classification chosen was Minimum Distance. This classification was applied to all three bands selected (CV1, CV2 and bathymetry). This method provided positive results with only two stratification zones, 'all east' and 'all west' (Figure 8). The area identified as turbid was later manually classified as seagrass using ground truthing information. The final benthic habitat classification was 21 habitat classes, the original 17 plus four "mix" classes (Figure 9). The final map was then vectorised and area calculations were run on each class.

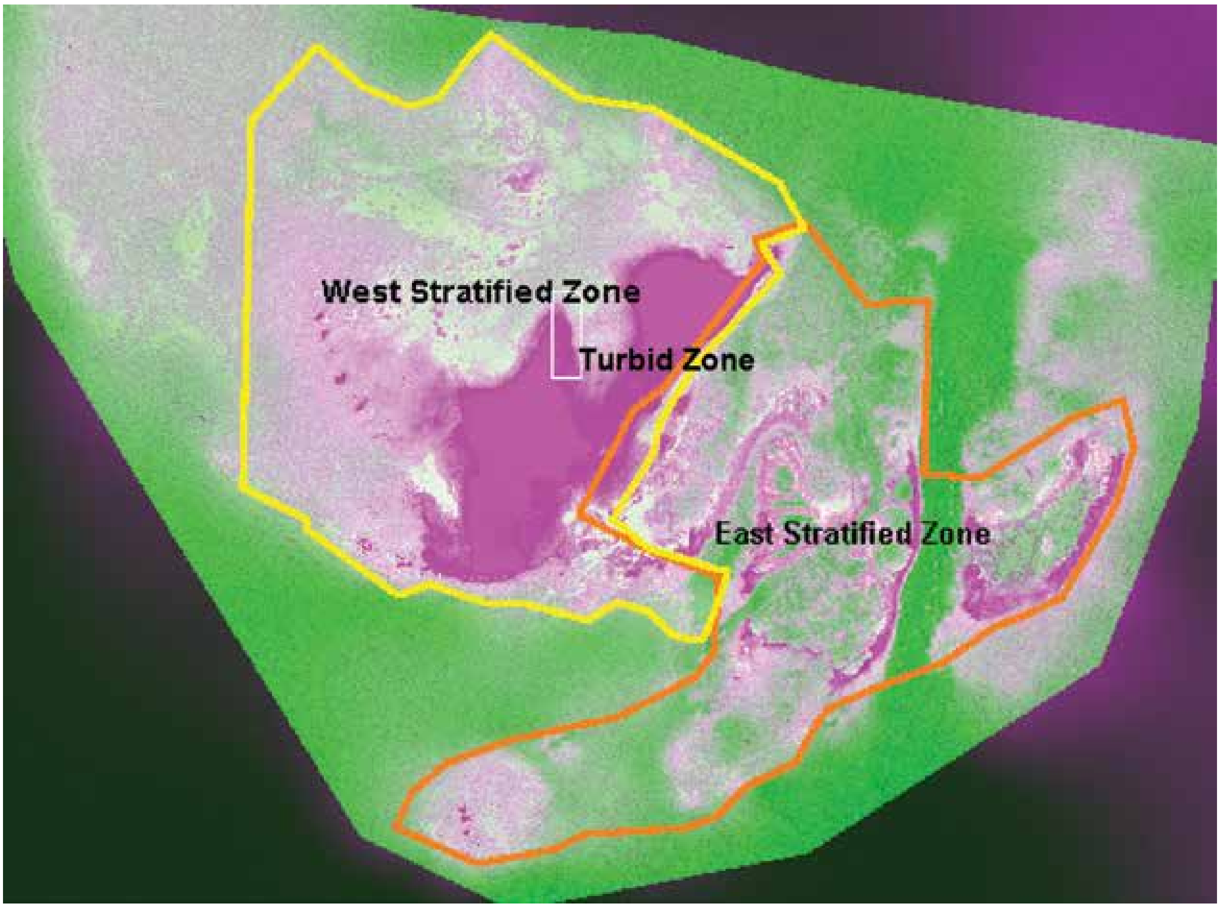

Figure 8. Stratification zones of the Wallabi Group. Yellow - west boundary; Orange - east boundary and White - turbid area. The background image is an enhancement using CV1, CV2 and bathymetry.

2.3.3 Validation of supervised classification

Using the intersect tool of the ArcGIS© program an additional 227 sites were selected using the ground truthing transects and the final benthic habitat map for validation. The additional sites were stratified to ensure each habitat type was resurveyed, however the sites were randomly located within these habitats. Using the same methodology as the original data processing (see Section 2.2.1) these sites were analysed to assess the accuracy of the final habitat classification map.

For the final map, habitat classes in the 21 class map (Figure 9) were merged to create eight broad habitat classes (Figure 10). Habitat classifications were then verified by comparing the supervised classification habitat categories to ground truthing data collected in the field. Habitat classification was assessed as accurate if there was greater than 60% similarity between the map and the ground truthing, partially accurate (1 – 59%) and incorrect if there were no similarities.

3.0 Results

Two habitat maps were produced for the Wallabi Group; one with 21 habitat classes (Figure 9) and one with eight habitat classes (Figure 10). Preliminary results showed that the accuracy of the 21 class map was low therefore an eight class map was produced by merging similar habitats from the 21 class map into broader categories i.e. coral, seagrass etc.

The eight class habitat map shows that the east-southeast or leeward side of the Wallabi Group is dominated by coral habitat, while the northern and western sides of the Wallabi Group are dominated by algae, seagrass and abiotic habitats (Figure 10).

The classification of coral habitats had the lowest accuracy with habitats correctly classified 25% of the time but incorrectly classified 68% of the time (Table 2). The habitat type classified with the highest accuracy was abiotic (sand, rubble, silt and dead hard coral) with 89% classified correctly.

Table 2. Percentage accuracy (%) of supervised habitat classification for eight class habitat map. Percentage accuracy was calculated by comparing supervised classification and ground truthing data. Accurate (> 60%), partially accurate (1 – 59%) and incorrect (0%).

Habitat	Accurate (%)	Partially accurate (%)	Inaccurate (%)	Total (n)
Coral	25	6	68	31
Seagrass	56	7	17	29
Algae	45	23	31	48
Abiotic	89	8	3	39
Coral / Abiotic	13	52	35	23
Seagrass / Abiotic	30	50	20	10
Algae / Seagrass	23	67	14	22
Coral / Algae	12	76	12	25

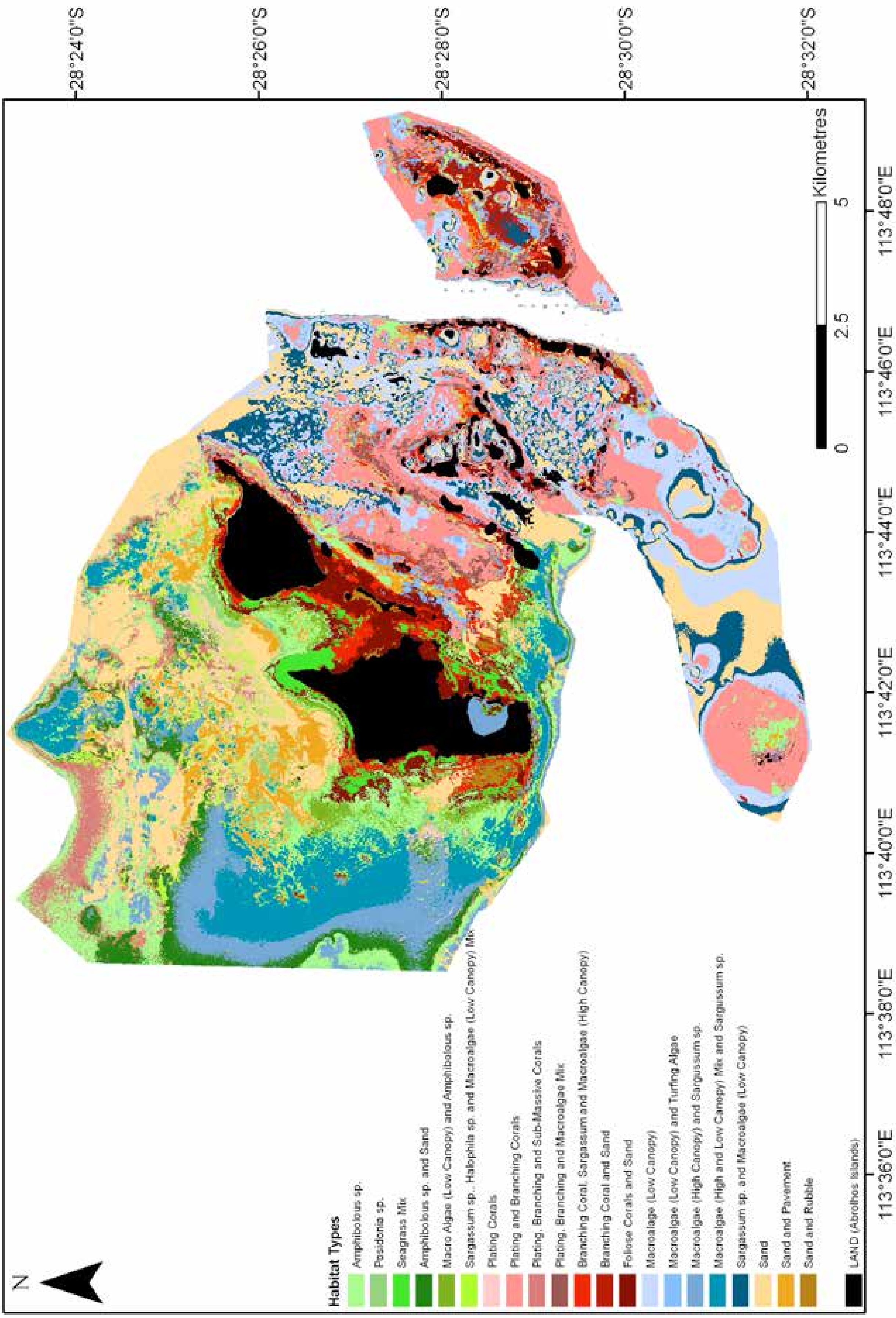

Figure 9. 21 habitat class benthic habitat map for the Wallabi Group.

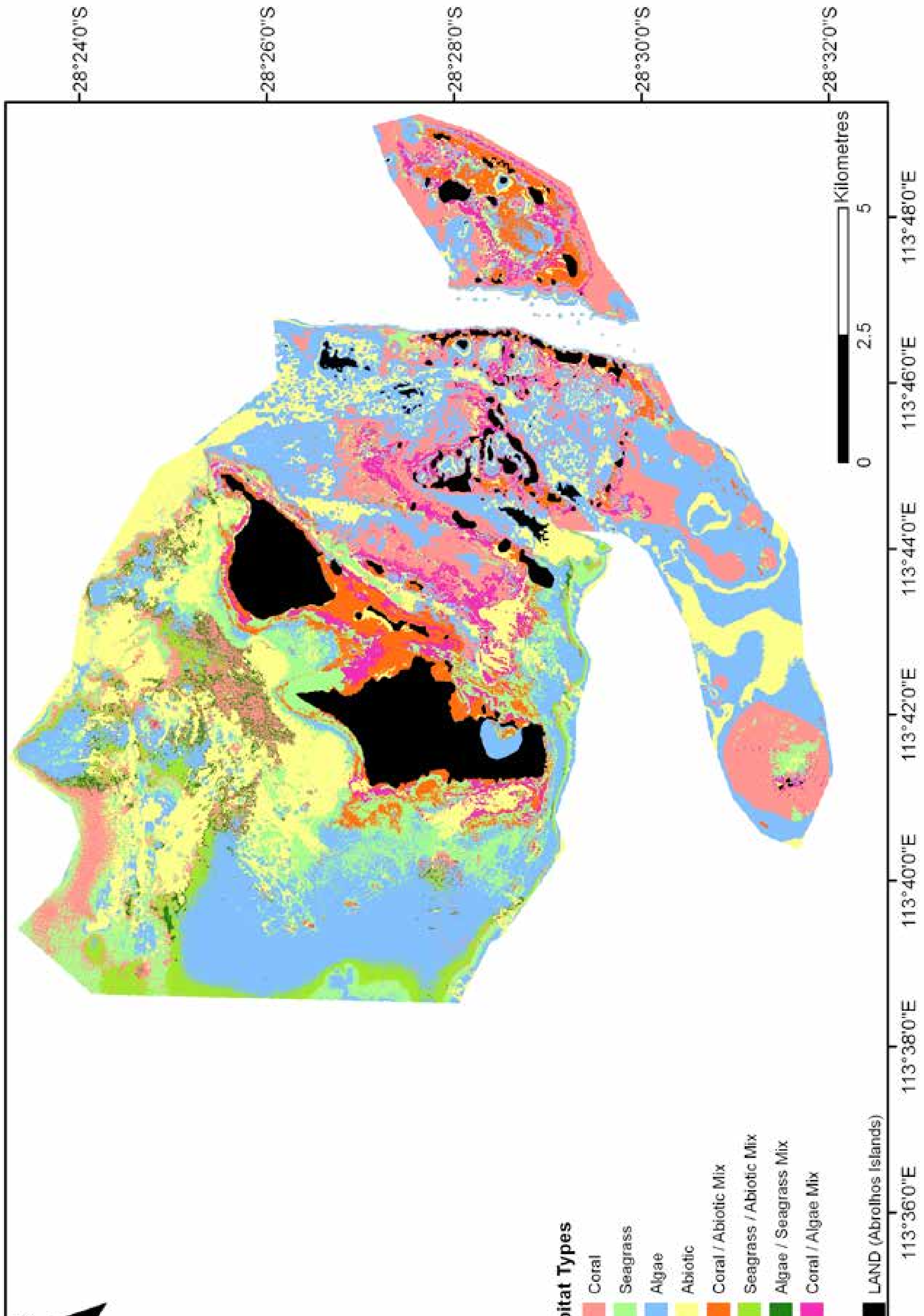

Figure 10. Eight habitat class benthic habitat map for the Wallabi Group.

4.0 Discussion

Marine ecosystems worldwide are under increasing pressure due to anthropogenic impacts by a range of marine users such as coastal development, pollution and overfishing (Jackson et al. 2001, Lotze et al. 2006, Sala and Knowlton 2006, Worm et al. 2006). Previous studies have suggested that the impacts of these pressures are being reflected in a decline in biodiversity, outbreaks of marine pests and declining habitat quality (Sala and Knowlton 2006, Worm et al. 2006). Increasingly an essential component of marine planning is the assessment of habitat distribution so that the needs of a variety of marine users can be accommodated while minimising the impacts on sensitive habitats, i.e. providing moorings for boats to prevent anchor damage of sensitive coral habitats. However, field surveys to assess habitats using traditional methods (i.e. diver based surveys) are time consuming, expensive and only cover a small spatial scale. Therefore, cost effective methods to assess marine habitats over large spatial scales are an important management tool (Hochberg and Atkinson 2003, Mumby et al. 2004a and b).

The development of remote sensing tools have revolutionised the way we assess and understand the marine environment. Remote sensing is a cost effective method of habitat assessment on a large scale and has been widely used in the terrestrial environment. There are, however, considerably less successful examples of its application in the marine environment. A number of factors influence the ability of remote sensing tools to accurately distinguish different habitats including platform (satellite, airborne or towed), the type of sensor (spectral, spatial and temporal resolution), atmospheric clarity, surface roughness, water clarity and water depth (Mumby et al. 2004b).

In this study of the Wallabi Group at the Abrolhos, satellite based remote sensing (Landsat 5 TM and ALOS AVNIR-2) were used to distinguish eight different benthic habitat classes. Mumby et al. (2004b) suggest that Landsat can be routinely used to classify habitats within reefs using five or less habitat classes. Experiments based on simulations (Hochberg and Atkinson 2003) and field data (Mumby et al. 2004a and b, Andréfouët et al. 2001) further demonstrate that Landsat (TM or ETM+) can distinguish three to six habitat classes (e.g. coral reef, seagrass, sand and hard substrate) with reasonable accuracy (60 – 75%).

In our study eight habitat classes were distinguished. The abiotic habitat class (sand, rubble, etc) was found to have the highest accuracy (89%) while coral habitats had the lowest accuracy (25%). Previous studies have also distinguished abiotic habitats with the highest accuracy due to the distinct spectral characteristics of sand (Hochberg an Atkinson 2003). In our study the lower accuracy of distinguishing coral habitats was primarily due to coral habitats being incorrectly classified as algae and vice versa. Distinguishing coral and algal habitats can be more difficult as these two habitats have nearly the same reflectance variance (between 500 – 625nm) (Hochberg and Atkinson 2003). Normal multi-spectral imagery such as Landsat 5 TM or ALOS AVNIR-2 only have three or two bands respectively, covering the 500 – 625 nm wavelength range. These sensors therefore have limited capacity in distinguishing between coral and algal habitats, as was found in this study.

Therefore, to accurately distinguish between coral and algal habitats the sensor must have adequate resolution and sensitivity (Hochberg and Atkinson 2003). Sensor limitations in spectral and spatial resolution may lead to ambiguous benthic classes that require significant interpretation by the researcher based on prior knowledge or extensive ground truthing (Hochberg and Atkinson 2003). Newer sensors such as Digital Globe’s Work View 2 (WV2), Work View 3 (WV3) which is to be launched in mid-2014, or a hyper-spectral instrument have more bands in this 500nm – 625nm wavelength range and would therefore likely have a greater chance at discriminating between coral and algal habitats. Unfortunately WV2 was not operational at the commencement of this project, however for future benthic habitat studies for the Abrolhos these more developed sensors should be considered.

Additionally, unlike previous studies that have used remote sensing techniques to distinguish benthic habitats on tropical coral reefs, the Abrolhos are located in a tropical/temperate transition zone which means that many of the Abrolhos's benthic habitats are a unique blend of coral and algal species which further exacerbates this problem. In our study the resolution of coral and algal habitats required significant ground truthing and interpretation based on prior knowledge.

5.0 Conclusion

Remote sensing provided a rapid and cost effective method of distinguishing shallow water marine habitats across a large area (approximately 154 km^2) at the Abrolhos. The accuracy of the eight class habitat map compared well with previous studies. However, due to the unique nature of the Abrolhos, significant interpretation based on prior knowledge and extensive field based ground truthing was required primarily to distinguish coral and algal habitats. Development of a species specific habitat map was not possible using the remote sensing tools employed in this study. However for future benthic habitat studies at the Abrolhos the use of newer more developed sensors (i.e. WV2 or WV3) should be considered for increased accuracy of habitat discrimination.

The current eight class map can provide managers with a planning tool capable of distinguishing broad habitats classes with different levels of sensitivity, to help guide both management and development proposals within the Abrolhos.

6.0 Acknowledgements

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