High Resolution Benthic Habitat Mapping for Marine Management in the Eastern Caribbean

Cartografía de Alta Resolución de los Habitats Bénticos para el Manejo de Areas Marinas en el Caribe Oriental

Cartographie à Haute Résolution des Habitats Benthiques pour la Gestion Marine dans les Caraïbes Orientales

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EXTENDED ABSTRACT

Introduction

Detailed and up-to-date benthic habitat data are extremely rare in the Caribbean and typically limited by resources and technical capacity. We present the first high resolution benthic habitat and bathymetry product for shallow areas (< 30 m depth) across the five OECS countries. High resolution satellite imagery (2 x 2 m pixel) combined with an extensive underwater field surveys were used to create this important marine GIS baseline that serves to quantify the extent and location of key marine ecosystems, providing insight to resource managers when making critical marine management decision. This method demonstrates how Small Island Developing States (SIDS) with limited resources, can employ a scientifically sound, yet relatively low-cost method to develop coastal benthic habitat and bathymetry maps.

Methods

The Nature Conservancy (TNC) has collected over 1,700 GPS-referenced underwater video surveys throughout the OECS countries that have been used to guide subsequent satellite mapping exercises. The team uses a tethered drop camera (dropcam) with which high-definition seabed video was acquired. A GPS point is captured at the beginning and end of the survey transects which is typically 30 - 60 seconds. This provides the information needed to classify the benthic habitat at that location which is later used as training data for the satellite image benthic habitat classification.

All benthic habitat products produced are derived from satellite imagery acquired from WorldView-3 or 2, Pléiades , Quickbird, Ikonos, or Landsat 8. All satellite images used were radiometrically corrected and then atmospherically corrected to yield units of reflectance at the water surface. These routines were conducted using ENVI software (RSI Inc., v. 4.8). Since ancillary bathymetry data were collected by the field team, it was possible to apply a water column correction to the shallow water areas that were not confounded by excessive sun glint. An object-oriented approach was adopted for delineating benthic habitat. This approach contrasts the more commonly employed "pixel-based" unsupervised classifiers that have traditionally been used for coral reef mapping. The principal disadvantage of the unsupervised classification approach in a submerged setting, such as shallow habitats, since light in the visible spectrum is so rapidly attenuated by water, bathymetric variations account for the majority of spectral variation within the remote sensing imagery, rendering the seabed habitat differences challenging to separate.

In contrast to pixel-based classification methods, object-oriented image analysis, the strategy used to produce the maps, segments satellite data into landscape objects that have ecologically-meaningful shapes, and classifies the objects across spatial, spectral, and textural scales. In the context of this study, we employ object-oriented classification to delineate habitat "bodies", interpreted to be distinct patches of uniform benthic habitat. Because of the flexibility afforded by including non-spectral attributes of the imagery (e.g., texture, spatial, and contextual information) into the classification workflow, object-oriented methods have been shown to yield significant accuracy improvements over traditional pixel-based image analysis techniques (Kelly and Tuxen 2009, Purkis and Klemas 2011. Purkis et al. 2014a,b). The software used for mapping in this study, eCognition (v. 8.9, Trimble Inc.), tenders a suite of object-oriented image analysis algorithms having particular utility for creating thematic maps from remote sensing data, including coral reefs.

The ground-control points guide the object-based mapping of benthic habitats. These field observations straddle all benthic habitats found atop the coastal shelf. Statistics pertaining to the spectral and textural properties of the satellite imagery corresponding to the habitat types were extracted at points where samples provide an unequivocal determination of benthic character. These statistics were used to drive a preliminary segmentation of the imagery into landscape objects using eCognition. Using expert experience, all landscape objects were subsequently assigned to a habitat category based on their spectral and textural signatures. Finally, a filter was applied to remove redundant divisions between objects – i.e. those divisions separating two objects of the same habitat category.

For bathymetric modeling a ratio-algorithm method of Stumpf et al. (2003) was applied to the satellite imagery. Single-beam depth soundings collected in the field were used as training data to tune the algorithm's coefficients and spectral bathymetry was extracted from the image mosaics. Digital elevation models (DEMs) were constructed that capture seabed topography from the low-water mark to 25 m water depth. Vertical resolution of the DEM is approximately 0.01 m, but variable dependent on the quality of the spectral imagery from which it was derived. Units in the DEM are meters with float (16-bit) precision. Values are negative such that "-5.55" represents 5.55 m below sea level. Masked areas of the bathy surface are flagged with value = 0 and areas obscured by clouds have a value of +1.

Conclusions

These data, along with other marine use information, were reviewed through stakeholder involvement and are being used for designating important conservation areas and in some cases, multi-objective marine zoning plans. This work fulfills an important need as it provides insight to marine resource managers making decisions on how to balance both environmental and economic needs. It is hoped that these types of products will ultimately lead to the long-term sustainable use of marine resources throughout the Eastern Caribbean.

KEYWORDS: Benthic habitat, bathymetry, satellite Imagery, marine management

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