ROBOTIC EXPLORATION AND SAMPLING OF DEEP-WATER CORALS

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Abstract

In October, 2013, the MIT Sea Grant College, Autonomous Underwater Vehicles Lab used sonar and a small ROV to investigate deep-water, soft, branching coral habitat in the Bump 114 area of the Gulf of Maine. We identified candidate ROV dive sites with side-scan sonar and made video recordings of coral "gardens" during ROV dives. The small ROV proved to be a limited but effective sampling tool, resulting in the recovery of four branching corals and additional samples of the related benthic community.

Introduction

Deep-water corals are of special interest since they contain a record of ocean temperatures and can be an important tool in assessing climate change. The MIT Deep-water Corals Expedition of 2013 had several research objectives, including:

- Gather sonar data of an area known to have deep-water corals. Examine topographical features to find likely Gorgonian coral habitat and look for evidence of coral colonies on the sea floor.
- Use an ROV to provide a visual record of coral habitat and confirm the presence of coral colonies.
- Attempt to harvest coral from the sea floor using the ROV robotic arm.

As corals require hard substrate to form and as it is possible to distinguish between hard and soft substrates with sonar, it was hypothesized that sonar analysis could be used to locate coral colonies. This capability could be helpful in future, wide-area, autonomous surveys.

The ROV for this expedition was relatively small (37.5, 28.9, 22.3 cm) and light-weight (6.1 kg). The incremental cost of adding this ROV to an expedition was relatively small and the potential benefits significant. We sought to determine how well this type of ROV would perform in currents at the expected depths and if it could provide useful service even without dynamic positioning in its surface vessel. Acquiring actual coral samples would be useful to our research partners.

Methods

The expedition field work consisted of one sonar training day trip, two ROV training trips, and one five-day research cruise. Dive video and sonar data from the research cruise were processed to correlate coral presence to sea floor substrate type.

Sonar day trip: The purpose of the sonar day trip was to become familiar with our sonar equipment and procedures, and to gauge how well we could resolve a coral facsimile target. Training was conducted in August, 2013 in New Bedford harbor, with assistance of the Massachusetts Division of Marine Fisheries.

The sonar for the trial was a Klein 3000, 100 kHz/500 kHz, dual side-scan sonar system and laptop-hosted SonarPro 12.1 software. The sonar towfish was connected to its topside unit by a short tether. A Trimble ProXT GPS provided sonar position data. At this time in our project, the target species was a hard coral (*Desmophyllum dianthus*). The coral facsimile target consisted of a hard, branching coral approximately 20.3 cm by 27.9 cm mounted on a cement base, 15.2 cm square by 8.9 cm. The survey area was a silty area of New Bedford harbor approximately 6 m deep. We attached a line and float to the target, set it, and made numerous sonar transects.

ROV training trips: Two ROV training field trips provided hands-on experience with the VideoRay Pro4 ROV, fitted with standard lights, video, manipulator and a depth rating of 300 m. This ROV can generate 21 lbs. of sustained thrust, for a thrust weight ratio of 2:1. Dives were made in the vicinity of Graves Lighthouse, Boston Harbor, and the Charles River, providing good manipulator, tether handling, and videography practice.

Research cruise: As will be discussed in Results, the target species of our research cruise shifted to soft, branching corals. To this end, we evaluated photo sled data gathered by colleagues at NOAA and University of Connecticut from the Jordan Basin in the Gulf of Maine. These data provided positions and clear images of soft, branching corals and coral gardens at depths between 224 and 248 m. Bump 114 in the Gulf of Maine (Fig. 1) contained a number of good target locations and so became our research destination.

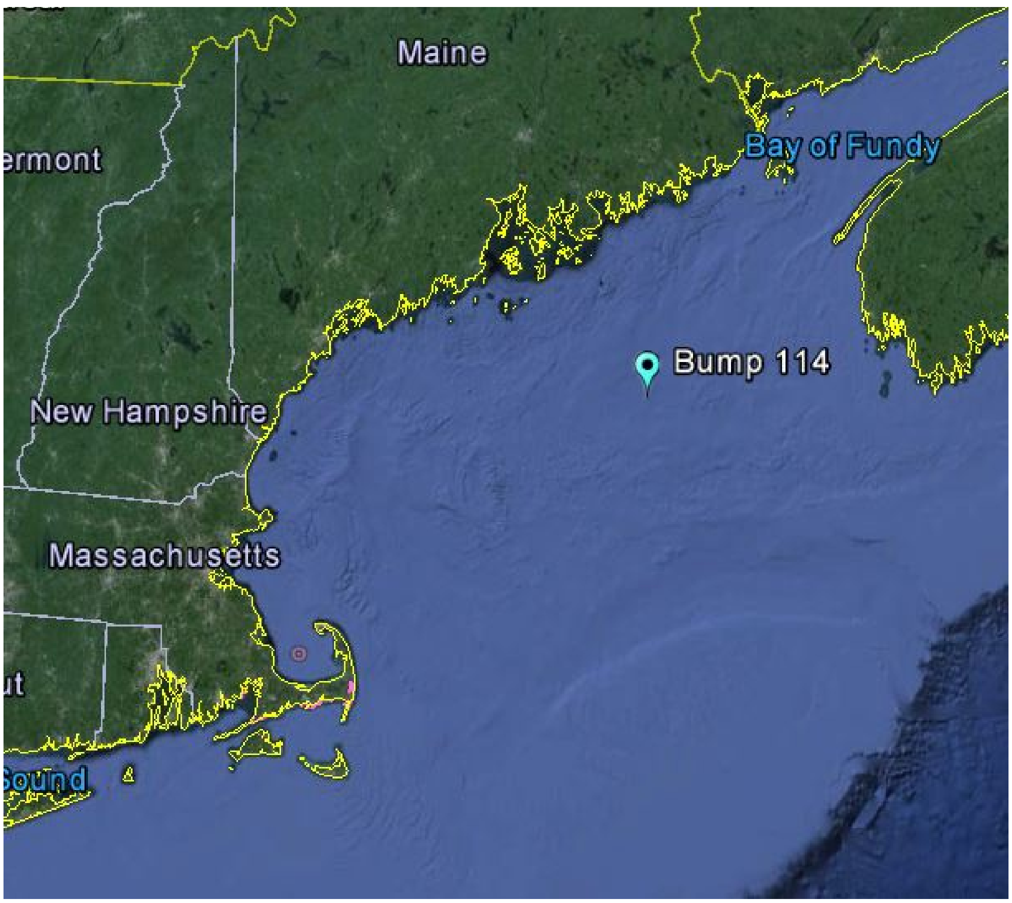

Fig. 1: Bump 114, Jordan Basin, Gulf of Maine

The 96' long foot fishing trawler *Langley Douglas* was our research platform for five days of fieldwork in October, 2013. This vessel has one inboard propeller and no dynamic positioning system. We navigated and documented our positions with a GlobalSat BU-353 GPS and PolarView NS software.

As in the preliminary trial, we used a Klein 3000, 100 kHz/500 kHz, dual side-scan sonar system with SonarPro 12.1 software to collect sonar data. The sonar towfish was connected topside by a 300 m armored cable, resulting in towfish depth of approximately 80 to 120 m. A Trimble ProXT GPS provided sonar position data. The sonar was deployed by powered winch through a snatch block (sheave) over the starboard quarter.

We performed sonar surveys of an area roughly 1500 m by 5200 m in the Northeast corner of Bump 114 at range 400 m. Sonar review resulted in numerous candidate dive sites. The ROV was deployed at or near these sites with the support vessel out-of-gear to reduce the likelihood of damaging the tether. The ROV was deployed over the starboard beam the first day of dives, and by snatch block on the starboard quarter the second day.

We used a 300 m, negatively-buoyant tether combined with terminal 50 m performance tether to connect the ROV to topside controls. The tether was collected on a VideoRay Tether Deployment System. A weight ("clump weight") of 5.4 to 7.3 kg was attached about 10 m from the end of the tether to provide negative buoyancy and provide some anchoring during dives. Additionally, we made a tab out of electrical tape on the tether above the clump weight that the ROV could grab at the beginning of dives. This helped keep the tether tangle-free on descent. Once at the bottom, the tab was released. Virtually all the tether was deployed on dives.

Vessel drift due to wind or current could drag the clump weight and, indirectly, the ROV. Even current alone could do this. Once bottom was reached, ROV operators had only a few minutes to explore before the clump weight began to move and drag on the ROV. Sometimes operators were able to maneuver quite well in spite of this, keeping pace with the moving clump weight, other times not as well. Several times, if clump weight effect became unmanageable, the tether was reeled in part way and unreeled to provide additional 'free' bottom time. Tether twisting and looping was a factor in multiple dives, requiring careful deck management.

We started recording video when the ROV reached bottom and continued until ROV ascent. Video data included on-screen time of dive, depth, heading, temperature, and dive number.

Hauling the ROV to the surface took between ten and fifteen minutes of demanding manual labor. The tether reel, though manual, was enormously helpful in avoiding snarls during recovery.

Once landed, branching corals were tagged and divided. Those destined for DNA analysis were preserved in 95% ethanol, changed twice in 6 to 12 hours. Those intended for aging analysis were frozen.

Correlation of sonar with ROV video: One research objective was to determine how well sonar data could be used to locate coral populations. Our initial analysis attempted to correlate coral absence or presence as indicated by dive site video with substrate type as characterized from sonar.

Our first step was to determine the overall boundary of our sonar survey. This was accomplished by review of sonar data files in Chesapeake Technology Inc. SonarWiz 5. Dive video gave us the beginning and end time of each dive. Combining this with GPS data gave us the track of each dive, which we overlaid onto sonar survey bounds (Fig. 2).

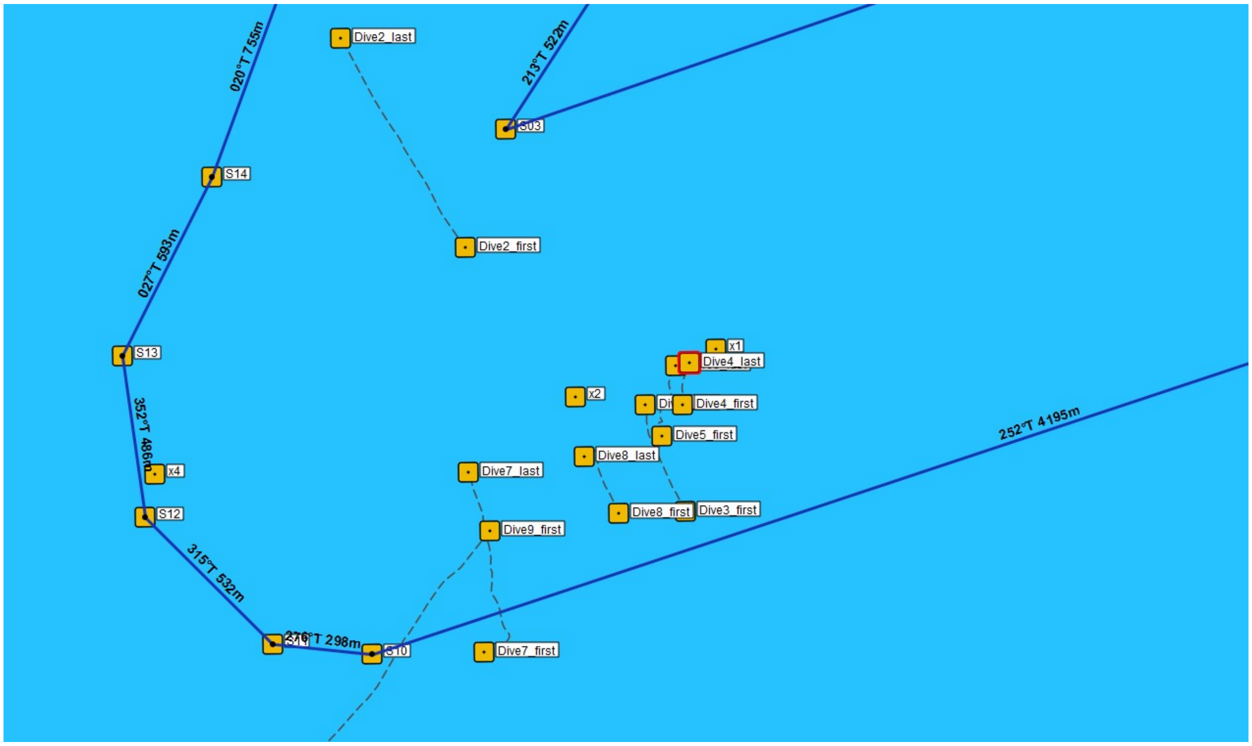

Fig. 2: Detail of sonar survey area (inside heavy blue line) and overlaid dive tracks

We then assessed video of each track within the survey area to determine if branching corals were “present” or “absent” periodically along each track. To correlate video results to sonar, however, we needed the actual ROV, not GPS, position and a way to overlay these onto sonar images.

Accurately determining ROV position was extremely problematic, as we had significant tether deployed during dives and did not have an ROV positioning system on our simple system. We did have the deck geometry, that is, the relative location of the GPS and deployment points. Based on this, we determined with some confidence the position that the tether entered the water. We also derived GPS heading during each dive.

We generated boundaries for ROV location based on assumptions of where the clump weight was relative to the vessel. The “nearest” the weight could be was directly under the deployment point. For a “furthest” point, we calculated the weight location based on maximum tether deployed in a direction 180° opposite the GPS heading, at the depth indicated on the video for that time. Given these assumptions, the ROV would be within 10 m of a point between “nearest” and “furthest” clump weight positions, a difference on the order of 250 m. Sonar and dive position data were integrated in SonarWiz 5, finally showing estimated ROV positions overlaid onto sonar images.

For this part of the analysis, the color palette (mapping between sonar intensity and screen color) was “ImagenexNormHi”, a standard selection in SonarWiz. In this palette, highest to lowest reflected signal strength maps to gradations of white, yellow, orange, green, blue, and black, in that order.

At each overlaid ROV position, an assessment of substrate type was made as follows:

- High relief: Substrate within 10 m of position appeared white, yellow, or orange in sonar
- Low relief: Substrate appeared green, blue, or darker

- Datum discarded: Off-scan or between side-scan beams

Coral attachment-type analysis of dive video: Attachment-type analysis consisted of review of all dive video to identify branching corals and categorize coral attachment-to-substrate type. We reviewed video frame-by-frame to determine if corals were a) attached to apparent rocks or boulders (Fig. 3) b) attached directly to the sea floor substrate (Fig. 4) or c) if attachment was indeterminate.

The corals that constituted “corals present” were branching, soft corals (e.g. *Primnoa*, *Paramuricea*) that resembled those identified in NOAA photo sled images. They were typically yellow, but could also appear orange, purple, or white in frame.

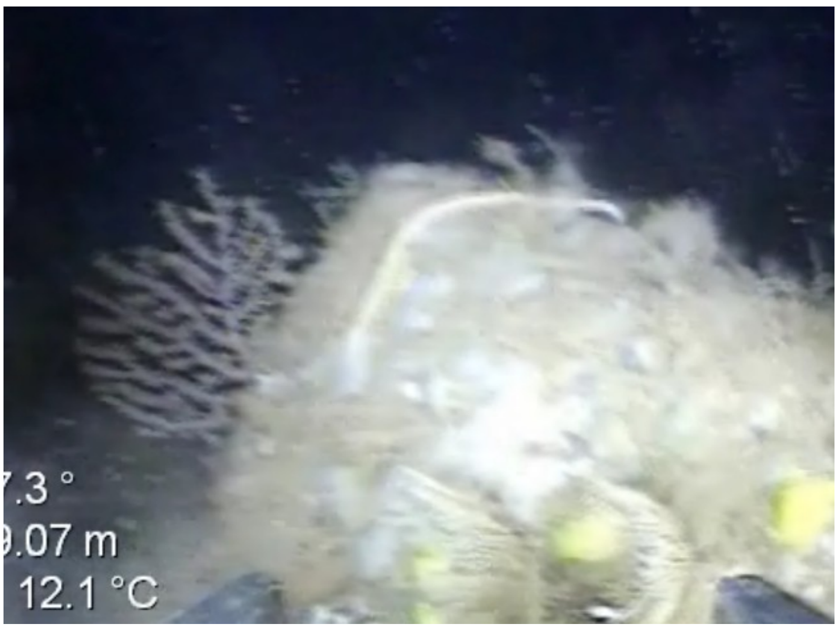

Fig. 3: “Rocky” attachment

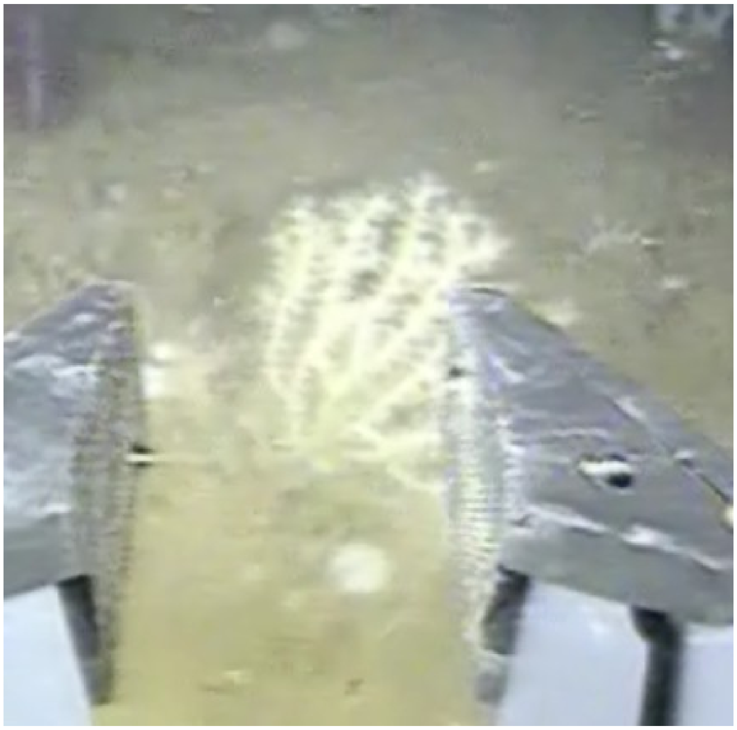
Fig. 4: “Not rocky” attachment

Results and Discussion

Sonar day trip: At a range of 20 m, we were able to identify the facsimile target base quite easily on high frequency surveys, but could not reliably distinguish the coral itself (Fig 5.) Since *D. dianthus* grows on canyon ledges at depths typically exceeding 500 m and our towfish depth limitation was approximately 100 m, detecting this kind of coral directly with sonar seemed extremely difficult.

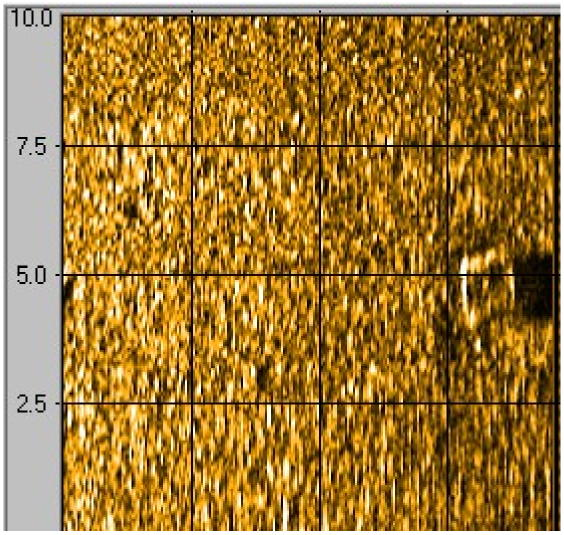

Fig. 5: Hard-coral facsimile in sonar

NOAA/University of Connecticut photo sled data of the Jordan Basin gave clear images, depths, and locations of soft, branching corals. Given our difficulties in discerning the hard coral facsimile and depth limitations, we reoriented our project towards soft corals in these known locations, which we hoped would yield better opportunities to match sonar with confirmed coral populations, and direct exploration with the ROV. For our research cruise, we selected the area of the Jordan Basin identified as Bump 114.

Research cruise: Review of high frequency sonar scans did not yield useful detail. The low frequency sonar (Fig. 6), however, revealed ridges and occasional, highly patterned, contrasting regions interpreted as 'rocky' (Fig. 6, 7, and 8). Several areas like these became candidate ROV dive sites. Slanting artifacts in the images are due to 2 to 3 m waves during the survey.

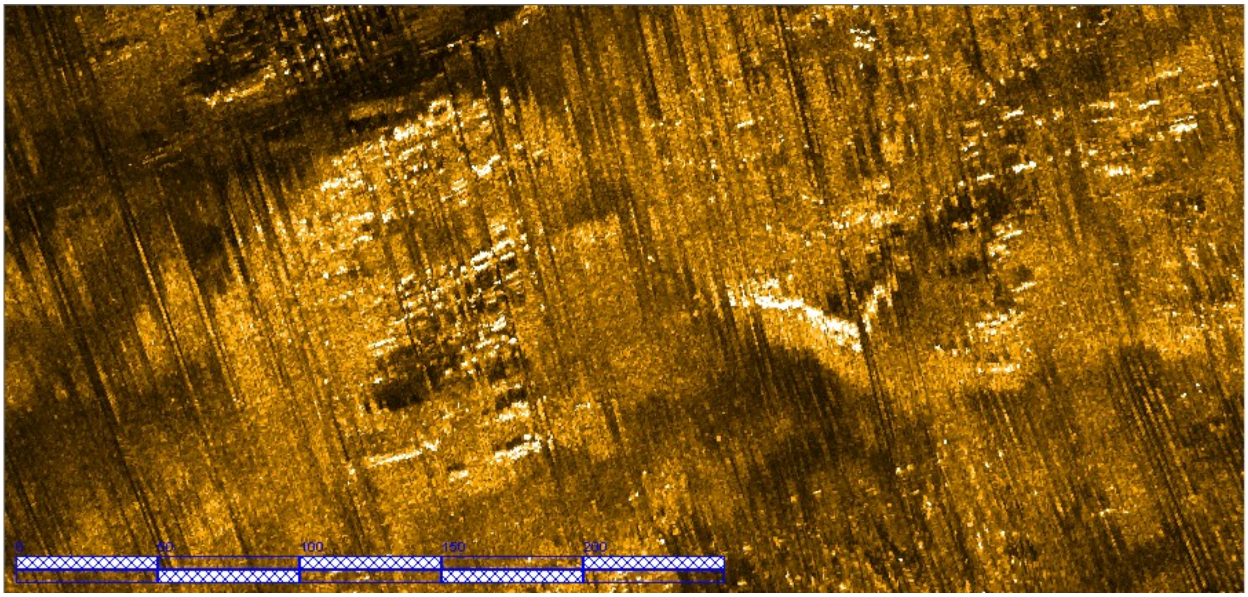

Fig. 6: Bump 114 region in 400 m sonar. Color palette: “Klein”. Scale segment: 50 m.

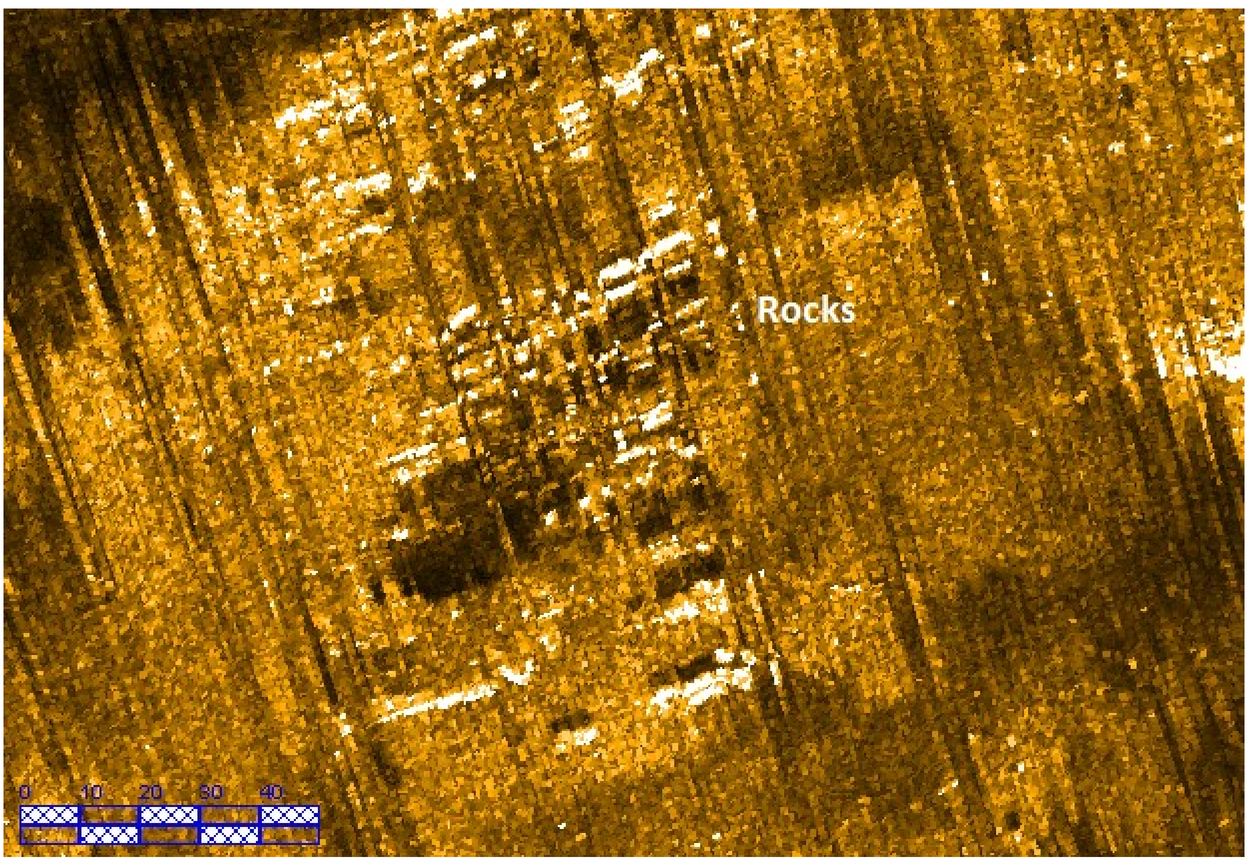

Fig. 7: Bump 114 400 m sonar detail of Fig 6. Scale segment: 10 m.

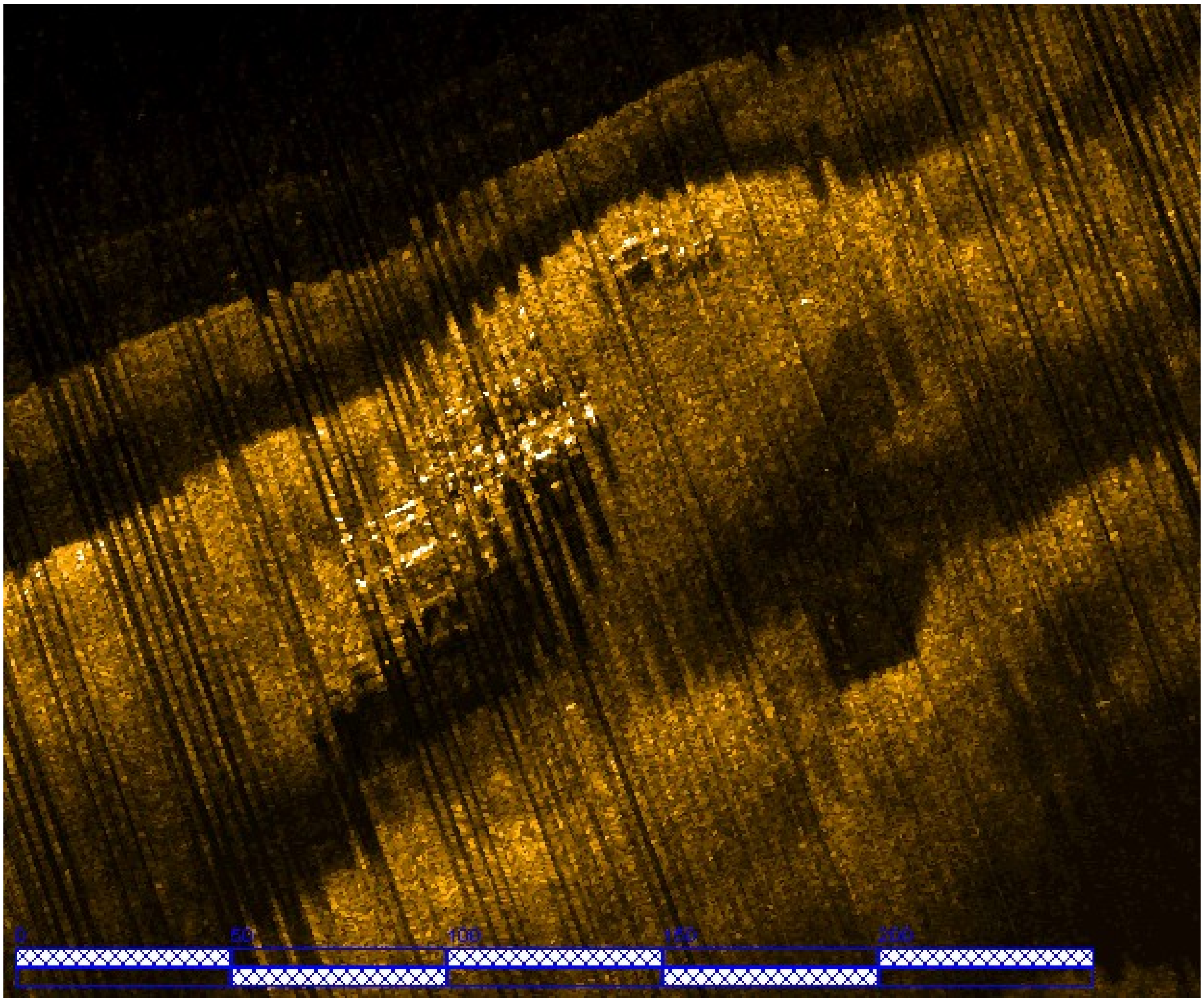

Fig. 8: Bump 114 400 m sonar - potential dive site. Scale segment: 50 m.

There were a total of nine, distinct ROV dives, eight of them in or partly in the 400 m sonar survey area. Fig. 9 is an example screen-shot from the dive video. Branching corals were seen on at least five of the dives. We were able to bring four distinct samples to the surface (Fig. 10), plus a “Sea Pen” (*Pennatulacea*) and one probable Hydrozoan.

Fig. 9: Branching coral encounter during ROV dive

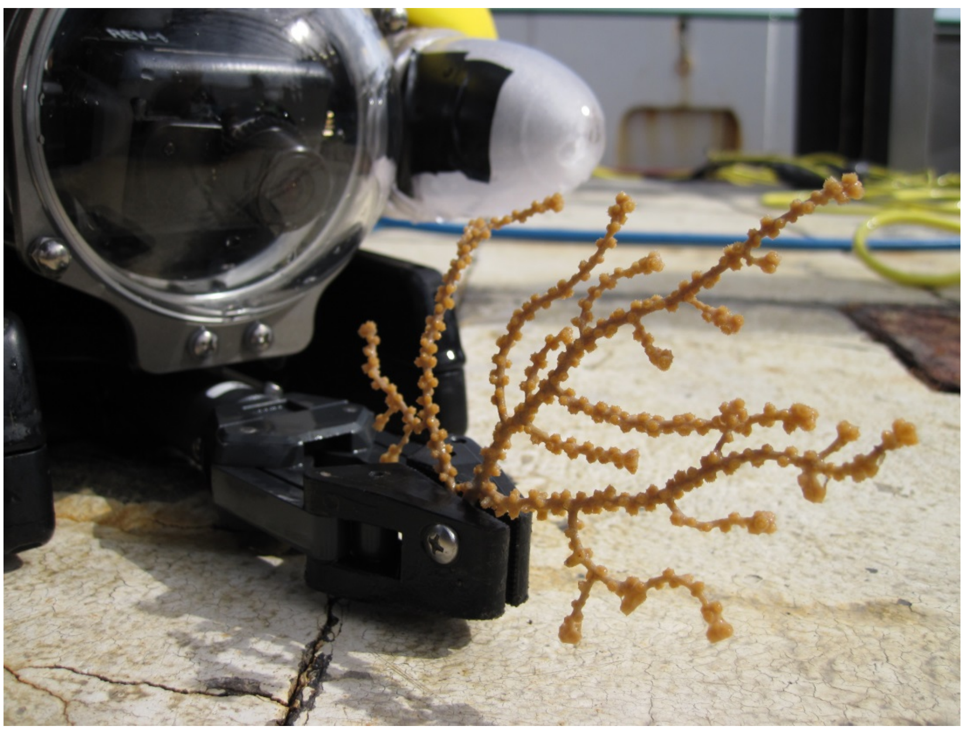
Fig. 10: Recovered coral on deck

The performance of the ROV in recovering samples was surprisingly good. Despite lack of dynamic positioning of the support vessel, complex manipulators, or especially powerful thrusters, we were able to bring back a number of branching corals. As the cost to lease the system was only about $2,000, this was an excellent result for small incremental expense.

DNA analysis: Four branching corals were sent to the Department of Biology, University of Louisiana at Lafayette for DNA analysis to assess, among other things, clade membership. Mitochondrial mtMutS analysis revealed the samples to belong to the same clade as colonies collected from Bump 114 in 2003.

Correlation of video to sonar: Video analysis yielded 145 total seafloor positions ('samples'), with coral present in 39 of them. For each of these positions, clump weight positions were estimated, and overlaid on sonar in SonarWiz (detail in Fig. 11). Analysis based on the estimated clump weight position when tether was fully extended from the vessel, as was rather typical during dives, yielded the results shown in Tab. 1.

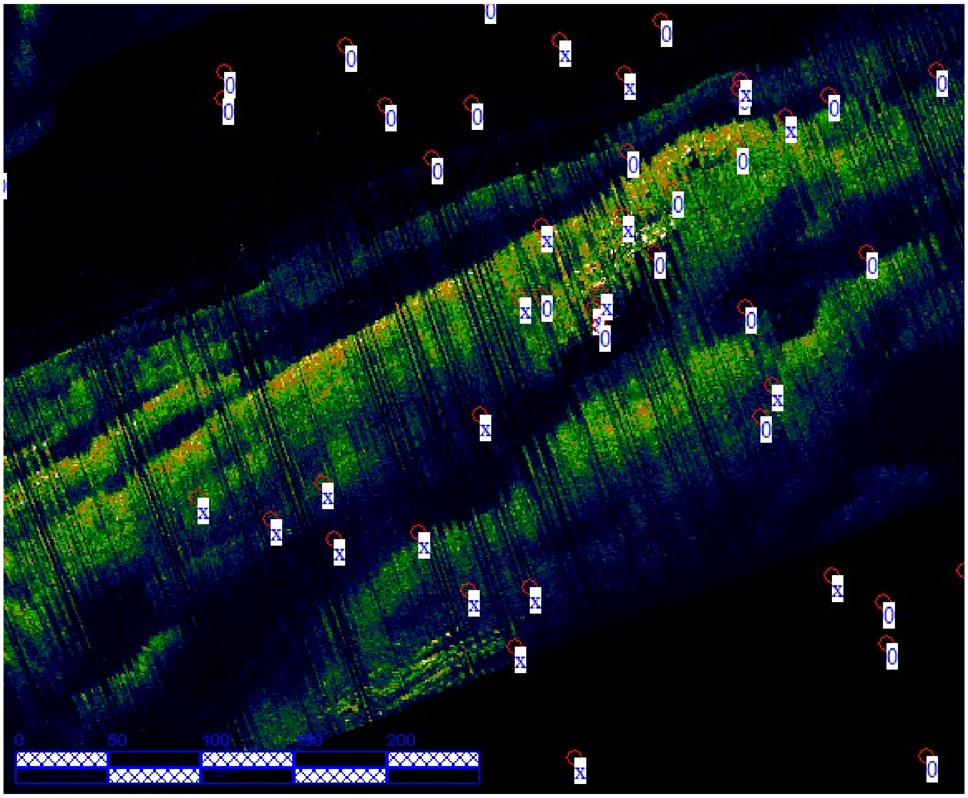

Fig. 11: Dive sites on sonar (detail): x = corals present, o = corals absent. Color palette: "ImagenexNormHi". Scale segment: 50 m.

Corals/ Relief	Absent	Present
Low	44	11
High	12	15

Tab. 1 Coral presence/absence vs. Relief from video/sonar analysis

Although we found a modest correlation between coral presence and relief, fundamental data uncertainties call this method and results into question. These include:

- ROV position uncertainty: This is the largest factor. With tether fully extended and at recorded dive depths, the ROV could be on the order of 250 m from the vessel GPS position. This is similar to the width of an entire side of the sonar scan. An ROV positioning system would dramatically reduce this uncertainty.
- Sonar towfish layback uncertainty: Towfish layback (offset from vessel) is a calculation assuming, among other things, that the towfish is directly in back of the vessel attachment point. Layback can be calibrated in SonarWiz, for example, by comparing

charted features in multiple, overlapping scans and adjusting “layback percentage” for each sonar file. In any case, towfish depth inclusion in the data set and deck geography measurements are critical.

- Low site coverage: ROV dives to an area are not by any means exhaustive. A visit to a “high relief” area may well miss corals that are present in numbers.
- Low total samples: After eliminating video where substrate could not be seen, poor sonar quality, and ROV positions that are off sonar surveys, there were only 82 data points remaining.

Attachment-type analysis: Our video analysis showed that branching corals typically attached to rocky substrates (Tab. 2). This suggests that regions that appear rocky on sonar could be good candidates for discovery of such corals and so relevant to surveys by autonomous vessels.

Rocky/boulder attachment:	102
Not rocky:	31
Indeterminate:	24
Total samples:	126

Tab. 2: Rocky/not-rocky attachment

However, our NOAA colleagues also indicate that typography alone does not necessarily indicate where corals will be found. They did not find branching corals in rocky areas similar to Bump 114 off of Monhegan Island and the Schoodic Ridges in the Gulf of Maine.

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