Habitat composition and coverage mapping in La Parguera, Puerto Rico using AVIRIS and IKONOS imagery

Ramon Lopez Rosado
Department of Marine Sciences
University of Puerto Rico at Mayagüez
P.O. Box 908 Lajas, Puerto Rico 00667
rlopez@cima.uprm.edu

Abstract

Remote sensing techniques have become an invaluable tool in the assessment of coastal habitat coverage mapping. The present project intended to first, analyze the relationship of spectral and spatial resolution on the outcome of supervised classifications by using IKONOS multispectral and AVIRIS hyperspectral images. Secondly it was intended to analyzer the gradient of habitat coverage from toward the shelf edge of La Parguera keys. Spatial resolution resulted on accurate class definition over higher spectral information, although equal number of classes was mapped with both AVIRIS and IKONOS imagery. Sea grass beds dominate the coastal portions of La Parguera with an increase on reef habitats toward the shelf edge. In general remote sensing techniques when applied to coastal ecosystem assessment analysis are valuable but extensive field work still is needed.

Introduction

In recent years remote sensing has become an invaluable tool in the assessment of habitat coverage of coastal ecosystems. These techniques are emerging as invaluable tools in the study of coral reefs; they provide effective means to observe and monitor shallow coral reefs worldwide, to evaluate inter-reef structural differences, to map intra-reef habitat diversity and zonations, and to assess bathymetric variations. This recent increase in the implementation of remote sensing techniques respond to the global interest in the rapid and effective assessment of vast coral reef areas that could be subject to the effects of global warming.

Satellite acquired data allows to the large scale monitoring and evaluation of coastal areas at different spatial resolution levels. The satellites most commonly used since the mid-1980s for direct observation of coral reefs have been medium spatial resolution digital images, i.e. a spatial resolution of 10–30 m. This includes data acquired by the Indian Remote Sensing Satellite C (IRS-C), Satellite pour l'Observation de la Terre (SPOT) 1–4 High Resolu- tion Visible (HRV), Landsat 5 Thematic Mapper (TM),

and more recently by SPOT 4–5, Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) sensors (Andréfouët et al. 2003). In contrast, ‘‘high resolution’’ images are those with a spatial resolution greater than 10 m such as those provided by IKONOS or Quickbird (1–4 m). Higher spectral resolution sensors have also gotten their place in coastal remote sensing studies, these include satellite and aircraft mounted devices, i. e. Hyperion and AVIRIS. Hyperion is a satellite hyperspectral sensor covering the 0.4 to 2.5 micrometersspectral range with 242 spectral bands at approximately 10nm spectral resolution and 30m spatial resolution from a 705km orbit. On the contrary the Airborne visible/infrared imaging (AVIRIS) is an unique optical sensor that is mounted on an aircraft that delivers calibrated images of upwelling spectral radiance in 224 spectral bands with wavelengths from 400 to 2500 nanometers with an spatial resolution that varies from 4 to 20 meters.

The growing concern on coral reefs and associated ecosystems assessment had let to the need of accurately measurements of the extent of these habitats to monitor their deterioration or expansion. It is from this premise the currently need for specialize sensors such as those with higher spatial and spectral resolution to develop the critically needed tools to accomplish this tasks. Recently IKONOS and AVIRIS sensors had filled these demands gaining their place on this field, IKONOS had proven world wide its resourcefulness on this types of studies due to its high spatial. Its higher resolution makes it an exceptional tool at the moment of habitat mapping resulting in higher class separation and accuracy over other sensors (Andréfouët et al. 2003). (Purkis 2005) recently also proved IKONOS effectiveness of non concurrent field data and image acquisition in the analysis of coral reefs ecosystems and habitat mapping, which allows the use of the constantly growing collection of IKONOS images available.

This project has the objective of first assessing the usefulness of for the application of IKONOS imagery in the evaluation of the extent of habitats present in several coral reefs located in succession from the coast to the shelf edge of La Parguera, Puerto Rico. La Parguera keys are an area characterized by a series of reef patches that extend from the coast to shelf edge. These patches are subject to several environmental factors such as differences in water column depth, wave energy coastal sedimentation.

The relative position of the habitats from the coast may present variations in their area coverage and possibly in their position with respect to the back and fore reef zones. It is hypothesize that sea grass beds would dominate the back reef portions of La Parguera area with and increase in sandy bottoms and coral reef cover close to the reef edge. Secondly it is intended to asses the differences in class definition achieved through a supervised classification of multispectral and hyperspectral data. The objective was to distinguish the usefulness of spectral resolution over spatial resolution in the classification of coastal habitats by using AVIRIS with 17meter pixel resolution and 224 spectral bands and IKONOS a 1 meter pixel resolution and 4 spectral bands, anticipating that due to the higher spectral resolution in AVIRIS a finer class scheme will be obtained even though its lower spatial definition when compared to IKONOS.

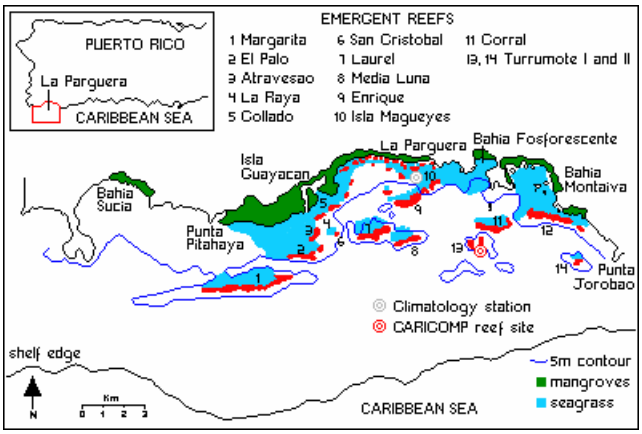
Materials and Methods

Satellite and airborne images

An IKONOS image captured on 2002 and AVIRIS image captured 2004 of La Parguera images were obtained from the Marine Science and Geology Departments of the University of Puerto Rico at Mayaguez, respectively.

Study site

La Parguera is a coastal village within the township of Lajas on the southwestern coast of Puerto Rico. Its insular shelf boundaries extend from Punta Montalva in the east (66°59'W) to Punta Tocón in the west (67°06'W) and from the coastline (18°01'N) to the shelf edge (18°07'N) (Figure 1). The insular shelf of La Parguera, on the southwest coast of Puerto Rico, is characterized by an extensive development of coral reefs, seagrass beds, and mangrove forests. The dry, warm, and relatively stable climate, low wave energy, high water transparency, relatively wide shelf, oligotrophic offshore waters, and low urban coastal development are some of the factors that contribute to the conditions of the marine ecosystem of La Parguera.



Taken from Garcia et. Al.. UNESCO document

http://www.unesco.org/csi/pub/papers/garciab.htm

Fig. 1. Location map of La Paraguera, Puerto Rico, and its marine ecosystems.

Image processing

Prior to the analyses of the images atmospheric and bathymetric corrections were performed to the images. For IKONOS a dark subtraction was performed to subtract the effect of the atmosphere on the spectral information gathered by the sensor. AVIRIS image was calibrated by using the software Atmospheric Correction Now (ACORN).

To identify the habitat classes, a supervised classification through maximum likelihood classification will be used. Maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class (Campbell, 2002). This algorithm has also been widely used by reef remote sensing scientists in similar studies using multispectral sensors such as IKONOS.

The sun glint caused by influence of wind-driven waves and incident sunlight was removed applying the method presented on Hochberg et al. (2003). This method assumes that the near-infrared region (NIR) of the spectrum (*i.e.* band 4 in IKONOS) is totally absorbed by the water. Thus, any recorded NIR upward radiance above a water body should contain the reflected sunlight, as a function of geometry. Assuming that the glint effect remains relatively constant independently of wavelength then the NIR can be used to lead the recognition and removal of sunglint across wavelengths in the visible range. The glint correction was performed after correcting for the atmospheric effect.

Lyzenga (1981) algorithm for depth-invariant index of the bottom types was used with IKONOS imagery to discards the effects of variant dept on the reflectance of the substrate (Figure 2). Sand pixel regions were chosen as an invariable substrate by ground truth and visual observations in areas of approximately between depth 2 to 15 meters. The resulting dept invariant bands were used in the supervised classification, considering that the algorithm has discarded the effect of variations in bottom reflectance due to water column depth differences.

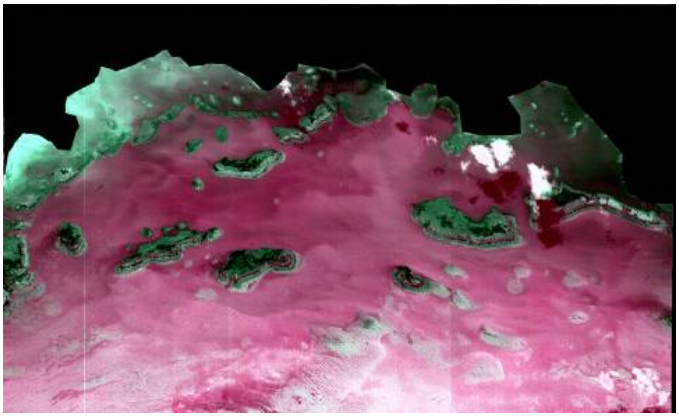


Figure 2 Depth invariant image of La Parguera, Puerto Rico.

Field observations were performed to analyze the different habitat compositions around La Parguera Keys, 20 points were selected around the Enriques , Mata la Gata, Caracoles and Collado Keys as training areas as means of training areas for the classifications and subsequent analysis. The following classes were selected for the supervised classification based on the field observations Octocorals (Softcorals), Seagrass, Sparse Mix Corals (SPMC), Sand, and Mangroves.

Results and Discussion

Spatial vs Spectral Resolution

To resolve the number of classes that could be obtained through image classification an unsupervised classification was performed to an IKONOS and AVIRIS subsample images of Cayo Enrique. The unsupervised classification resolved a total of

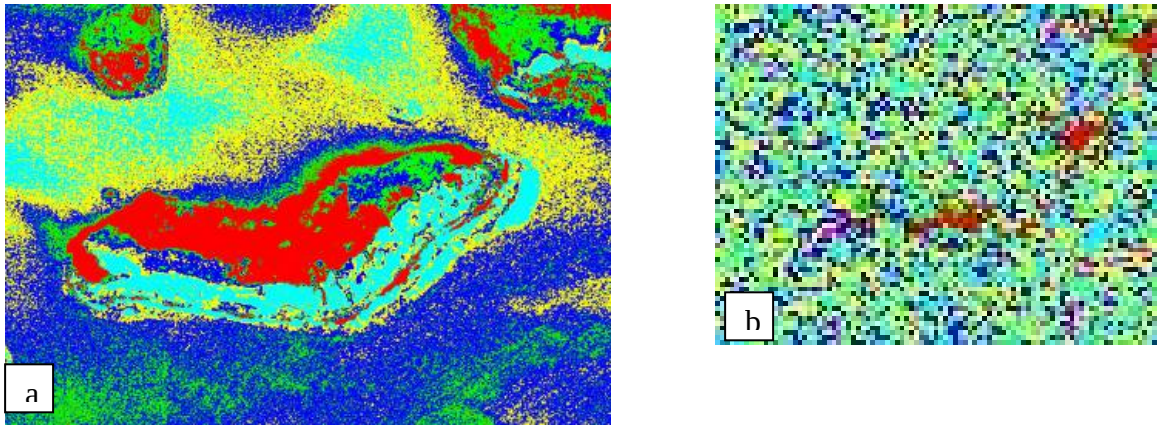


Figure 3. Unsupervised classification of IKONOS (a) and AVIRIS (b) Cayo Enriques images.

five classes with the IKONOS image. AVIRIS showed lower class resolution what can be attributed to lower spatial resolution thus higher substrate spectral signal mixing. The supervised classification of both images resolved equal number of classes despite their

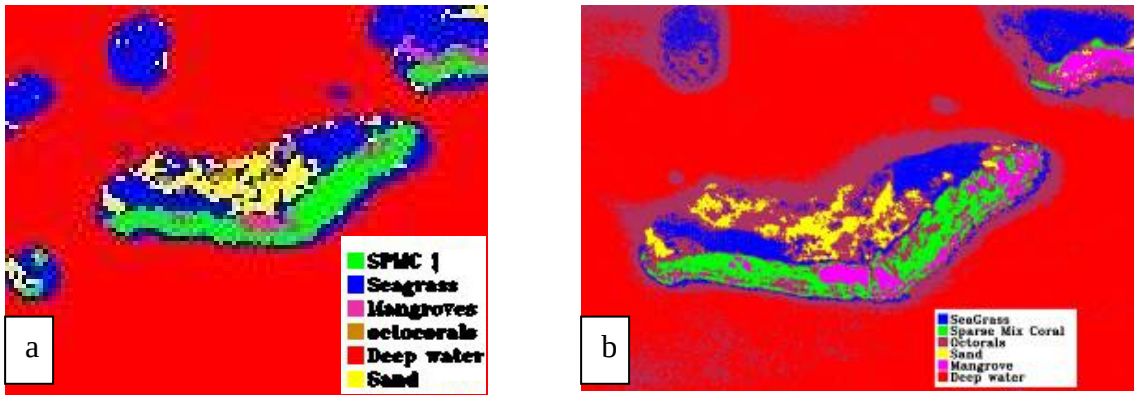


Figure 4 Supervised Classification of Cayo Enriques a. AVIRIS b. IKONOS.

differences in spatial resolution and spectral signal mixing. IKONOS higher spatial resolution facilitated higher precision and class definition over AVIRIS higher spectral information. Probably higher spectral resolution would be of significance with an increase in AVIRIS spatial resolution where mixing of substrates spectral signals are minimizes. When the percentage of habitat cover is analyzed relative similar abundances of habitat can be observe on the amount of extension every habitat covers, with the exception of the class octoral (Figure 5). IKONOS octocoral class present an over estimate on the amount of octocorals present on Cayo Enriques when confronted with insitu

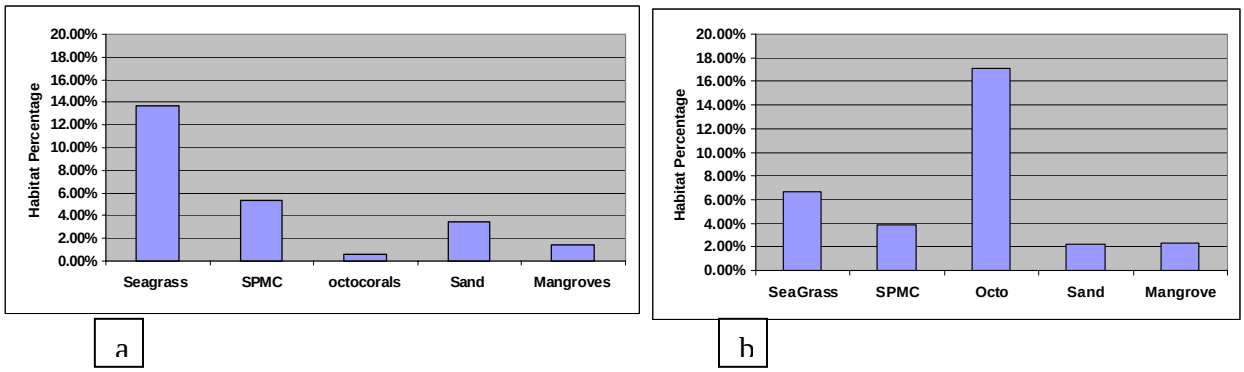


Figure 5 Supervise classification habitat distributions on Cayo Enriques. a. AVIRIS b. IKONOS.

observations. This over-estimate may be attributed to low spectral signal and mixing, the training sites used in the classification correspond to octocorals located deep under water between 10 to 15 meters. Therefore resulting in a weak signal as it is captured by the sensor, in spite of atmospheric and bathymetric corrections the signal easily mixed with surroundings substrates, resulting in a higher estimate of the class extension.

Habitat Composition of La Parguera Keys

A succession of habitat coverage was expected was observed in La Parguera, higher segrass cover is observed close to the coast line with its decrease toward the shelf edge. Back reef portions also were found to be mostly cover by seagrass with an increase of sandy bottoms in the keys closer the shelf edge.

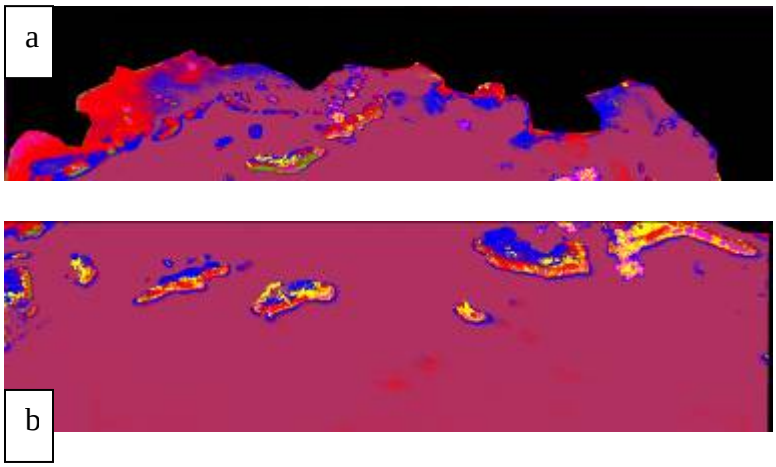


Figure 6 IKONOS Supervised classification of habitats in La Parguera.

a. Coastal portion b. Shelf edge portion

Sea grass beds dominate coastal portions of the habitats present in La Parguera, although the classification demonstrated to mapped octorals areas at the coastal portion of La Parguera, this is an incorrect classification. Most of these areas are covered by sea grasses, therefore seagrasses (red on the classification) account for most of the coastal cover portion and it includes octorals (blue in the classification). These areas are highly sedimented and it seems that the spectral signal resembles that of the mix signal of the octoral class as previously stated (Figure 6). Figure 7 corroborates the observation, higher seagrass portions are observed on the coastal portions close to 30 percent if the octoral class is added in contrast to 3.5 percent on the shelf edge portion. The observed mangrove cover presented in both graphs

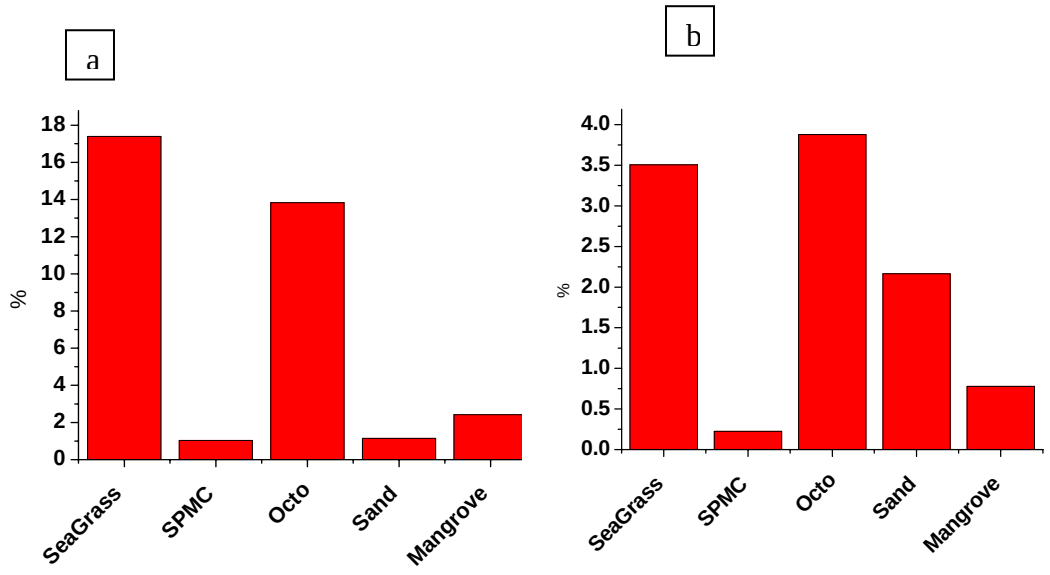


Figure 7 Habitat composition at the (a) coastal portion and (b) shelf edge portions of La Parguera.

account for the amount present in La Parguera Keys excluding the Mangroves present on the coast of La Parguera, these areas were masked prior to the classification to facilitate the classification process. Therefore represent the percentage of cover in the keys demonstrating similar composition in both zones. The sandy bottoms comprise also similar amount of cover between the areas, around 2 % for both portions. Sparse mix corals regions cover more extension of area on the keys close to the coast.

In summary IKONOS higher spatial resolution proves to be of advantage over spectral resolution. Higher spectral resolution is of importance when the spectral signal of individual substrates can be isolated which consequently can only be achieved by increasing spatial resolution.

Seagrass as expected beds dominate the coastal portion of La Parguera with a decrease in cover toward the shelf edge. Its occurrence in coastal areas is most likely related to shallow bottoms thus highly influenced by light ability to penetrate the water column. Seagrasses also dominate shallow back reef portions of the reefs close to the shelf edge but Coral reefs and associate habitats are more prevalent close to the fore reef

zones. Reefs habitats incidence close to the shelf edge is perhaps due to its distance from coastal sedimentation effects.

Based on the observed results of this project accurate habitat analysis is possible with remote sensing techniques, but considerations in terms of the appropriate sensor, its spatial and spectral resolution, required pre-processing, and specially extensive field work is still needed to create accurate habitat maps.

Cited Literature

ANDRÉFOUËT, S. and others. 2003. Multi-site evaluation of IKONOS data for classification of tropical coral reef environments. Remote Sensing of Environment.88, pp.128-143

Campbell, J.B. (2002) *Introduction to Remote Sensing*, 3rd edition. Guilford Press, New York

García, J.R., Christoph Schmitt, Craig Heberer, and Amos Winter. Environment and development in coastal regions and in small islands.UNESCO. La Parguera, Puerto Rico, USA. http://www.unesco.org/csi/pub/papers/garciab.htm

HOCHBERG, E. J., S. ANDRÉFOUËT, and M. R. TYLER. 2003. Sea Surface Correction of High Spatial Resolution IKONOS Images to Improve Bottom Mapping in Near-Shore Environments. IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING 41: 1724-1729.

Lyzenga , D.R., (1981). Remote sensing of Bottom reflectance and water Attenuation Parameters. International Journal of Remote sensing , 2(1):71-82.

PURKIS, S. J. 2005. A “Reef-Up” Approach to Classifying Coral Habitats From IKONOS Imagery. IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING. 43:1375-1390