

Title: **INTER-REEFAL MAPPING OF HABITATS IN BELIZE**

Sponsor: Conservation International

Research Permit: Belize Department of Fisheries

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Total Project Period: October 2006 through Feb 28, 2010

Boston University Accounting Information 020 202- 9829-5

Introduction

The broad goal of this activity was to understand the inter-reefal areas of the coastal ocean as a habitat mosaic, or “megahabitat” encompassing the complex maze of connected coral reef, mangrove, seagrass, soft-bottom, and river plume environments. The components of this megahabitat that lie between the reefs have largely been absent from direct marine conservation activities. These habitats, however, are becoming known as sites of significant biodiversity and endemism. It is also noteworthy that many non-emergent reefs occur in these areas and the complex mosaic as a whole supports an interconnected system of coastal ecosystems. Effective scientific mapping is an essential first step for targeted research and subsequent conservation management and Marine Managed Area (MMA) design addressing the entire megahabitat. This activity addressed this need for effective scientific mapping and exploration of the inter-reefal domain.

This project mapped the nature and extent of the constituent habitats and occupant species in and around MMAS located in the Meso-American Barrier Reef (MABR) system of Belize using advanced Side-Scan Sonar and Acoustic Doppler Topographic mapping survey devices. The project was located in the inter-reefal mangrove caye and lagoon complex, found the Southwater Marine Reserve Area, Belize. Like many other once remote areas, the Belize lagoons are under immediate threat from rapidly emerging development projects. The Belize lagoonal system is situated between the coastline (with mangrove forests and freshwater rivers) and the meso American barrier reef (adjacent to deep ocean). It is a unique mega-habitat that consists of sand shoals, mangrove cays, freshwater rivers, coastal forests, coral reef, soft-bottom marine plains, seagrass meadows and submerged algal ridges that are all arranged in a complex 3D geography and confined within a limited domain. The biodiversity significance of this region has been underappreciated. Belize lagoons have recently yielded several new fish species and, while the biota are clearly Caribbean. We have found several new species of fishes that are endemic to this area. Others researchers have also found additional endemic fishes and invertebrates from this Meso-American domain.

The accomplishments of this project fall under three main categories:

1 Site-specific studies of the Belize inter-reefal with discovery of several new reef fish species and the finding of a previously unknown deep habitat. We have published 5 papers to date with several more in preparation (see below).

We have already discovered and described 3 new species of reef fishes from the area of study (Randall & Lobel 2009; Lobel et al Copeia 2009; Randall & Colin 2009). Furthermore, we have three additional new fish species from this area that we are in the process of describing (see below). The possibility that there are additional undescribed fishes in the unique habitat seems highly likely given our past findings in the region.

2 This project assembled a unique portable “suitcase” deployable mapping system (side-scan sonar and acoustic Doppler plus lots of key accessories for remote field operations). This innovative implementation of established technologies can be shipped worldwide and then used from any small boat to map areas of interest for marine conservation.

We have assembled a suit of devices including GPS, side-scan sonar, acoustic Doppler profiler, fathometer, laptop computer, etc that can be operated from a 12volt battery source off a small boat anywhere. The Acoustic Doppler system enables rapid topographic 3D images of the sea-bottom in high resolution over small areas. A 3D map can be created from data after only one-hour underwater survey and one-hour post-processing. The side-scan sonar enables searching for interesting habitat over vast areas. Sonar results are seen in real-time.

3 Developed a proposal submitted to NOAA’s Ocean Exploration Program that is entirely based on results of this study.

The area of particular interest is the deep stretch of lagoon between the coast and the first ridge of mangrove cays (e.g. Blue Ground Range) in the Southwater Marine Reserve Area. The unexplored sea-bottom beneath this expanse of murky water (water depth range 18- 25m) has long been regarded by locals and scientists as a featureless field of sand and silt, and therefore, relatively uninteresting from a biodiversity and ecological perspective. However, the results from our side scan sonar surveys in this area show a different picture. During our surveys, several patches of hard bottom features were discovered. This immediately dispelled the myth that this area is only sand/silt, a notion that was reinforced because boat-mounted fathometers do not resolve this low-lying bottom rubble habitat at depths below 20m. Given the location of the site and this more complex topography, we now have strong reason to believe that the project area is a distinct and complex ecological zone that experiences an ever-changing flux of ocean waters and river runoff.

This newly revealed deep habitat area has the potential to be a critical link in the life

history of important fisheries species such as snappers, groupers and lobsters. The patchwork of hard-bottom oases that is distributed in the vast planes of sand and silt could provide an important intermediary habitat for fishes as they transition in their life history from juveniles in coastal mangroves to adults on the barrier reef. It is also perfect habitat for finding the Belize population of the endangered sawfishes (*Pristis perotti* and *P. pectinata*), if any still exist. If so, then this previously unexplored region has tremendous potential economical importance for Belize fisheries and conservation management. Thus, the proposed project will support informed decision making by providing the Belize Fisheries Department and Conservation NGOs with factual information. There is a special urgency to obtaining such data, as the area is regularly exposed to agro-chemicals in river runoff. It is also subject to the destructive impacts of bottom trawls used by the shrimp fisheries. We learned at the MMAS meetings in Belize City (Feb 2010) that the Oceana Foundation is investigating the adverse ecological impacts of the shrimp trawling fisheries in the inter-reefal channels of Belize.

RESULTS

PUBLICATIONS; n=5 to date

- 2009 Stetson P., B. Shank, P. S. Lobel in press. Mapping reef structure and bathymetry in Belize using Cobra-Tac. Proceedings of the 11th International Coral Reef Symposium July 2008.
- 2009 Randall, J. E. & Lobel, P. S. A literature review of the sponge-dwelling gobiid fishes of the genus *Elacatinus* from the western Atlantic, with description of two new Caribbean species. *Zootaxa* 2133: 1-19
- 2009 Lobel P S, L Rocha, & J E Randall. The color phases and distribution of the western Atlantic labrid fish, *Halichoeres socialis*. *Copeia* 2009 No. 1, 171-174
- 2009 Randall, J. E. & Colin, P. L. 2009. *Elacatinus lobeli*, a new cleaning goby from Belize and Honduras. *Zootaxa* 2173: 31-40
- 2009 Kovitvongsa K. E. & P. S. Lobel Convenient fish acoustic data collection in the digital age. In P, Pollock (ed.) *Diving for Science 2009*. Proceedings of the 28th American Academy of Underwater Sciences Symposium. Dauphin Island, AL: AAUS; 2009:

MANUSCRIPTS; n=4 currently in preparation for completion summer 2010

Description of a new species of hamletfish, *Hypoplectrus* from Belize (P. S. Lobel and J. Randall).

Description of a new species of *Microgobius* from Belize (P. S. Lobel, L. Lobel and J. Randall).

Description of a new species of *Elacatinus* from Belize
(P. S. Lobel and L. Kaufman).

The bioacoustics of Belizean toadfish
(K. Kovitvongsa and P. S. Lobel)

Scientific Presentations: 11th International Coral Reef Symposium, July 2008

Oral Presentation ABSTRACT:

MAPPING REEF STRUCTURE AND BATHYMETRY IN BELIZE USING COBRATAC

Stetson, P., Shank, B., and **P.S. Lobel**

The Cobratoc underwater navigation system (manufactured by RJE International, Irvine, CA, USA) was tested for its mapping capabilities in shallow (<20m) hard- and soft-bottom habitats on lagoonal reefs and in the inter-reefal around Wee Wee Caye, Belize. The Cobratoc was created as an autonomous underwater diving navigation system that measures depth and altitude for hydrographic and positioning purposes. It computes position using a fluxgate compass and a Doppler velocity log. The Cobratoc's effectiveness as a measuring tool for the rugosity of reef structure and for mapping bathymetry was evaluated. The accuracy, density, and breadth of data collection is dependent upon speed of travel and altitude above the bottom. Multiple passes over the desired area may be necessary to collect a complete dataset. Maps will be presented illustrating the capabilities of the Cobratoc in conjunction with GIS software, Surfer and ArcGis, and MatLab. Provided that the limitations of the system are understood, the Cobratoc appears to be a powerful tool for easily mapping the topography of small-scale and shallow marine systems and producing readily intelligible and informative bathymetric maps. This project was supported by the Boston University Marine Program, Conservation International's Marine Management Area Study and the US DoD Legacy Program.

Poster Presentation ABSTRACT:

INTER-REEFAL MAPPING TECHNOLOGIES FOR MARINE MANAGEMENT AREAS

Klein, D., Bastos, A., **Lobel, P.**, Dutra, G.F., Fischman, D., Musinsky, J., Kikuchi, R. & Moura, R.L and P. Stetson.

This poster describes and compares the different types of reef and inter-reefal mapping and monitoring technologies being used to support the Marine Management Area Science Program (MMAS), a scientific collaboration between Conservation International and Boston University seeking to understand the management effectiveness of marine management areas. In two study areas, the Abrolhos Bank in Brazil and the Mesoamerican reef in Belize, a combination of optical satellite imagery, side-scan sonar, multi-beam echo sounder and Remotely Operated Vehicle technologies are being used to map and validate shallow and deep water coral reefs and inter-reefal environments. These technologies were chosen for: 1) their ability to map extensive geographic areas; 2) their suitability to the varying environmental conditions of the reef and inter-reefal areas; and 3) cost and availability. For the shallow coral reef systems, Quick Bird and IKONOS satellite images are being used to classify fine-scale biophysical characteristics (e.g. macroalgae, corals, sand, mud) and create a baseline map for long-term monitoring of the growth and deterioration of the shallow reefs. We are systematically sampling deeper benthic habitats with side-scan sonar profilers and acoustic doppler topographic survey devices to detect and image potential reef structures and map bottom types. Anomalies and interesting features identified in the acoustic mapping surveys are subsequently *ground-truthed* using scuba dives to 30m and

Remotely Operated Vehicle coupled to video cameras to 100m. Comparisons between the technologies used and their appropriateness for the different habitat mapping objectives are discussed.

DETAILED REPORTS SECTION

New species of coral reef fishes found in the Meso-American Barrier Reef (MABR) system

Elacatinus coloni Randall & Lobel 2009

Elacatinus lobeli Randall & Colon 2009

Elacatinus sp nov Lobel & Kaufman in prep

Hypoplectrus sp nov Lobel & Randall in prep

Microgobius sp nov Lobel, Randall & Kerr Lobel in prep



Elacatinus coloni (Randall & Lobel 2009)

This species is a sponge dweller and feeds on a polychaete sponge parasite. It is endemic and found only inside the MABR usually in tube sponges. It was named for Pat Colon who has done extensive research on this fish genus.



Elacatinus lobeli (Randall & Colon 2009)

This species is similar in color to the neon goby found in Florida but it is genetically and morphologically distinct. It is a cleanerfish and removes ectoparasites from host fishes. It is endemic to the MABR but is found broadly inside the MABR and on the atolls. It was named for Phillip Lobel who photographed and collected the type specimens.



Elacatinus nov sp (Lobel & Kaufman in prep)

We surveyed Lighthouse Atoll just before the February 2010 MMAS meetings (Belize City) and discovered this new species! We returned to the atoll after the meetings and collected the type specimens. It has blue stripes similar to *E. lobeli* but this new fish is distinct by having a white-ish nose spot and is only found at deeper depths.



This new species of *Microgobius* is found only in deep (>15m) sand flats areas in the inter reefal channels between mangrove islands in Belize MABR. It is very hard to see as it prefers murky water, is very skittish and avoids divers. This species is being described by P. Lobel, J. Randall and L. Lobel.



This new species of hamletfish, *Hypoplectrus* is found only in Belize. This species is being described by P. Lobel and J. Randall



The identity of this tiny fish is not yet determined. It is possibly a new species of micro grouper (Serranidae) but it could also be blenny or ?. It is found only in deep (>15m) sand flats areas in the inter-reefal channels between mangrove islands in Belize MABR. It is very hard to see as it prefers murky water, is very skittish and avoids divers. This species is being described by P. Lobel, J. Randall and L. Lobel.



Halichoeres socialis

Male & female (in back)

We discovered this new Belize fish and described it in 2003 (*Halichoeres socialis* Randall & Lobel 2003). We continued study of its biology and biogeographic distribution as part of this project. We published a paper that draws attention to the now clear pattern that there are a number of reef fishes and invertebrates, which are only found in Belize or in the greater area of the Meso American Barrier Reef system (Lobel et al 2009).

Mapping Underwater Habitat

Global Applicability of Technologies developed for this project

We developed a highly portable system for bathymetric mapping coral reef and inter-reefal areas. It is small, modularized and transportable. This system has global applicability for mapping marine habitats in shallow water (<100m) worldwide. Our system is based in the core technologies of an Acoustic Doppler and a side-scan sonar plus GPS. *See results below....* [COBRATAC](#) and [Side Scan Sonar](#)

COBRATAC: The Technology

The Cobratatc underwater navigation system (manufactured by RJE International, Irvine, CA, USA) was tested for its mapping capabilities in shallow (<20m) hard- and soft-bottom habitats on lagoonal reefs and in the inter-reefal around a mangrove island surrounded by coral reefs Belize. The Cobratatc was developed as an autonomous underwater diving navigation system that measures depth and altitude for hydrographic and positioning purposes. It computes position using a fluxgate compass and a Doppler velocity log. See <http://www.rdinstruments.com/cobratatc2.html> for product information. The unit costs about \$20,000. It was purchased on an earlier project with funding from the Army Research Office originally for research at Johnston Atoll, Pacific.

The bathymetric mapping capabilities of the Cobra-Tac proved successful. The most effective data collection method involved towing the Cobra-Tac in a tight organized grid. The unit was able to map the bathymetry of small-scale shallow areas very well. While the accuracy was good enough to create bathymetric maps, it was not able to provided sufficient resolution to calculate rugosity.

Bathymetric Mapping

The bathymetry mapping capabilities, however, appear to be very good, especially when used in conjunction with a GPS in the towing vessel for later ground-truthing during post-processing. The accuracy of the map is limited by the method in which the data is acquired. The data gathered is more accurate when there is one person manipulating the unit and another person, either a diver or the pilot of the towing boat, navigating. If the bottom is not visible to the diver manning the Cobra-Tac, it is difficult to maintain an accurate course. While the compass in the unit helps, it is not always steady and when visual confirmations of course are obtained by surfacing, they often results in error as a result of the unit tipping off-level. The level gauge in the unit must be watched with vigilance to ensure accurate compass and bathymetric readings. Hence, accuracy in data acquisition is greatly improved when the Cobra-Tac diver is able to either follow another leading diver in the water or when towed behind a boat.

For developing a bathymetric map, a tight organized grid formation produces the result with the least amount of interpolation during post-processing. A random walk method, even as simple as swimming two straight lines with a 90° turn in the middle results in significant amounts of interpolated data in the final map. The level of interpolation is dependent on the gridding method used. In this study, we found that the Natural Neighbor Gridding method (provided in the Goldenware Surfer software) was the most appropriate and accurate. One solution to the falsely interpolated data problem is to separate the data into straight line segments during the grid creation step. Another method that allowed clear discernment of actual and interpolated data is to plot the data in another software program, such as MatLab. This allows for the actual points to be displayed independently or overlaid with a (MatLab) generated surface. Both Surfer and MatLab allow easy 3D manipulation of the final map products, however Surfer appears more limited in overall map manipulation capability, despite a more aesthetically pleasing final product.

Measuring reef structure for long-term monitoring

In terms of calculating coral reef rugosity, the Cobra-Tac did not map finely enough to calculate the heights and shapes of individual coral colonies. Several attempts were also made both at close and far proximity to map the morphological complexity of single coral colonies. One method involved making several passes (4+) over the same coral head holding the unit level. Another methods involved remaining stationary over a coral colony and moving the unit sideways and tilting it slightly in attempts to fully “paint” the coral with the acoustic beams from the Cobra-Tac. Neither method tried was successful.

Conclusion

The Cobra-Tac is a very tool for the rapid mapping small-scale shallow underwater areas and generating a low resolution bathymetric map. Its main advantage is that it fits into a suitcase, is easy to set-up and can be rapidly deployed by divers to map a designated location. Post-processing is somewhat more cumbersome, but not prohibitively so. We found the manual provided by the manufacture to be lacking in some key details but we have developed our own SOPs. We also found that additional third party software is needed in order to derive the best data quality.

South Water Cay, Belize Barrier Reef

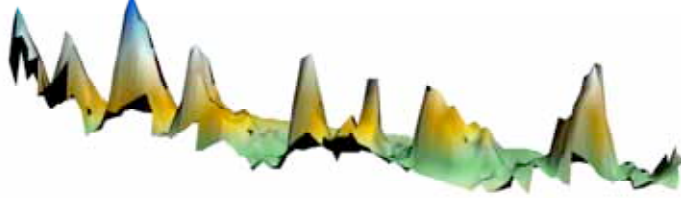
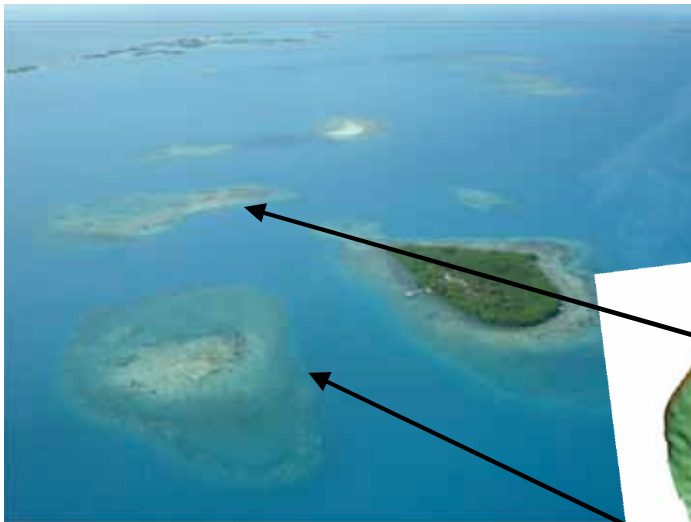


Figure 1- a section of spur and groove formation of a seaward reef mapped at Southwater Caye, Belize. The spur and groove formations are clearly visible in the figure. The map was created with a single transect of the Cobra-Tac operated by a snorkeling swimmer.



Figure 2 An aerial photo of the reef transect with the black line indicating the transect location.



Wee Wee Caye,
Belize Inter Reef

Figure 4 is an aerial photo of the habitat with the area mapped outlined (Aerial photos by Phillip Lobel).

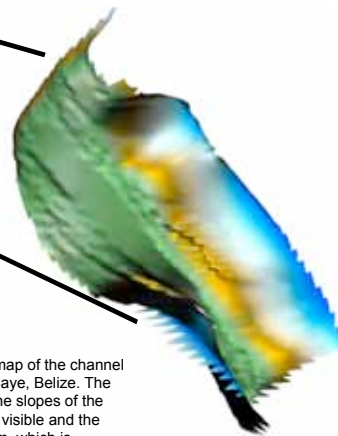


Figure 3 shows the bathymetry map of the channel immediately west of Wee Wee Caye, Belize. The slopes of the island, as well as the slopes of the shoals to the west and north are visible and the bathymetry of the channel-bottom, which is otherwise too deep to see from the surface, is well defined. The map was created by a towed diver and six grid lines that ran parallel to the length of the channel



Figure 5 shows a diver being towed underwater holding the Cobratac (photo by Lauren Gonzalez)



Figure 6 shows the diver with the Cobratac about to enter the water (photo by Alissa Assad).

Results of this study were published

- 2009 Stetson P., B. Shank, P. S. Lobel in press. Mapping reef structure and bathymetry in Belize using Cobra-Tac. Proceedings of the 11th International Coral Reef Symposium July 2008.

Searching for deep habitats using Side-Scan Sonar

We successfully mobilized a “suitcase portable” side scan sonar system that can operate at sea using a 12 volt battery with solar panel. The system was field tested in Dec 2007 around Wee Wee Cay and used to map deep habitats during the 2008 and 2009 field seasons.

The area of interest for this study is an uncharacterized part of ocean at the interface between oceanic and terrestrial ecosystems that span several miles between the coastline of Belize (Central America) and the first ridge of emergent mangroves cays and shallow (<2m) reefs inside of the Meso-American Barrier Reef. The water in this area is typically very turbid due to influx of terrestrial rivers that drain into it. Because it is murky and deep (for divers), it has not yet been explored. Furthermore, inspection of the most detailed nautical chart (DMA 28ACO28167) will show that the bottom soundings in this area are quite sparse. This unexplored sea-bottom beneath this expanse of murky water (water depth range 18-25m) has long been regarded by locals and scientists as a featureless field of sand and silt, and therefore, relatively uninteresting from a biodiversity and ecological perspective. However, the results from side scan sonar surveys in this area show a different picture. We found several patches of hard bottom features. This immediately dispelled the myth that this area is only sand/silt, a notion that

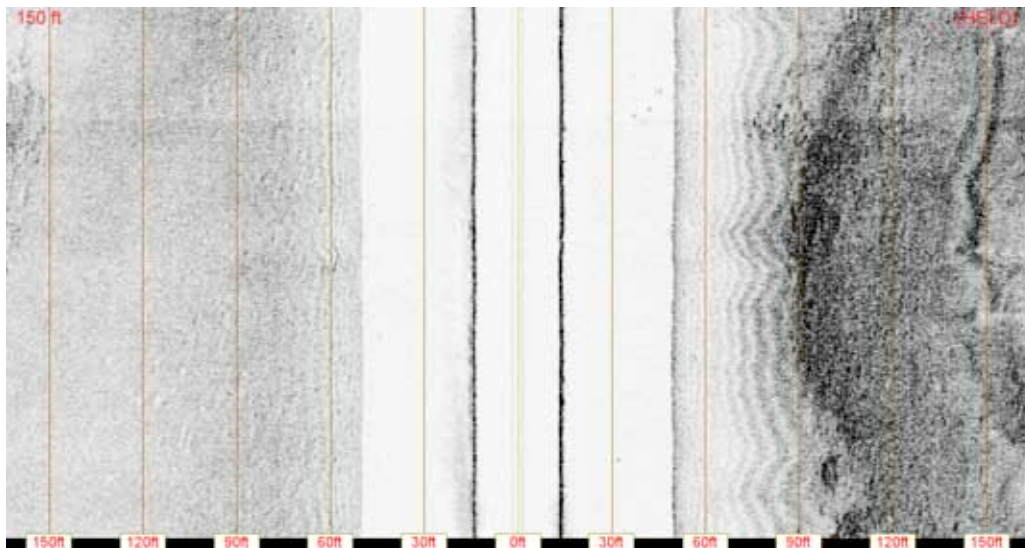
was reinforced because boat-mounted fathometers do not resolve this low-lying bottom rubble habitat at depths below 20m. Given the location of the site and this more complex topography, we now have strong reason to believe that the project area is a distinct and complex ecological zone that experiences an ever-changing flux of ocean waters and river runoff.

System Description:

The Imagenex Model 872 "YellowFin" is a full-featured triple channel, high resolution, sidescan sonar. The YellowFin is a user friendly system that incorporates a high speed Ethernet connection to a Windows™ based laptop or desktop PC. Integrated power and a built-in differential-ready GPS receiver complete this system. Zoom windows are available for target investigation without interrupting real-time data acquisition. Data is displayed in real-time, with or without speed correction, in 9 user selectable color tables.

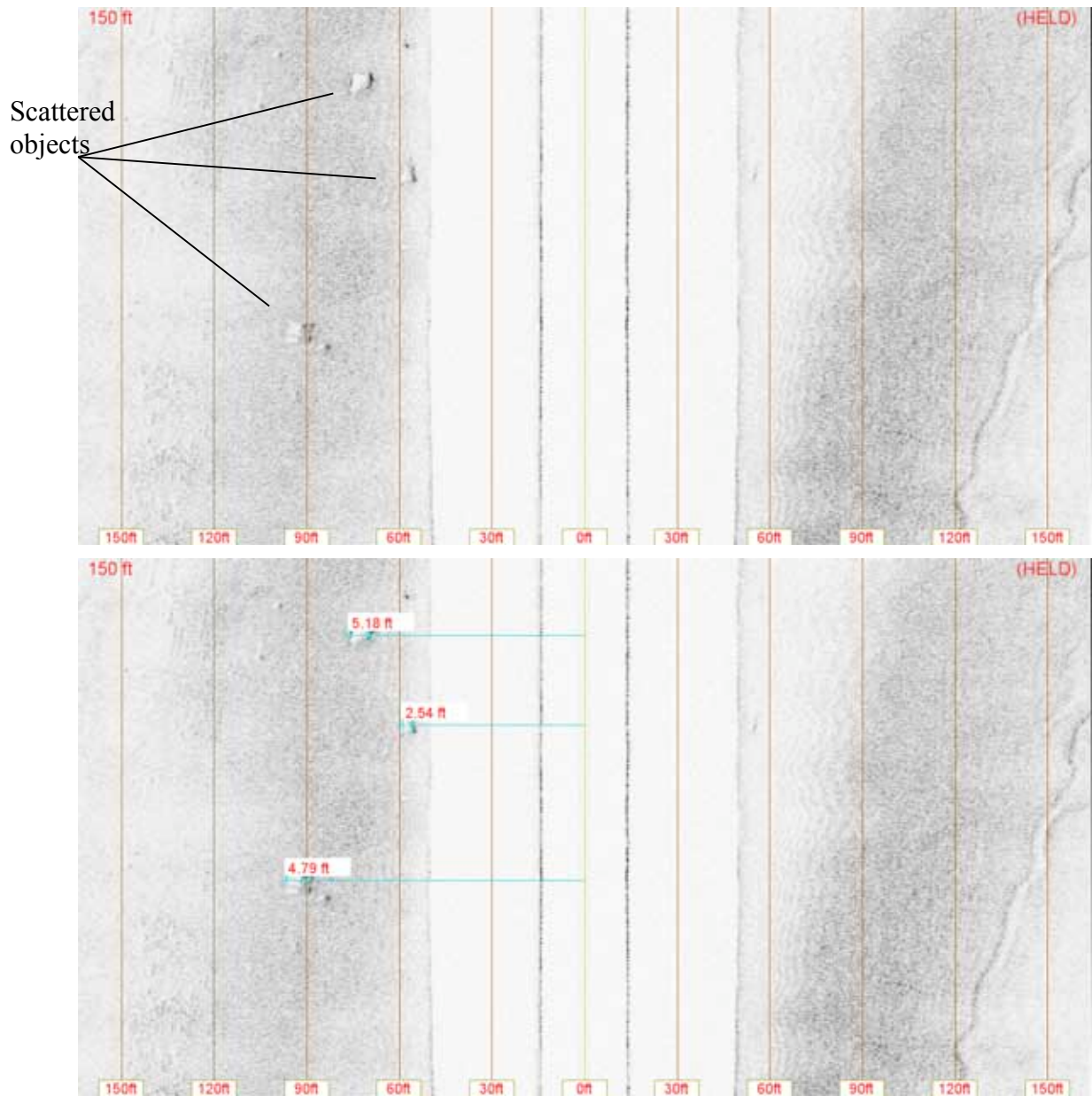
- * Triple frequency: 260 kHz, 330 kHz, 770 kHz,
- * High resolution 1000 data points per side
- * 300 m depth rating
- * Up to 400 m (1300') total coverage
- * Built-in track plotter
- * Built-in internal GPS receiver
 - Record to .XTF in real-time

Samples of sonar output



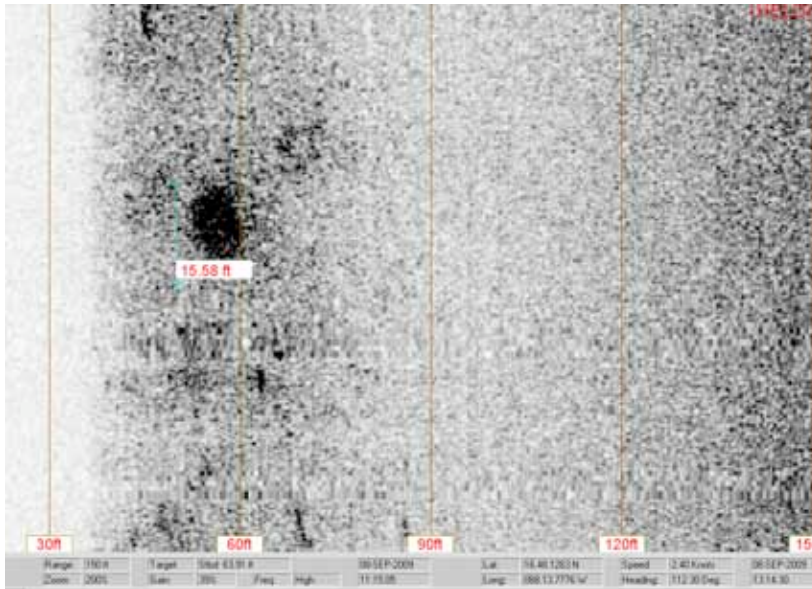
Sand bottom on slope along channel

Reef on slope along channel

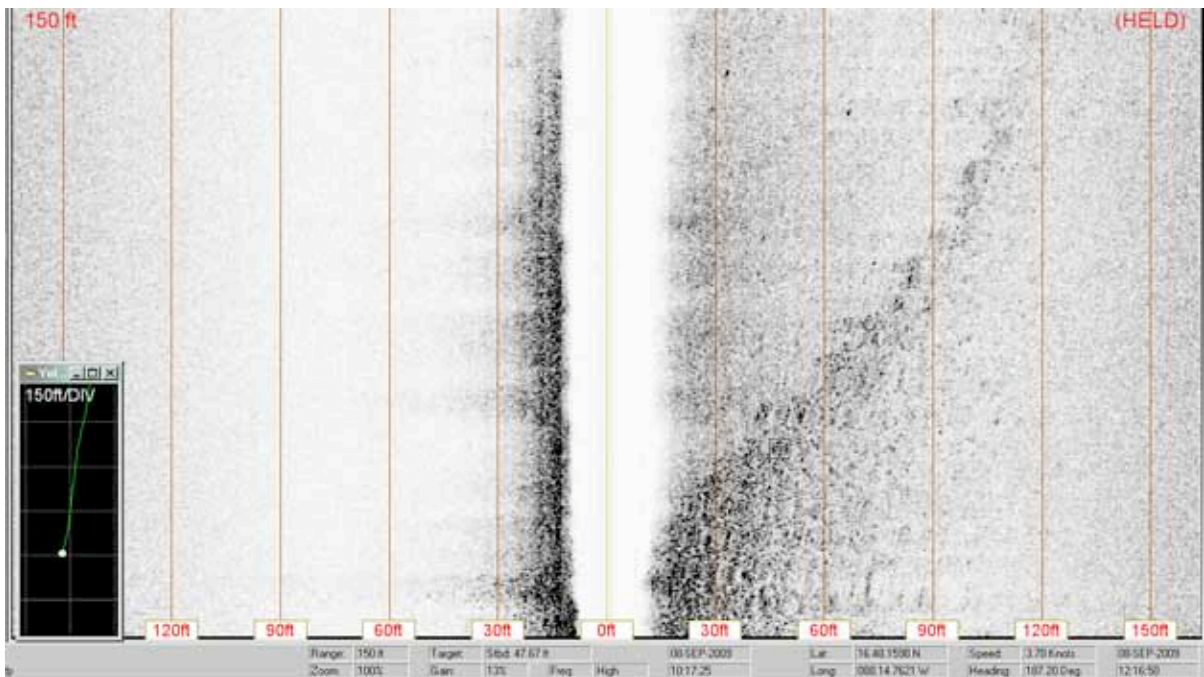


The top picture shows the sonar recording along a sand bottom with three large “objects” on the left-side. The lower picture shows the same image with the heights of the “objects” measured using sonar software. We did not visually confirm these “objects” but large barrel sponges and scattered patch reefs were common in this area.

Examples from Sept 2009 side-scan sonar survey showing hard bottom features in an area otherwise reported as only sand and silt bottom. To our knowledge these areas have never been scientifically surveyed. The potential to find new species is very high..



A hard-bottom patch reef of about 10-15 ft diameter. In murky water depth about 75 ft.



This sonar tracing shows a long hard-bottom ledge-like feature extending over 200ft in length.



Example cruise track. Waypoints during the September 2009 survey using the side-scan sonar.

Preliminary conclusions

Our hypothesis is that there is a patchwork of scattered hard bottom oasis habitat that fish use to cross the open sand/silt planes. If these oasis habitats are clustered (geological basis?), they may form an important “stepping stone” corridor for migration and thus, would be important sites for environmental protection. The features detected in the inner lagoon could well be topographic highs of Cretaceous age, which in the outer lagoon provide the antecedent topography on which the rhomboid shoals, or fore reefs, are founded. Remnants of these Cretaceous highs can be seen on the coastal plain of the Belizean mainland as well. Because this area regularly experiences dramatic fluxes in water quality, a key question is how are fishes, coral and other organisms physiologically adapted to this stress? Such adaptations, coupled with the geographic isolation of area (inside of the Meso-American Barrier Reef System) could possibly be one adaptive basis for speciation in this region.

Ecological Importance of “Missing” Reef: Inter-Reefal Hard Bottom Habitats in the turbid inshore waters of Belize

While it is common to think of coral reefs in isolation, we now know that much of the character, abundance, and diversity of a coral reef owes to its proximity to other marine and terrestrial habitats. For example, the importance of adjacency to mangrove forests and seagrass meadows is well established. However, coral reefs comprise only a minute fraction of the actual surface area of tropical continental shelves, and even after accounting for mangrove and seagrass, the bulk of the shelf remains *aqua-incognito*. This greater stretch of shelf waters is too deep, turbid, or seemingly uninteresting to have attracted much attention. Elsewhere in the world, attention to inter-reefal tropical shelf environments has reaped rich rewards, including, most spectacularly, a lot of previously “missing” reef and associated soft bottom habitat. Our recent studies in Belize indicate that this missing habitat on the Mesoamerican Barrier Reef system can harbor suites of endemic species along with large and spectacular threatened species such as sawfishes. They could also be part of the answer to the mystery of where the nursery habitats are for many commercial snapper and grouper species.

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