BENTHIC HABITAT MAPPING OF WEST MAUI MARINE LIFE
CONSERVATION DISTRICTS UTILIZING REMOTELY SENSED DATA

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ABSTRACT

Maps produced by coral reef remote sensing are utilized for marine conservation and management, as well as locating areas of high biodiversity, and monitoring alteration of ecosystems over time (Maragos and Gulko 2002). Benthic habitat maps produced from remotely sensed data enable reef managers to make informed decisions with respect to coral reef conservation and management (Anderson 2001, Maragos and Gulko 2002). The goal of this project was to utilize remotely sensed data in the form of color aerial photography to map benthic habitats of Marine Life Conservation Districts (MLCDs) on the Island of Hawaii. In addition, a GIS (Geographic Information System) database was created to archive these habitat maps, as well as store pertinent information such as quantitative fish and benthic habitat data, MLCD regulations, aerial photos, and underwater video clips documenting transect sites. Resource managers may gain an enhanced perception of the marine ecosystem by combining remotely sensed imagery with current in situ data (Barrett and Curtis 1999). It is the intent of this project to provide a powerful tool to resource managers and marine researchers, in addition to enhancing future marine protected area design in the Hawaiian Islands.

INTRODUCTION

Coral reefs provide vital habitat for many culturally and commercially important marine organisms. The Hawaiian Islands shelter almost 85% of all coral reef area under the jurisdiction of the United States (Clark and Gulko, 1999). In Hawaii, Marine Life Conservation Districts (MLCDs) were designed to protect coastal areas in order to replenish and preserve marine resources. Molokini Shoal MLCD generates gross revenues of more than $8.6 million annually from ecotourism (Clark and Gulko, 1999). In order to ensure these marine protected areas are successful, they must incorporate a diversity of coral reef habitat types to sustain a high diversity of marine species (Freidlander and Parrish 1998, Wells 1998).

It was reported (Maragos and Cook 1995) that the use of aerial photography provides an extensive geographic coverage that was ideal for interpreting and mapping coral reef habitats. Most data obtained on the marine ecosystems is gathered via in situ data collection. By interpreting color aerial photographs of coral reef habitat, managers can broaden the information gathered by in situ ecological assessments. The advantage of compiling and interpreting remotely sensed data is that larger and more frequent ecosystem surveys can be completed (Wilkie and Finn 1996). Such information provided by coral reef mapping encompasses abundance and distribution of live coral, as well as structure and morphology of the reef (Field et al. 2001). For instance, when interpreting
an aerial photo of a coral reef over time interdecadal changes in algal cover, live coral and sediment distribution can be extracted (Field et al. 2002).

METHODS

Colwell (1983) states that color aerial photography is preferred when interpreting remotely sensed data for coral reefs. Color infrared aerial photographs were obtained from NOAA/NOS as georeferenced, mosaiced images in UTM Zone 5, NAD 1983. The remotely sensed data was imported into Arc View 3.3 database as an image analysis data source. ESRI Image Analysis extension was utilized to enhance images for assistance in photo-interpretation. The benthic habitat polygons were manually delineated by photo-interpretation and heads-up digitizing methods. The polygons were digitized at a scale of 1:2,000, with a minimum mapping unit of 1011.714 square meters. To ensure that the photointerpreter has a consistent level of detail, the 1:2,000 scale used consistently during the digitizing process.

The National Ocean Service (NOS) has developed a benthic habitat classification scheme that will be used as a model for delineating marine habitat types. The management community in Hawaii collaborated to develop a benthic habitat classification scheme specifically for the Main Hawaiian Islands (Anderson 2001). This habitat classification scheme will be used in order to compare and contribute to maps produced by NOS, which were digitized at a scale of 1:6,000. In addition, NOAA has created an ArcView extension to assist with the process of creating benthic habitat maps in an ArcView database. The habitat digitizer extension was downloaded from the NOS website and utilized during this project.

The shape file of the Island of Hawaii was obtained from the State GIS Program website in UTM Zone 4, Old Hawaiian Datum. The Hawaii Island shape file was reprojected to UTM Zone 5 NAD 1983, using the Hawaii Datum and Projections Extension. The shape file for Marine Life Conservation Districts was obtained from the Division of Aquatic Resources in geographic projection. The Marine Life Conservation District shape file was converted to UTM Zone 5, NAD 1983 using the Hawaii Datum and Projections extension. All other shape files were created in Arc View 3.3 using the habitat digitizer extension, random point generator extension, and the hot potato extension.

In order to assure that the benthic habitats in the aerial photos were classified correctly the accuracy of the maps were assessed. The Random Point Generator Extension v 1.1 extension obtained from Jenness Enterprises website was utilized. GPS coordinates for each random point were generated and converted to geographic projection. 111 random accuracy assessment points were generated and validated in the field. The use of a boat for field accuracy assessments was available for two days; so two MLCDs were assessed each day. At the respective GPS point, the benthic habitat at that location was noted, as well as the benthic habitat in a 7 meter radius. The depth at each site was recorded using a depth sounder. In addition, field notes were recorded at each site on waterproof paper. The number of random point field observations varied in each habitat due to accessibility in high surf on one field day, and the limited boat access. The field observations were compared to the air photo interpretation of benthic habitat in the GIS database to provide an accuracy assessment of the maps created.
Figure 1. Sample map produced with random accuracy assessment points

Hot links were created utilizing the "Hot Potato" extension downloaded from the ESRI website. Additional quantitative and qualitative data, digital underwater video, and other pertinent data was obtained from the State of Hawaii, Division of Aquatic Resources, Washington State University, and the University of Hawaii. Hotlinks to each MLCD polygon can provide pdf files of aerial photographs of each MLCD with boundaries and sub-zones noted. Each MLCD also has hotlinks to a pdf document of the pertinent State of Hawaii, Division of Aquatic Resources regulations, and a site description from the DAR website. In addition, Kealakekua Bay and Lapakahi MLCD have GPS locations of underwater transect sites of the West Hawaii Aquarium Project (WHAP). A summary of some of their finding is found linked to these GPS points. Video clips of Lapakahi and Kealakekua Bay were edited from footage obtained from West Hawaii Aquarium Project. Fifty to sixty second clips of these sites demonstrate the benthic habitat and fish diversity characteristic of the transect and general study area. The hot links can open several pdf documents by selecting the image icon and clicking on the point once the hot link icon has been selected.

RESULTS

The spatial database created consists of polygons containing the Big Island coastline, MLCD boundaries, and the benthic habitat maps. The database contains point files containing such themes as GPS locations of study sites, and random points generated for field accuracy assessment. Depths recorded at each random point were added to the
associated table for the accuracy assessment points. The MLCD polygons for Lapakahi, Waialea Bay, Old Kona Airport, and Kealakekua Bay all contain hotlinks to State of Hawaii, Division of Aquatic Resources regulations, boundary description, and additional information. These polygons are hotlinked to pdf files all obtained from the Division of Aquatic Resources website. All of this information is in the form of a spatial (GIS) database and projected in UTM Zone 5, NAD 1983.

The accuracy of the benthic habitat maps generated by photo-interpretation of the aerial photographs was 88 percent. This was determined by dividing the number of correct random accuracy assessment points divided by the total number of sampled points.

![Image of GIS database with video and pdf hotlinks open]

**Figure 2. Screen capture of GIS database with video and pdf hotlinks open**

**DISCUSSION**

This spatial database contains a large amount of habitat and fish data collected from a number of sites on the Kona Coast. The use of hotlinks can create a powerful interactive database in which pertinent study site information can be opened from clicking on a GPS point, or MLCD boundary. A significant amount of related information can be accessed quickly now by marine resource managers due to the capabilities of GIS.

The assessment of the delineated habitats had 111 random points validated in the field. More field assessments could produce a higher degree of accuracy for the maps created.
It is hope that in future studies more resources could be available for a more thorough field accuracy assessment.

The 88 percent accuracy of the digitizing should take into account the fact that photo-interpretation skills of the producer were being acquired during the digitizing process for this project. It is hoped that further projects have a higher level of accuracy due to increased experience with photo-interpretation. In addition, most of the photo-interpretation errors occurred in three specific habitat polygons. In Kealakekua Bay the aggregated coral occurs very close to the shoreline, the delineated habitat containing a fair amount of accuracy assessment points was deemed colonized volcanic rock instead of aggregated coral. In addition, an area in Waialea Bay was labeled as scattered coral/rock in unconsolidated sediment. However, upon field observations it was evident that the area was better characterized as colonized pavement with sand channels.

CONCLUSION

In conclusion, mapping coral reef habitat is crucial to locating biodiversity hotspots and environmentally susceptible areas (Maragos and Gulko 2002). Providing reef managers with accurate benthic habitat maps can greatly contribute to proper management of coral reef ecosystems (Anderson 2001, Maragos and Gulko 2002). In addition, this spatial (GIS) database can provide resource managers in Hawaii with comprehensive information about our marine protected areas that has traditionally been difficult to access, because such information can be located in many different agencies and institutions. The applications for this database can provide marine resource managers in Hawai‘i with a robust analytical tool and source of information. Thus allowing resource managers to make more informed decisions about the protection of Marine Life Conservation Districts. It is hoped that this project will provide a baseline in order to assist in the future creation of a more extensive network of marine protected areas on the Kona Coast that encompass a greater diversity of reef habitat.

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