Queensland Researchers Develop Photo-Mapping Technique for Benthic Habitats

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Reef habitats in benthic environments provide tremendous economic benefits to coastal nations. Local people rely on the aquatic wildlife as a source of food, while others make their living from the tourists who swim, snorkel or fish there. In addition, a thriving ecosystem of seagrasses and coral reefs provides an extra line of defense for coastal communities, protecting them from storm and wave erosion.

These benefits, however, depend upon the health of the near-shore ecosystem. As the condition of reefs and seagrasses deteriorates, so does the diversity of fish, birds and other plant life in the immediate coastal environment. Without these attractive and essential features in the ecosystem, local people miss out on a food source, fishermen lose their livelihood, and snorkellers / scuba divers take their tourist dollars elsewhere.

Unfortunately, these inter-tidal habitats – coral reefs, in particular – are just as fragile as they are important. Benthic environments worldwide have been stressed for decades by pollutants carried by rivers and rain water from industrial and urban sources located many miles inland. More recently, marine scientists have begun to investigate the negative impacts of climate change on the diversity of these ecosystems. This latter threat may prove especially devastating for developing countries, which are only now learning to promote their coastlines to boost their economies.

Very few benthic environments have been mapped in detail, but the Center for Remote Sensing and Spatial Information Science at the University of Queensland, Australia, is spearheading efforts to develop survey techniques to map underwater reef habitats. These surveys can be used to establish the baseline conditions of corals, seagrasses, fish and other living organisms that compose the reef ecosystem. Analyzed in association with satellite images in a GIS, this information enables researchers to quantify the impact of environmental change on the health and biodiversity in the benthos.

Mapping Below the Water Surface
The use of aerial photography and satellite imagery has shown promise in mapping seagrasses and coral reefs in clear water. Many inter-tidal zones, however, are characterized by varying levels of water clarity, especially in estuaries and bays where the flow from rivers and streams fills the water with sediment. This makes it very difficult to identify underwater features in any type of remotely sensed imagery.

Research at the University of Queensland has focused on directly mapping the reef habitats in turbid to clear waters by integrating field survey and satellite image data. Field data is collected to develop and check maps of benthic features derived from
satellite imagery. Field data is comprised of in-water photographic surveys coincident with the acquisition of high-resolution satellite images.

These photos are analyzed to quantify the percent of reef surface covered by various classes. During operational deployment on reefs off the coast of Australia, Fiji, Belize and Palau, the Queensland researchers devised a survey technique that is fast, safe, inexpensive and accurate.

The field technique requires advanced expertise in only one discipline – scuba/snorkeling. Otherwise, it utilizes a standard digital camera and handheld GPS receiver along with two easy-to-use software packages, GPS-Photo Link for photo mapping and Coral Point Count Excel extension for photo feature classification. The still photographs acquired with this method integrate into an existing GIS or Google Earth environment in their correct georeferenced locations for accurate analysis and classification.

The basic procedure involves the selection of one or more transects across a reef study site. A diver or snorkeller, depending on the water depth, then swims the transect taking photographs of the reef surface while towing a surface GPS. The track of the diver or snorkeller is recorded automatically at set intervals by a GPS, which is towed by the diver in a dry bag floating at the water surface. The GPS unit is kept at the surface as the GPS signal cannot be received below the water surface.

As the diver swims along, keeping the GPS above him/her as much as possible, the GPS records at set time intervals. The diver snaps photos with one hand and tows the GPS line with the other, if it is not connected to his/her buoyancy control device. An offset should be applied to correct for the horizontal distance between the diver and the towed GPS position.

The resulting georeferenced field photographs are used by the researchers to develop and check maps of benthic cover features from high spatial resolution multi-spectral satellite imagery, such as Quickbird and Ikonos.

Underwater photography is quite common in marine research and a standard camera in a waterproof housing is often sufficient. Like the use of a GPS, digital underwater photography is steadily growing in popularity in marine activities and the equipment is getting more affordable and accessible.

The biggest challenge in underwater photo mapping is the same as on dry land – correlating the photos with their precise GPS coordinates. In the early phases of the reef mapping projects, the Queensland researchers devised a workable but time-consuming procedure to accomplish this. A 100-meter transect tape was marked with two-meter increments and pulled tight across the reef area to be mapped. In the water, the marks provided the diver with an accurate reference point where each photo should be taken. But the cord method had its downsides too.

During post-processing, the researcher assigned a GPS point to each photo by interpolation. The researcher knew where each transect began and ended in the GPS track log and could therefore correlate values in between. Although accurate, this
correlation was entirely manual and very time-consuming, involving up to 400 photos per day.

Other drawbacks to this method related to the in-water acquisitions. For safety reasons, divers/snorkellers don’t like working with tapes that could entangle them. In addition, the tape approach required two divers/snorkellers in the water at all times to position the line and take the photos. A simpler and safer photo-mapping method was soon devised.

A Faster Photo-Mapping Technique
The University of Queensland researchers purchased the GPS-Photo Link photo mapping software from GeoSpatial Experts. Selected for its compatibility with any commercial GIS and digital mapping software, this package eliminated the need for a transect tape and automated the correlation process. It also dramatically improved the efficiency of in-water time, enabling the divers/snorkellers to acquire three times as many photos in a given period. From a safety perspective, this meant less overall time diving/snorkeling in the reef environment, which has certain inherent risks for divers/snorkellers.

Implementation of the photo-mapping software altered the in-water procedures. Rather than deal with the transect tape, the researchers began each dive by snapping a digital photo of the GPS screen showing the start time on the receiver’s built-in clock. This simple step is needed to synchronize the respective clocks in the GPS and the camera for location correlation during post-processing.

Once this was done, the diver could take as many photos as possible in transects of any length or pattern. To achieve the desired photo spacing, the diver usually snapped one image for every three kicks of his/her fins depending on the detail needed. The surface area that needed to be covered by one photo was determined by the lens type and its height above the bottom. To ensure the camera distance was always the same above the substrate a plumb-line was used. Divers kept on track with underwater compasses or visual markings. Magnetic marker boards were used to photograph written annotations of transect names and significant reef features.

After the water work was completed each day, the researchers returned to the office. The photos and GPS track were download simultaneously using the GPS-Photo Link software. The software automatically linked every photo to its correct GPS location coordinates based on the time synchronization using the GPS time screen photo. GPS-Photo Link created GIS layers from the input data, which were then imported into ArcGIS or Google Earth.

The resultant data layers had an icon for each photo placed GIS base map or Google Earth Image. In some cases where Google Earth has sufficiently high spatial resolution images for a reef, the output data layers can be plotted on top of the image and their location verified from field work. The automated downloading and correlation process typically required only five minutes per transect, each with 100-200 photos.
A GIS project was also developed with ESRI ArcGIS software on a laptop computer allowing the GPS photo file to be presented as a layer on top of the coincident Quickbird 2 satellite imagery.

With the photos georeferenced to the GIS layers, the researchers could click on any icon to view a full-resolution image of the underwater photograph taken there along with any notes that had been saved as attributes. However, the Queensland researchers wanted to quantify the information contained in the photos for developing mapping algorithms and verifying the output maps from Quickbird images. They used the Coral Point Count Excel extension application (CPCe), a free visual basic program created by the National Coral Reef Institute in Florida for the determination of coral and other types of reef coverage using a random point count methodology (www.nova.edu/ocean/cpce/).

The CPCe software allowed the researchers to place multiple points in each photo frame and then assign each point a benthic cover type class label. Researchers could assign very general classifications, such as sand or sea grass, or the classifications could be as specific as possible depending on the research needs. For many classes of algae and seagrass, for instance, the researchers identified the exact species, while identification of corals focused on the growth forms.

The Queensland team generally needed only about one minute per photo to assign point classes. From there, the software calculated the percent of reef area covered by that type of coral or grass in that photograph. The software stored these classification statistics in an Excel file linked to its appropriate photo. The Excel data were then linked to the GIS layer and this enabled the researchers to display the reef coverage by class across the transect in the form of a pie chart or bar graph, providing insights into variations in condition and health of the reef ecosystem.

With the Excel files linked to the photos in the GIS via GPS-Photo Link, the researchers were able to analyze the classifications from a quantitative perspective in the spreadsheet. If a specific coverage class or percentage seemed out of place compared to other data points, a researcher could click on the spreadsheet field and instantly access the photograph in question to view and double check the class identification.

Looking Ahead
The University of Queensland reef survey technique proved a fast, safe and accurate method for gathering information on the composition and condition of coral reef and seagrass environments. This information is being used for mapping reef features in coastal and reef environments around the world with variable levels of water clarity. Future research will focus on determining the level of detail of the reef coverage classes that can be extracted from the in-water survey technique, and how to precisely match these with satellite imagery or aerial photography. The ultimate objective will be to use the field data and apply automated digital classification techniques to these sources of remotely sensed data.

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