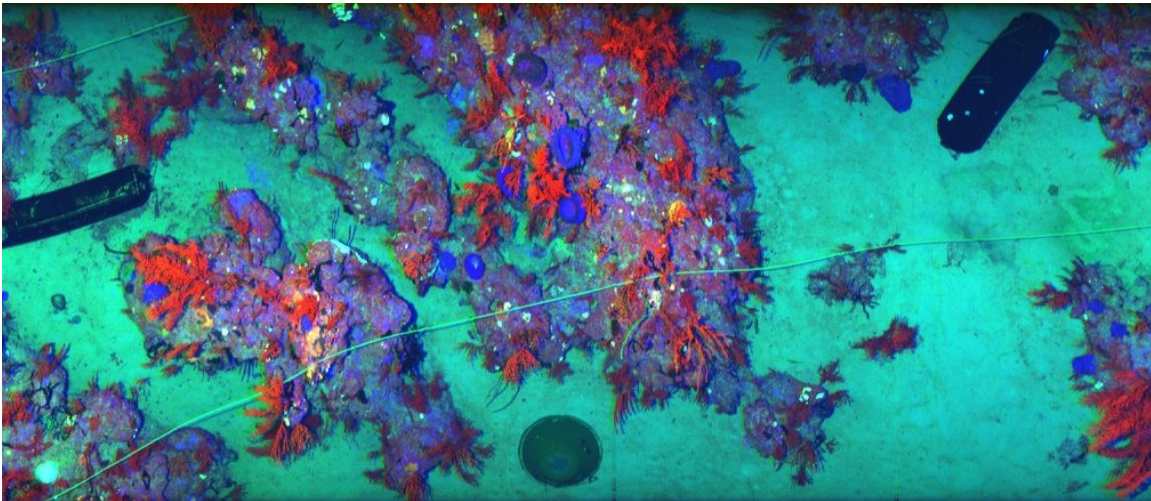


Coastal Benthic Optical Properties Fluorescence Imaging Laser Line Scan Sensor

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LONG TERM GOALS

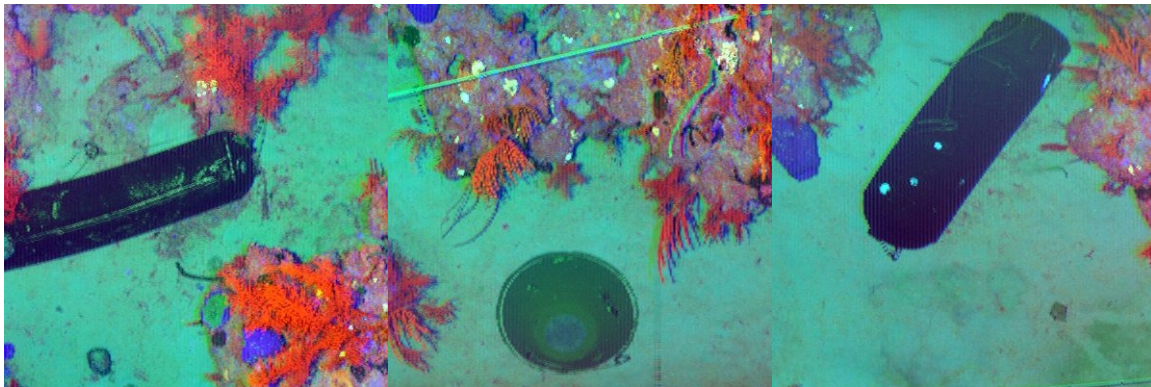
Identification of mine-like contacts (MLCs) is a pressing fleet need. During MCM operations, sonar contacts are classified as mine-like if they are sufficiently similar to signatures of mines. Each contact classified as mine-like must be identified as a mine or not a mine. During MCM operations in littoral areas, tens or even hundreds of MLCs must be identified. This time consuming identification process is performed by EOD divers or ROVs, and is the rate limiting step in many MCM operations. A method to provide rapid visual identification of MLCs would dramatically speed up such operations. Acquisition of Laser Line Scan sensors for MLC identification is currently planned to support both Air Mine Counter-Measures (AMCM) and Surface Mine Counter-Measures (SMCM) operations.



The scenario outlined above is viable in acoustically benign environments, but faces many obstacles in highly cluttered environments. Coral reefs are a prime example of an environment where current acoustic methods can be expected to have great difficulty. Our prototype Fluorescence Imaging Laser Line Scan (FILLS) sensor[1,2,3,4] has demonstrated that fluorescence imagery provides strong signatures which may be used to separate the coral clutter from mines. The image above demonstrates the ease with which a human observer can differentiate the mine like objects (MLOs) from the natural clutter in an environment which is difficult for sonars. The subimages below suggest the image detail that the FILLS sensor is capable of producing. Accordingly, this technology is a leading candidate for

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extending MCM capabilities into highly cluttered environments. In this role, FILLs imagery can be used for MLC detection, classification, and identification.



OBJECTIVES

The exploitation of FILLs imagery to extend MCM capability into highly cluttered environments depends upon establishing a firm understanding of the elastic scatter and fluorescent scatter signatures of mines, clutter, and natural backgrounds. Establishing this understanding is a key objective of this CoBOP project. We will establish FILLs signatures for mine-like objects (MLOs), coral reefs, sediments, and sea grasses as part of this project. Collaboration with other CoBOP principal investigators will be utilized to establish interpretations of these signatures.



The FILLs signatures of mines are expected to change significantly as colonies of biological growth establish themselves on the mines. As an example, the image above shows a photo of an MLO that has been in the water for approximately four weeks near Panama City, Florida. The signature this MLO presents to an underwater imaging sensor is markedly different from that which a freshly placed MLO presents. This biofouling will be a strong function of the environment of the mine. Accordingly, the second objective of this project is to characterize, within the scope of the environments available for

CoBOP, the “optical aging” of the FILLs signatures of MLOs. This optical aging affects the performance of both monochromatic and fluorescence based underwater imaging sensors.

APPROACH

The test site selected for CoBOP is the Caribbean Marine Research Center (CMRC) on Lee Stocking Island (LSI), Bahamas. This site was selected because it provides research support facilities in environments compatible with the overall objectives of CoBOP. The environments available include coral reefs, sediments, and sea grasses. Specific study sites in each of these environments were selected by CoBOP.

The primary sensor used by this project is the prototype FILLs sensor. This is supplemented with a Reson Seabat 6012 ahead looking sonar which is used for target reacquisition, and a down looking Seabat 9001 sonar, which provides swath bathymetry information.

For CoBOP-98 the FILLs sensor and the Seabat 9001 were deployed on the Harbor Branch Oceanographic Institute’s (HBOI) Clelia minisubmarine. On this deployment platform it was possible to image the deeper water CoBOP environments. However, it was not possible to deploy in study sites shallower than about 50 feet. Moreover, the Clelia provided only relatively crude control of the FILLs sensor altitude. In addition, accurate navigation information, such as that provided by differential global positioning system (DGPS), could not be obtained. This precluded useful FILLs surveys of areas other than study sites where divers installed transect lines.

For CoBOP-99 it was decided to install the FILLs sensor and the Seabats on a towed body in order to 1) enable FILLs imagery at shallower water CoBOP test sites, 2) provide accurate control of sensor altitude, and 3) merge accurate navigation information (DGPS) with the FILLs data stream. This change also enables deployment of the FILLs sensor at other sites where the Clelia cannot operate. It enabled a deployment of FILLs at the derelict World War II minefield near Key West.

Image processing and image enhancement algorithms, originally developed for the monochromatic EOID Sensor, have formed the basis for development of similar algorithms for processing and enhancement of FILLs imagery. Similarly, the IMPERSonator model, originally developed for the EOID Sensor, is the basis for a similar model being developed for the FILLs sensor. This model is necessary for the quantitative interpretation of the FILLs data.

The optical aging of MLOs is being studied through long-term placement of MLOs at LSI. In addition, MLOs have been provided to the “Fouling of mine casing surfaces by fluorescent organisms” project at Bigelow Laboratory.

Raytheon (Bryan Coles, William Radzelovage, and Richard Regan) is responsible for maintaining and calibrating the FILLs sensor; and providing, maintaining, and interpreting the data from the Seabat 9001 sonar. The Coastal Systems Station (CSS) is responsible for the image processing (Andy Nevis), the deployment of the FILLs sensor on the towed body (Sam Taylor), and the modeling and interpretation of the FILLs data (Mike Strand).

WORK COMPLETED

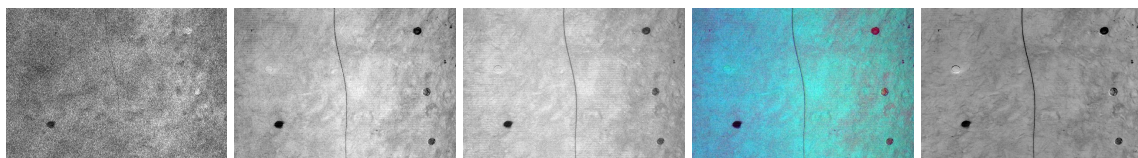
The FILLs sensor was deployed at the CoBOP LSI test site during the May 1998 field test[5,6]. FILLs imagery was obtained of coral reefs, sediments, sea grasses, and various other targets including mine-like objects.

The FILLs and Seabat sensors were integrated into a CSS active depressor towed body for the May 1999 LSI field test. This integration was fully successful, and FILLs imagery was successfully obtained of all the desired target environments (sediments, sea grasses, and coral reefs) and targets (MLOs and fluorescence panels) at North Perry, Rainbow Gardens, Adderly Cut, and Channel Marker. It is very unfortunate that two of the channels of the FILLs sensor failed after the shakedown test at Panama City. As a result, little useful data was acquired at LSI-99.

Automated image enhancement routines have been extended to apply to the FILLs imagery acquired at CoBOP and other tests[7]. The signal characteristics of the fluorescence channels are quite different from those of the elastic scatter channel of monochrome LLS systems. Specifically, the background fluorescence signal (from the sediment) is generally very weak, but there are typically certain items (e.g., coral heads) that have very intense fluorescence signals. The challenge is to enhance the weak background fluorescence signals without saturating the intense fluorescence signals. In the past this processing has required significant human intervention. Since the May 1998 LSI field test, a set of fully automatic routines has been designed and implemented. It was found necessary to develop two sets of automatic routines. The automatic processing / enhancement routines will allow a more rapid turn-around of the FILLs processed data at future CoBOP tests. Raytheon has developed, implemented, and exercised a technique for processing MLLS imagery which is promising for automatic target classification[8].

RESULTS

It has been clearly demonstrated that the type of sediment strongly influences the background fluorescence signal. The subimages below show a FILLs imagery (elastic, fluorescence pseudocolor, and red, green, and yellow fluorescence channels, respectively) of samples of five different sediment types (yellow mat, ooids, hard ground, quartz sand, and cyanobacterial mat) which were inserted into the natural calcium carbonate sediment at the LSI test site. Four of the five sediment samples could easily be distinguished from the carbonate background by their fluorescence signatures. It is not surprising that the ooids, formed by spontaneous precipitation of calcium carbonate, exhibit little contrast with the carbonate background.



FILLs signatures of sea grass have also been obtained. In the elastic scatter image the sea grass appears dark, since it absorbs the 488 nm light more strongly than the carbonate sediment. The sea grass also appears dark in the green (514 ± 20 nm) and yellow (570 ± 40 nm) fluorescence images, because the sediment fluoresces more strongly than the sea grass in these bands. The surprise was in

the red (680 ± 20 nm) fluorescence band. The general expectation was that strong fluorescence from the chlorophyll in the sea grass would cause the sea grass to appear brighter than the sediment. Instead the contrast is close to zero, apparently indicating comparable red fluorescence from the sediment and the sea grass.

IMPACT/APPLICATIONS

Results obtained by this and related CoBOP projects are expected to play a key role in the decisions of what technology to pursue for the next generation Advanced Electro-Optic Identification Sensor.

TRANSITIONS

In December 1999 the FILLS sensor in the active depressor towed body will be used to support a National Marine Fisheries Service project entitled "Oculina coral habitat restoration and recovery of reefish populations in the Experimental Oculina Research Reserve; an application of laser line scan imaging technology", Dr. Churchill Grimes principal investigator.

RELATED PROJECTS

This project is closely coordinated with the Coastal Benthic Optical Properties (CoBOP) DRI. This project is studying the optical signatures of backgrounds, clutter, and targets. These signatures are key to the development of the automatic target detection algorithms required to support AMCM and SMCM.

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