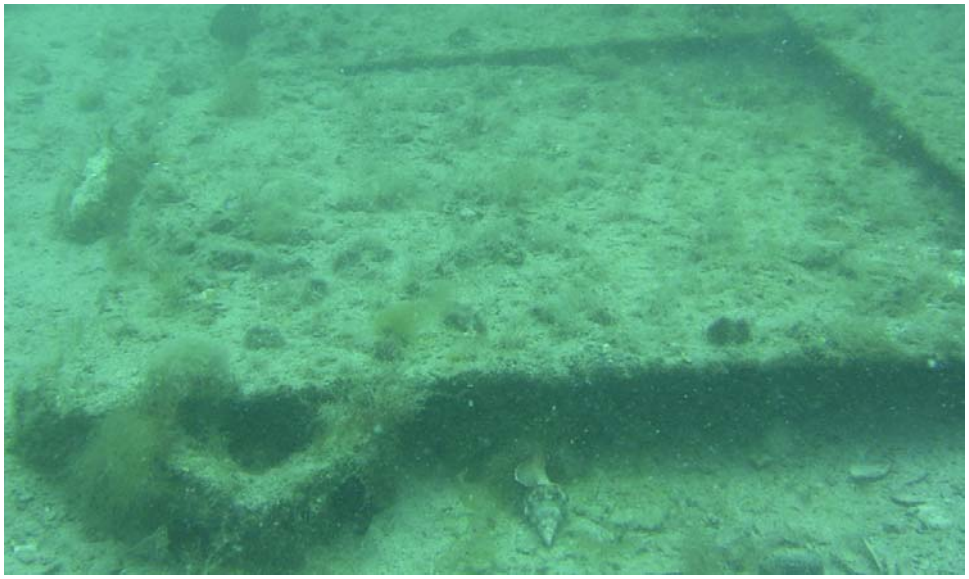
NOAA Technical Memorandum NMFS-SEFSC-530

THE USE OF SIDESCAN SONARS, MAGNETOMETER, AND VIDEO CAMERAS IN DETECTING ILLEGAL ARTIFICIAL REEFS IN WATERS OF THE FLORIDA KEYS

BY
REX C. HERRON



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Abstract

Four instruments were assessed in 2004 to determine their suitability for detecting and mapping illegally placed artificial reefs in and near the Florida Keys National Marine Sanctuary (FKNMS). The instruments were: 1) Datasonics SIS-1500 Chirp Side Scan Sonar System, 2) Geometrics G-882 Marine Magnetometer, 3) Imagenex's Sportscan Side Scan Sonar, and two locally manufactured video cameras attached to a towed body. The 42 foot RV HST-1 was deployed from Pascagoula to Key West as a platform to test the Equipment. The project was conducted from mid-June through the end of June in 2004. All instruments were towed simultaneously along five transects in a study area encompassing approximately 602 km². All transects were north of the keys between Key West and Big Pine Key. Two transects generally followed the 9.1 m (30 ft) and 12.2 m (40 ft) contours. Three transects ran from shallow water and continued perpendicular to bottom contours to a maximum depth of 14 m (46 ft). A large number of manmade structures were detected by all instruments along 4 of the 5 transects. Divers checked approximately 15 sites to verify targets. Based on the number of suspected illegal reefs detected with sidescan sonars, the estimated number of illegal reefs within the study area was 1463 (Illegal structures may number in the thousands when the study area is expanded).

Given the complexity and expense of the chirper and magnetometer (along with the large number of returns from the magnetometer), they are not recommended for further use for detecting and mapping illegal artificial reefs. The smaller and less expensive Sportscan sonar, which performed nearly as well as the chirper, and the video cameras are recommended for further illegal reef studies (Scuba divers will also be required to verify some of the targets). These instruments have proven to be excellent tools for detecting illegal reefs in the addition to other underwater features such as coral heads.

Introduction

The Caribbean spiny lobster (*Panulirus argus*), also commonly referred to as the Florida spiny lobster, is highly exploited by fishermen in its shallow shelf water habitat off the southern U.S., Bermuda, and the Caribbean (Harper and Muller 2001). Spiny lobster larvae spend an estimated 6-9 months in the planktonic stage (Herrnkind et al. 1988). Swimming postlarvae move inshore and settle in seagrasses, thick macroalgae, and other bottom habitats where they transform into bottom-dwelling juveniles. At about 15-20 mm carapace length, the juveniles take up residence in crevices, dens, and other sheltered places. They begin to roam several hundred meters at night at about 1-1.5 years of age, but still seek shelter during daylight hours. Adding artificial shelters enhances juvenile recruitment at these sites when postlarvae are plentiful. As adults, lobsters begin seasonal migrations from shallow to deeper waters (Herrnkind 1985) possibly to escape the shallower waters that become disturbed by weather conditions (e.g., cooler temperatures, turbulence, etc.). These migrations are regional in nature and do not appear to be related to reproduction.

The spiny lobster is exploited primarily from Palm Beach, Florida to the Dry Tortugas and into the Gulf of Mexico. It is the second ranked economically most important commercial fishery in Florida after pink shrimp (Harper and Muller 2001). Commercial landings in 1999 were 4.9 million pounds (Muller et al. 1999), and the number of recreational lobsters harvested was 1,190,000 individuals. Their ex-vessel value was over $22 million U.S. dollars in 1998.

Materials such as concrete blocks have often been used to create artificial habitat for spiny lobster. Many types of materials, such as concrete blocks, car hoods, etc., have been placed in shallow marine waters illegally by fishermen to attract lobsters where they are easy to capture. With global positioning satellite systems (GPS), these materials can be easily relocated by fishermen. The Florida Keys National Marine Sanctuary (FKNMS) has a program to find and remove these illegal habitats (Weekly Situation Report, FKNMS, July 31, 2001). Between July 16 and July 31, 2001, about 150 structures were removed at 69 waypoints within the Sanctuary. In Oct. 2000, two men were fined $2,000 for dumping materials meant to attract lobsters (U.S. Department of Commerce Press Release, Oct. 2000), and in July of 2001, two men were assessed a combined civil penalty of $75,000 (U.S. Department of Commerce Press Release, July 2001) for creating these illegal habitats (commonly referred to as ‘lobster condos’).

Possibly thousands of these artificial reefs have been installed on the ocean floor in the Florida Keys to attract and exploit spiny lobster. Most of these structures are believed to be in the waters of the Gulf of Mexico off the Lower Keys. Dumping trash, and other materials, to create ‘lobster condos’ violates FKNMS regulations that prohibit depositing materials into the Sanctuary without a permit. Dumping materials in excess of 5000 pounds or 100 cubic feet or any materials for commercial purposes is illegal under Florida law. It is also illegal to transport materials for artificial reef-construction without a permit. These structures may have impacted the natural spawning migration of the Florida spiny lobster, and there is very limited scientific information on the extent and impact of these artificial structures on migration patterns, reproductive behavior, catch-rates of lobsters. These ‘condos’ cause lobsters to congregate in large numbers in known

locations where they are subject to intense recreational and commercial fishing pressures. It should also be noted that many of these 'lobster condos' are made with industrial and other materials (e.g., refrigerators, oil barrels, car hoods, dumpsters, etc.) that contaminate and impact the coral reef environment and cause habitat (seagrass, coral) damage, particularly during storms. Additionally, the allocation of lobster catch amongst fishers is being impacted (i.e. those using illegal 'lobster condos' are much more efficient). Dumping these structures may be having an impact on the migration patterns, as well as the population size, of Florida Spiny Lobsters. The first step in addressing the 'lobster condo' problem is the development of a method for accurately detecting and mapping these structures so that accurate density estimates of these illegal reefs can be obtained.

The objective of this project was to evaluate the effectiveness of a towed array of optical, acoustic, and magnetic sensors for detecting and mapping illegal artificial reefs inside and near the FKNMS. Results from this project will assist resource managers and law enforcement personnel in the Florida Keys to remove existing illegal structures, and will support follow-up studies on 1) spiny lobster population impact, and 2) the socio-economic impact on the spiny lobster fishery. Results will also provide support for compliance and educational and outreach campaigns.

Study Area

The study area encompassed a rectangular area of about 602 km² (176 nmi²) in relatively shallow water north of the Florida Keys (Figure 1). This area was selected based on information provided by the Florida Fish and Wildlife Conservation Commission and contained known and suspected locations of illegal artificial reefs. The southwest corner of the study area began at Calda Bank (24° 36.82′ N, 81° 50.41′ W) and extended northeasterly for approximately 42.1 km (22.8 nmi) to the southeast corner (24° 48.49′ N, 81° 50.41′ W) at Content Keys. The east and west sides of the area extended toward the northwest for approximately 14.3 km (7.7 nmi)(northwest corner at 24° 43.36′ N, 81° 54.76′ W and northeast corner at 24° 55.21′ N, 81° 33.27′ W) into water approximately 15.3 km deep (about 50 ft). Most of the study area lies within the boundaries of the Florida Keys National Marine Sanctuary (FKNMS). The study area also overlaps the Great White Heron National Wildlife Refuge.

Five transects were in the study area to evaluate the instruments. Two of the transects (transects 2 and 5) were selected because they were generally parallel to bottom contours and because of known or suspected illegal reefs in the area (Figure 2). Three transects (transects 1, 3, and 4) were selected because little was known about the presence of illegal reefs in these areas. These three transects were oriented perpendicular to bottom contours. This allowed the instruments to be tested in shallow to deeper water to assess their performance at various depths. Additionally, a site was selected and materials were placed on the bottom to test instruments. The test materials were later removed by divers. Another site where a known illegal artificial reef existed was also examined to evaluate the instruments.

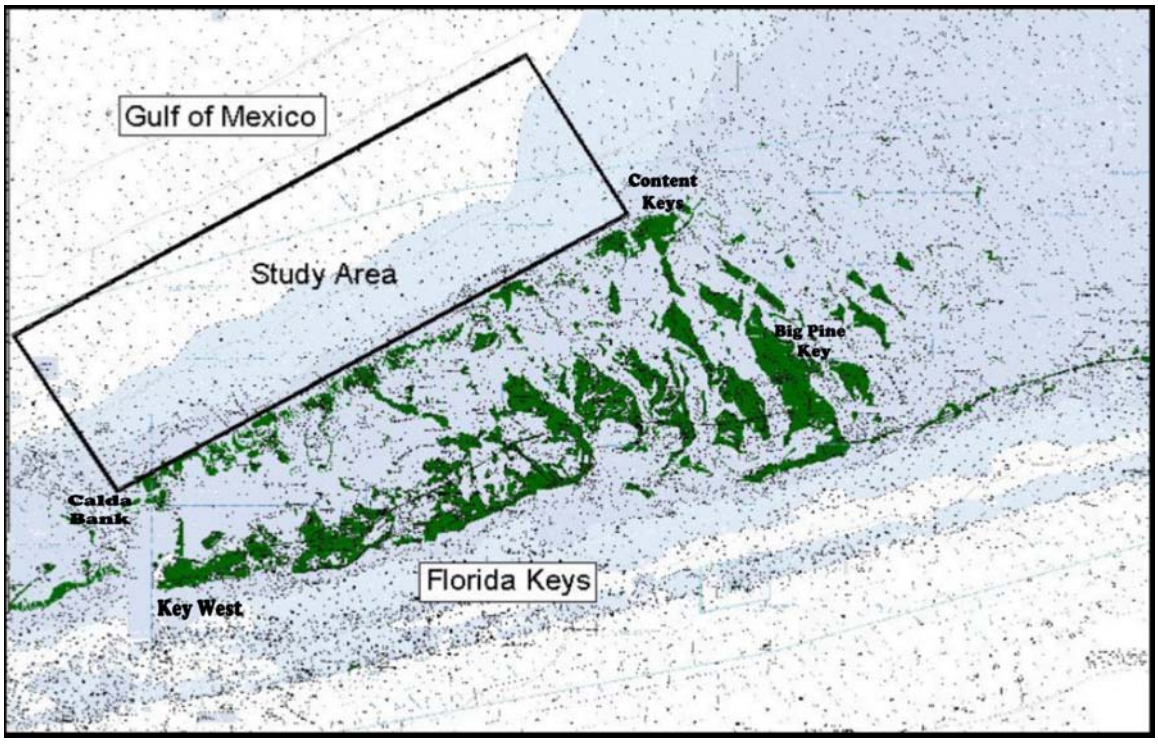

Figure 1. Location of study area in waters north of the Florida Keys.

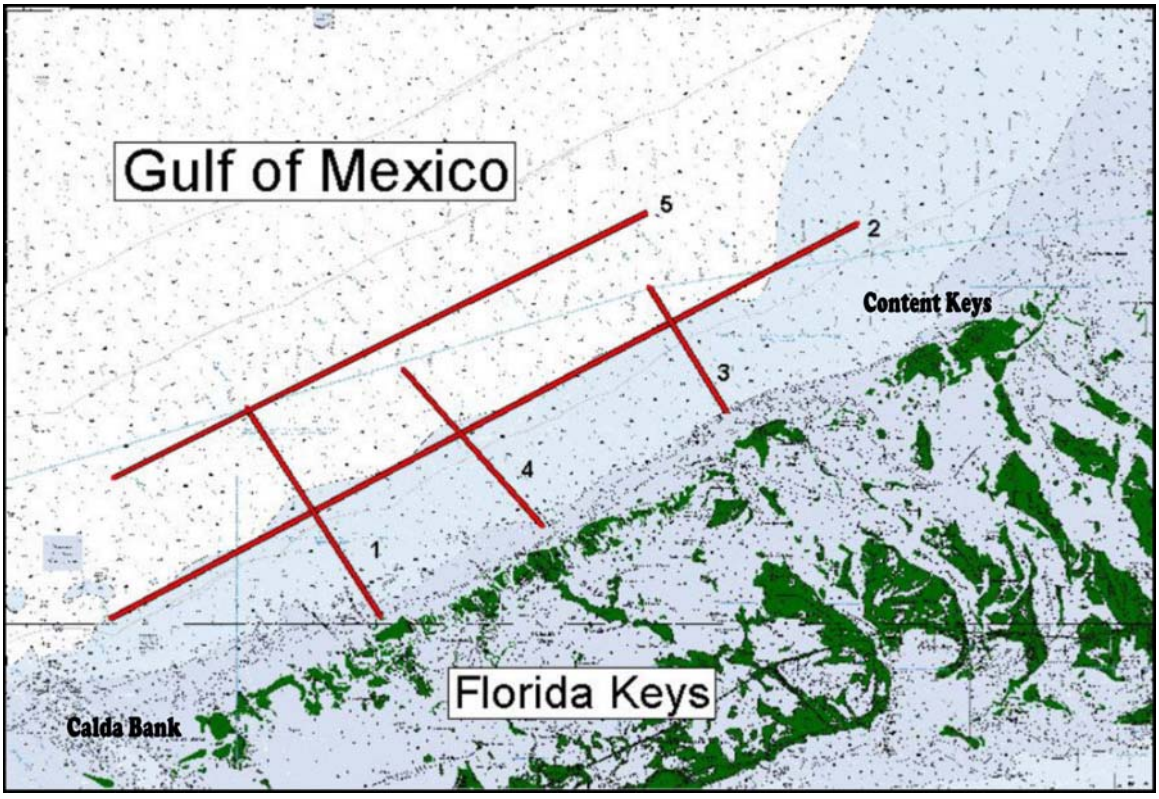

Figure 2. Locations of transects 1 through 5.

Methods and Materials

Four instruments were tested during this project to assess their suitability for detecting illegally placed artificial reefs that attract lobsters for easy harvesting. Datasonics' SIS-1500 chirp sidescan sonar system was tested (the use of trade names does not imply endorsement by the National Marine Fisheries Service). This chirp digital system operates in the 200 kHz band and provides high resolution imagery. Signals were processed and displayed by a Windows NT workstation provided with the instrument. This instrument was rented from Ashtead Technology Rentals at a cost of $300 per day, assessed while the instrument was in use and for the time the instrument was being shipped to and from the site, and shipping costs (estimated cost to purchase this or a similar system is approximately $65,000). The SIS-1500 was deployed directly behind the vessel and slightly off center to starboard. The instrument was set to image 50 m per side for an effective swath width of 100 m.

The second instrument evaluated during the study was Geometrics' G-882 Marine Magnetometer. The G-882 is a cesium vapor high performance system that can output data to any IBM personal computer. A workstation was provided with the instrument to process and display the signals. This system was rented from Ashtead Technology Rentals at a cost of $200 per day plus in transit rental time and shipping costs. The magnetometer was deployed slightly off center of the vessel's trackline and opposite the SIS-1500 sonar.

A third instrument assessed was Imagenex Technology Corporation's Model 881 Sportscan single or dual frequency digital sidescan sonar (maximum depth rating of 30 m or about 100 ft). This system was purchased for approximately $7000 along with the software necessary to operate it. The signal is processed with proprietary Windows software. The system allows an operating frequency setting of high (330/800 kHz) or low (330 kHz). When high frequency is selected, the overall range is limited to about 60 m (200 ft) per side. The instrument was connected to an onboard laptop computer for signal processing and displaying. The Sportscan sonar was deployed off the portside of the vessel near midship. It was set to image 25 m per side maximum so the swath width was 50 m. Although the sonar did not image 90 degrees downward, the video cameras were used to detect illegal reefs directly beneath the boat so the effective swath width was considered to be 50 m.

Two Bowtech·Ros Model BP-L3C-HR video cameras were attached to a tow-body and towed near the bottom for use in verifying targets. These cameras were designed for water depths as deep as 4000 m and cost approximately $1500 each. The video was displayed on shipboard monitors and recorded on video cassettes. The tow-body with attached cameras was deployed off the starboard side of the vessel near midship.

The 12.8 m (42 ft) RV HST-1 was deployed from Pascagoula, Mississippi to Key West, Florida as a platform to test the equipment. All instruments were connected to the shipboard GPS system. GPS coordinates were referenced to the location of the ship and not the location of the towed instruments.

A site was chosen to test and calibrate the instruments with known materials. The site was selected at the western edge of the study area near the outlet of Northwest Channel in 9.1 m (30 ft) of water with little coral and sea grasses on the bottom (24° 39.998′ N, 81° 52.523′ W). Materials were placed on the bottom by divers for instrument testing and were removed at the conclusion of the field study. A 1.2 m (4 ft) by 1.5 m (5 ft) sheet of concrete "Wonder Board" was placed on four 23 cm (9 in) concrete blocks, one at each corner, and four more concrete blocks were placed on top (one per corner) to hold the board in place (Figure 3). In addition, two metal pipes about 2.4 m by 10.2 cm (8 ft by 4 in) were placed on the bottom about 0.6 m (2 ft) apart, and parallel to each other, and a 0.6 m (2 ft) by 0.9 m (3 ft) steel plate 9.5 mm (0.375 in) thick was placed on top of the metal pipes and perpendicular to them. The three instruments, SIS-1500 sonar, Sportscan sonar, and magnetometer were towed within a few meters of the test material from different directions to assess their detection capabilities.

Several locations were provided by the Florida Fish and Wildlife Conservation Commission where illegal reefs had been found and destroyed, but the rubble had not been removed. Two of these sites, located at approximately 24° 44.208 N, 81° 46.877′ W, were subsequently examined with the test instruments.

Transect 1 began in shallow water approximately 3 m deep (about 10 ft) just north of the Lower Harbor Keys (24° 40.205′ N, 81° 44.630′ W) and continued perpendicular to bottom contours for a distance of 12 km (6.483 nmi) in a northeasterly direction and ending in approximately 14 m (46 ft) of water (24° 46.026′ N, 81° 48.350′ W). Transect 1 was imaged primarily by the SIS-1500, so the total area imaged was 1.2 km² (Table 1).

Transect 2 roughly followed the 9.1 m (30 ft) bottom contour (approximately 8.2 to 10 m depths (27-33 ft)) beginning at a point roughly north northwest of Key West (24° 40.144′ N, 81° 52.127′ W) and ending roughly north northwest of Content Keys (24° 51.117′ N, 81° 31.427′ W). The 9.1 m contour was not followed exactly. Instead the vessel followed a straight line course from the starting point to the end of the transect. Total distance of transect 2 was approximately 40.7 km (22 nmi). Transect 2 was imaged primarily with the SIS-1500 so that the total area imaged was about 4.07 km². Vessel speed varied from about 1.6 knots to 3.5 knots. As many as three sea anchors were deployed behind the vessel to try to maintain vessel speed at under 2 knots.

Transect 3 began near Sawyer Key (24° 45.914′ N, 81° 35.050′ W) in about 6 m (20 ft) of water and continued northwesterly, perpendicular to bottom contours, for about 7.41 km (4 nmi) and ended at a depth of about 10.7 m (35 ft) (24° 49.350′ N, 81° 37.199′ W). Vessel speed was about 3.5 knots. A tail wind reduced the effectiveness of the sea anchors to slow the vessel to an optimal speed for sidescan sonar imaging. The Datasonics SIS-1500 stopped functioning so the transect was completed with the Sportscan sonar, magnetometer, and video cameras. The total area imaged was about 0.37 km².

Transect 4 began in water approximately 12.2 m (40 ft) deep (24° 47.083′ N, 81° 44.004′ W) north of Mud Keys and continued southeasterly for approximately 10.73 km (5.79 nmi) ending in about 4.6 m (15 ft) of water in the Marvin Keys Channel (24° 42.701′ N, 81° 40.144′ W). Only the Sportscan sonar, magnetometer, and video cameras were used on this transect. The total area imaged was about 0.54 km².

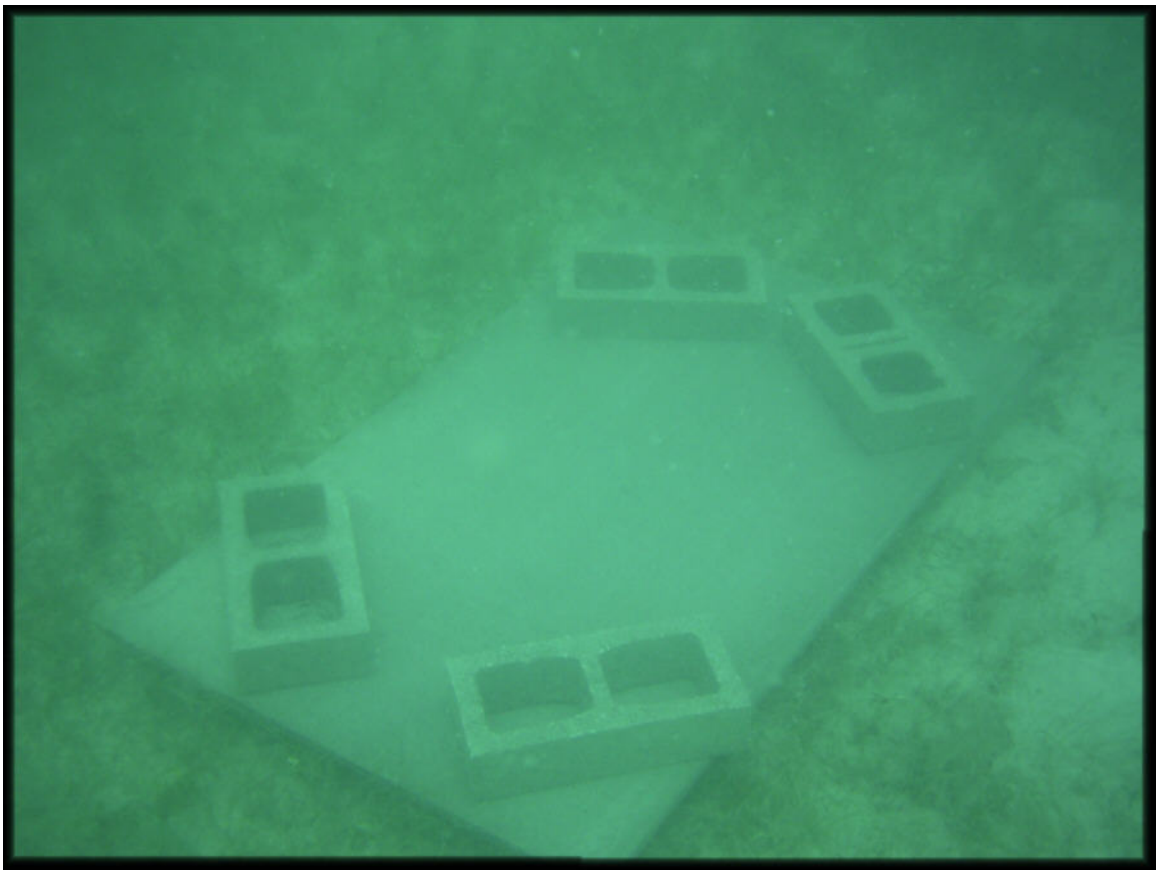

Figure 3. Image of temporary experimental reef consisting of a sheet of cement board supported by concrete blocks with additional concrete blocks on top to anchor it in place.

Table 1. Dimensions of transects and number of sidescan sonar targets detected during each transect.

Transect	Length(km)	Width (m)	Area (km²)	Targets	Targets/km²
1	12.00	100	1.20	2	1.7
2	40.70	100	4.07	13	3.2
3	7.41	50	0.37	0	0.0
4	10.73	50	0.54	3	5.6
5	27.80	50	1.39	3	2.2

Transect 5 began in 12.2 m (40 ft) of water approximately 15.3 km (8.3 nmi) north of Barracuda Keys (24° 51.412′ N, 81° 37.265′ W). The transect roughly followed the 12.2 m (40 ft) bottom contour (actual depth varied from about 11.3 m (37 ft) to 14.6 m (48 ft)) in a southeasterly direction for about 27.8 km (15 nmi) and ended at a point approximately 19.4 km (10.5 nmi) north of Mule Key at 24° 44.059′ N, 81° 52.020′ W. The Model 881 Sportscan sidescan sonar and video cameras were the only instruments tested along transect 5 because the Datasonics chirp sidescan sonar system was inoperable and the magnetometer detected so many false and real returns that its usefulness was limited. The total area imaged was about 1.39 km².

Results

The instruments did not perform as well as expected at the test site. The Sportscan sonar imaged the concrete blocks as very small targets, but the metal plate did not image well (Figure 4). The metal pipes and associated metal plate were not detected at all. The SIS-1500 sonar did not image the test materials. The magnetometer gave a signal at the test site, but it continued returning signals away from the test site. Initial results from the test site suggested that metal plates might be difficult to image using sidescan sonar, but later results proved this assumption to be false. The sites where illegal artificial reefs had been located by the Florida Fish and Wildlife Conservation Commission were subsequently imaged by both sonars and video cameras, with excellent results from the Datasonics SIS-1500, Sportscan sonar (Figure 5), and the video cameras (Figure 6).

Two clusters of illegal artificial reefs were imaged along transect 1, but the sites were not verified by divers or in the video images (Table 2, Figure 7). The Sportscan sidescan sonar functioned well, but was towed too far above bottom to image well. The magnetometer functioned well, but the numerous returns made interpretation difficult.

Transect 2 was a target rich environment. A total of 13 clusters of suspected illegal artificial reefs were imaged by the Datasonics SIS-1500 chirp sidescan sonar system set at 15 pulses per second (Figure 8). The Imagenex Model 881 Sportscan was towed too near the surface to image well because of the limitation of the 30 m tow cable, vessel speed, and to avoid interference with the SIS-1500 instrument. A 60 m cable was ordered to replace the 30 m cable so the Sportscan could be towed at 1-2 m above bottom. Site 12 was verified with video cameras as a corrugated metal sheet, and divers further verified the target with a digital camera (Figure 9). A second target was verified by divers in the water who took digital images of the illegal reef (Figure 10). The reef consisted of two adjacent rows of iron or steel plates with 4 plates per row. The plates were approximately 1.2 m (4 ft) per side, 6.35 mm (0.25 in) thick, and placed about 15 cm (6 in) above bottom on concrete blocks. The reef was in 9.1 m (30 ft) of water. Another target was subsequently verified by divers as a flat metal sheet (Figure 11)

No targets were identified by the sonar for verification along transect 3. The magnetometer continued to return too many signals to be useful. The vessel speed may

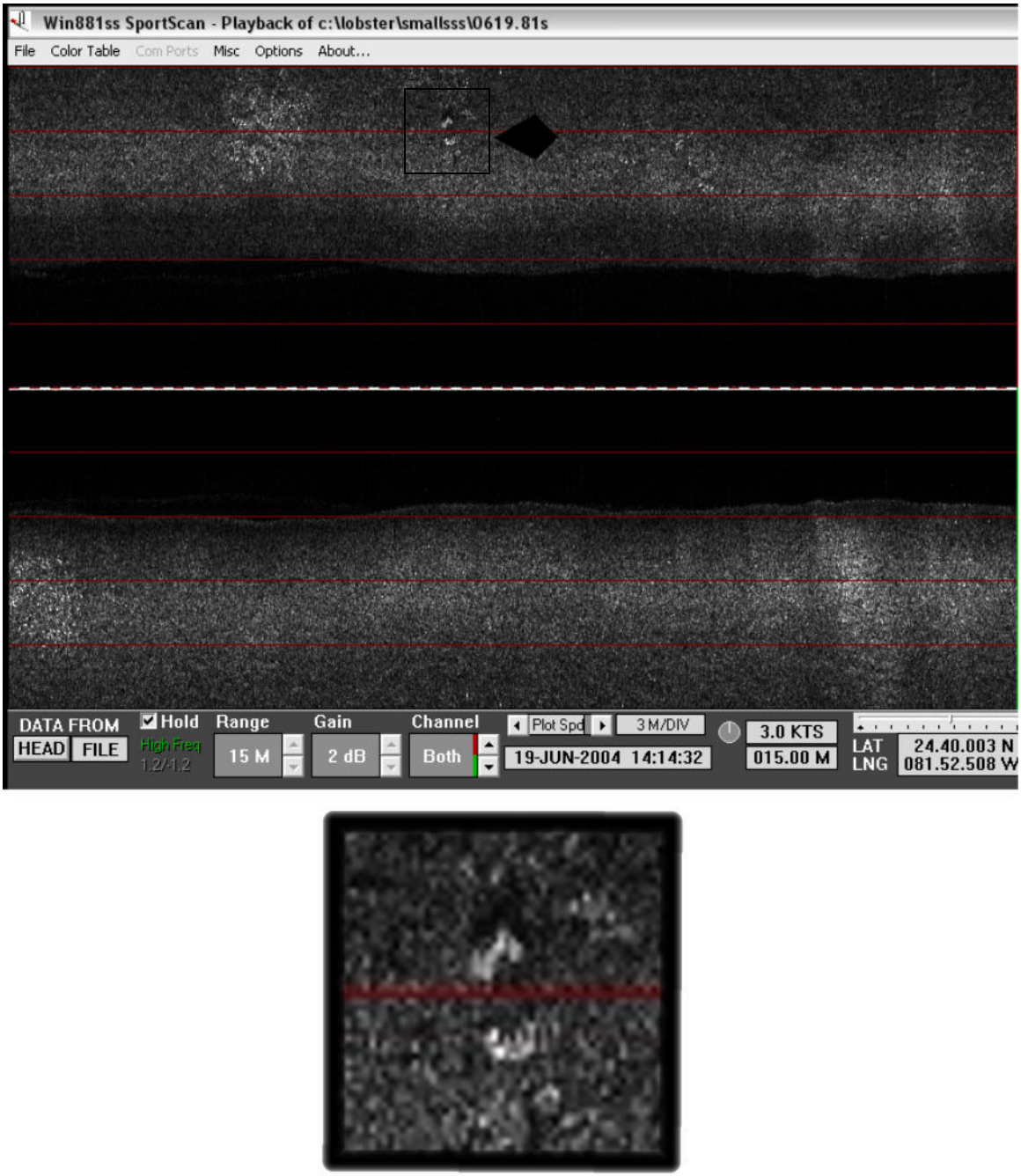

Figure 4. Image of the sea bottom from the Sportscan sidescan sonar (top image) depicting the experimental artificial reef (at tip of arrow in top center of the image). The area within the box is magnified (bottom image) for better detail. The bean shapes represent concrete blocks.

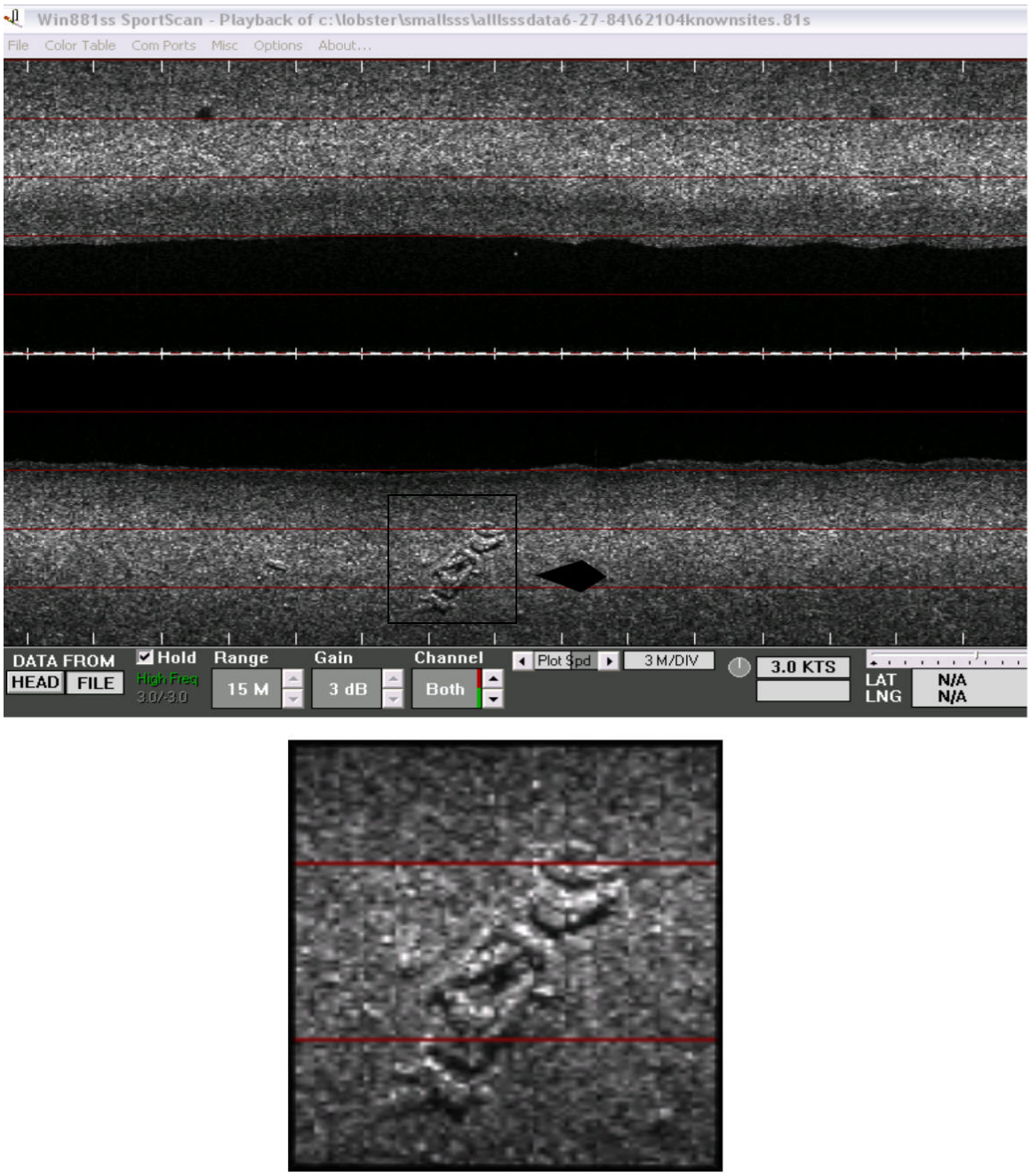

Figure 5. Image of the sea bottom from the Sportscan sidescan sonar (top image) depicting an illegal artificial reef (at tip of arrow) that the Florida Fish and Wildlife Conservation Commission had destroyed. The area within the box is magnified (bottom image) for better detail.

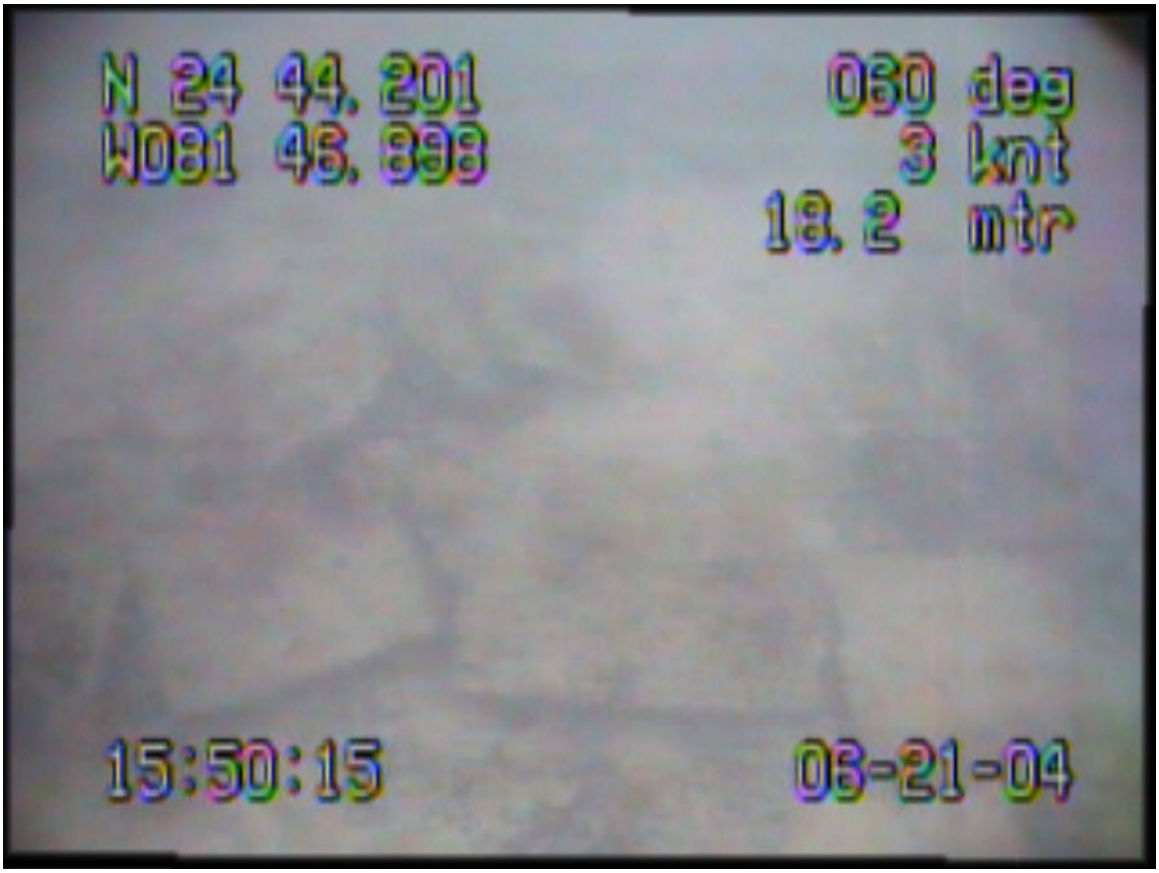

Figure 6. Video camera image of plates on the bottom used to attract lobsters.

Table 2. Approximate locations of suspected illegal artificial reefs.

Site	Transect	North Latitude	West Longitude
1	1	24° 44.216′	81° 47.204′
2	1	24° 43.783′	81° 46.901′
3	2	24° 41.222′	81° 50.255′
4	2	24° 41.457′	81° 49.793′
5	2	24° 43.030′	81° 46.860′
6	2	24° 44.480′	81° 44.990′
7	2	24° 44.590′	81° 43.790′
8	2	24° 45.080′	81° 42.810′
9	2	24° 45.150′	81° 42.670′
10	2	24° 45.285′	81° 42.425′
11	2	24° 45.553′	81° 41.942′
12	2	24° 45.828′	81° 41.349′
13	2	24° 47.401′	81° 38.305′
14	2	24° 47.438′	81° 38.232′
15	2	24° 50.203′	81° 32.997′
16	4	24° 45.358′	81° 42.452′
17	4	24° 45.095′	81° 42.206′
18	4	24° 43.777′	81° 41.049′
19	5	24° 44.190′	81° 51.712′
20	5	24° 50.057′	81° 39.838′
21	5	24° 50.338′	81° 39.225′

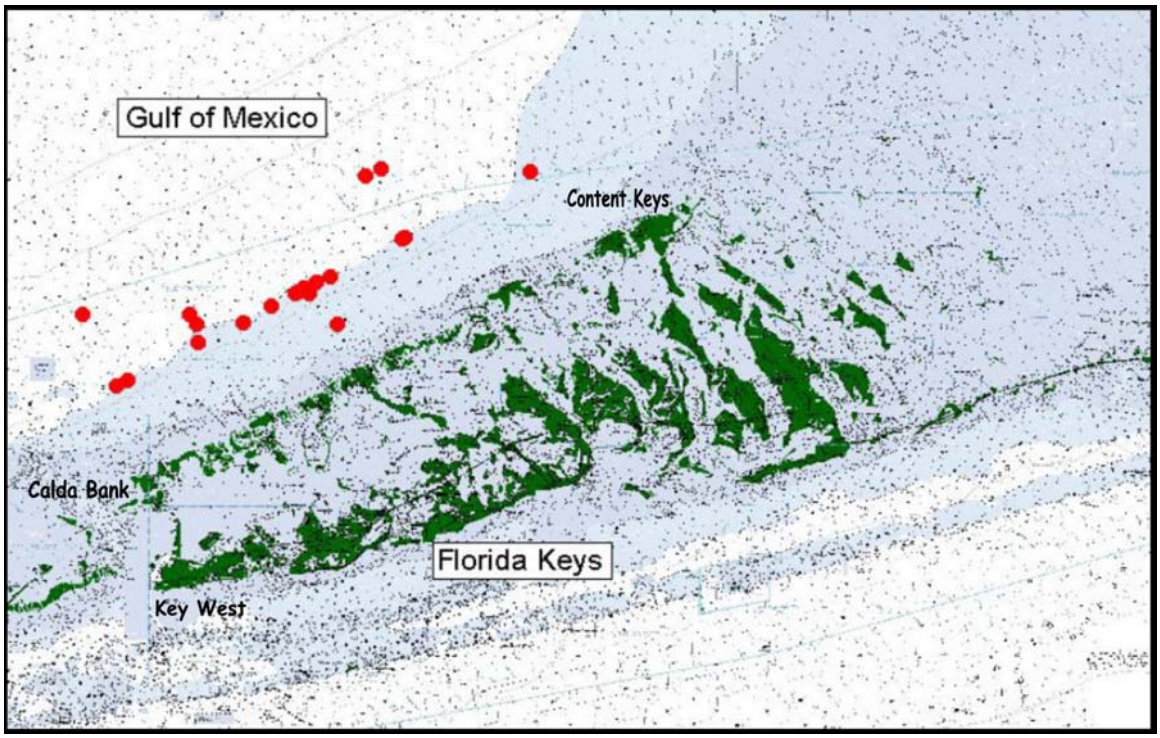

Figure 7. Locations where sidescan sonars imaged possible illegal artificial reefs (red) north of the Florida Keys.

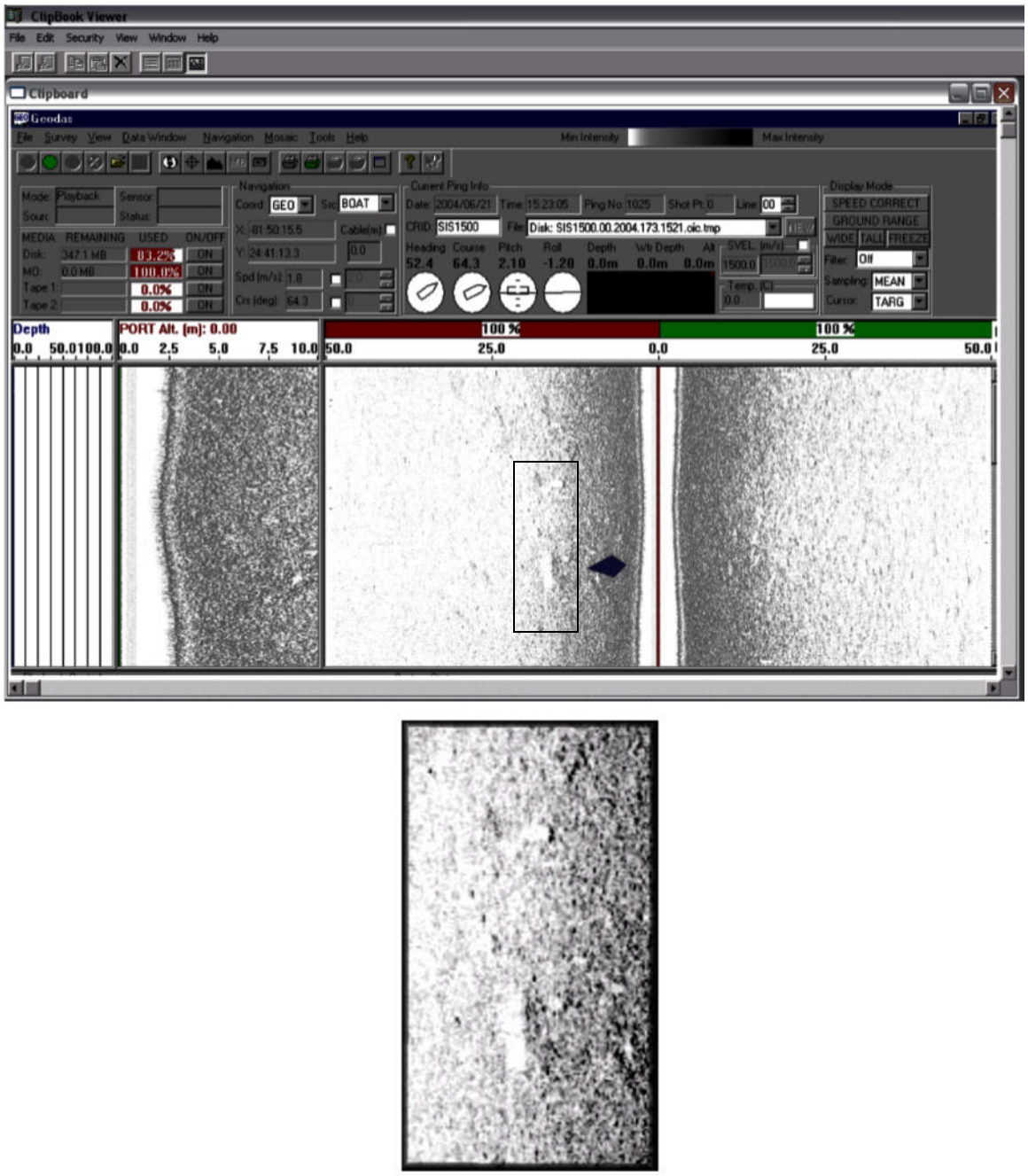

Figure 8. Image of the sea bottom from the SIS-1500 chirp sidescan sonar (top image) depicting a possible illegal artificial reef (at tip of arrow) consisting of at least four rectangular objects. The area within the box is magnified (bottom image) for better detail.

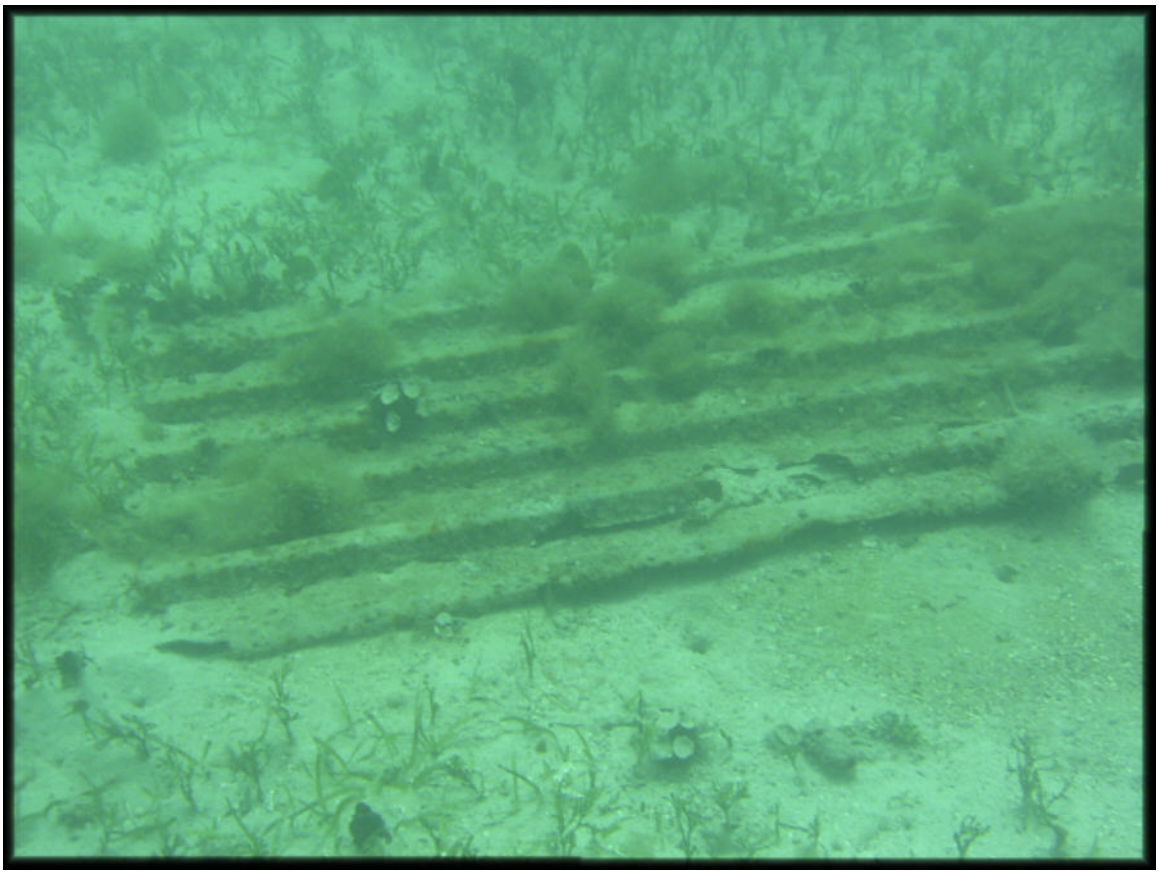

Figure 9. Image of a corrugated metal sheet taken by diver with a digital camera.

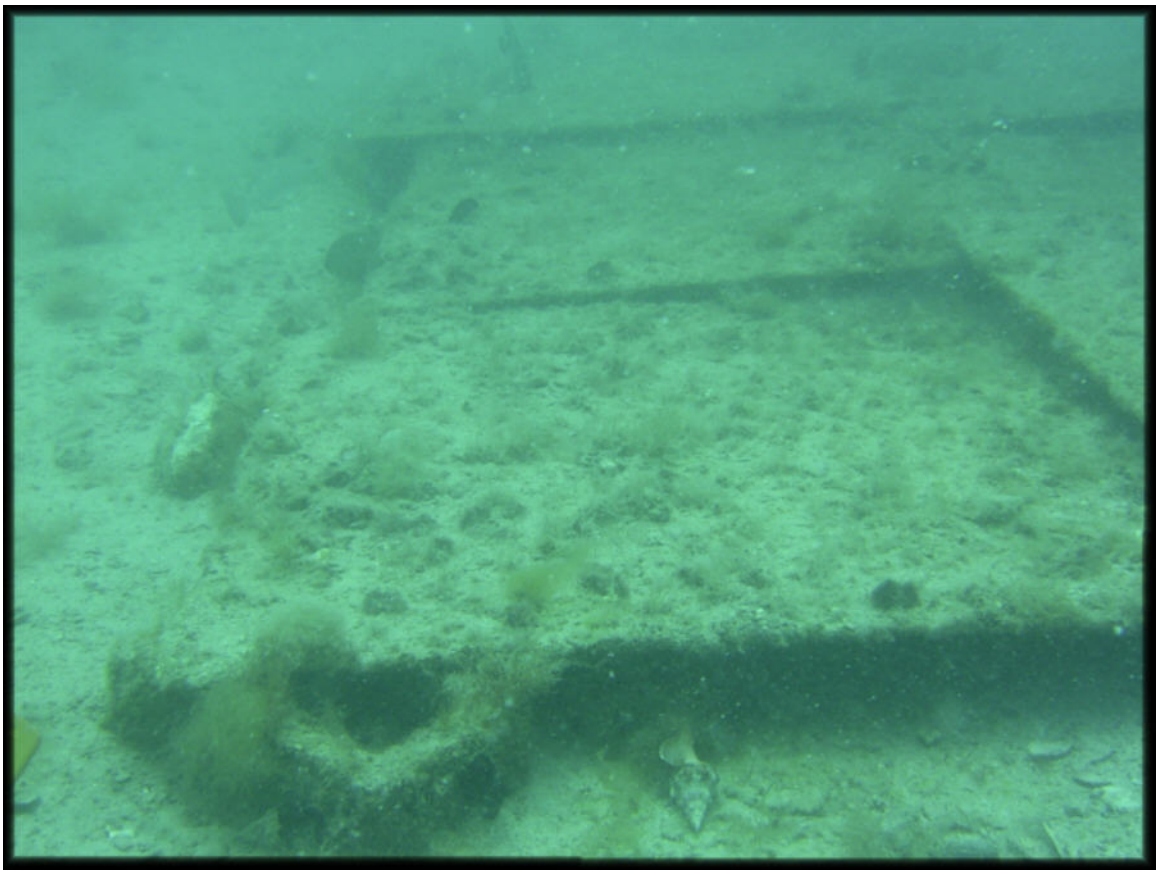

Figure 10. Image of an illegal artificial reef comprised of metal plates atop concrete blocks (image was taken by diver with digital camera).

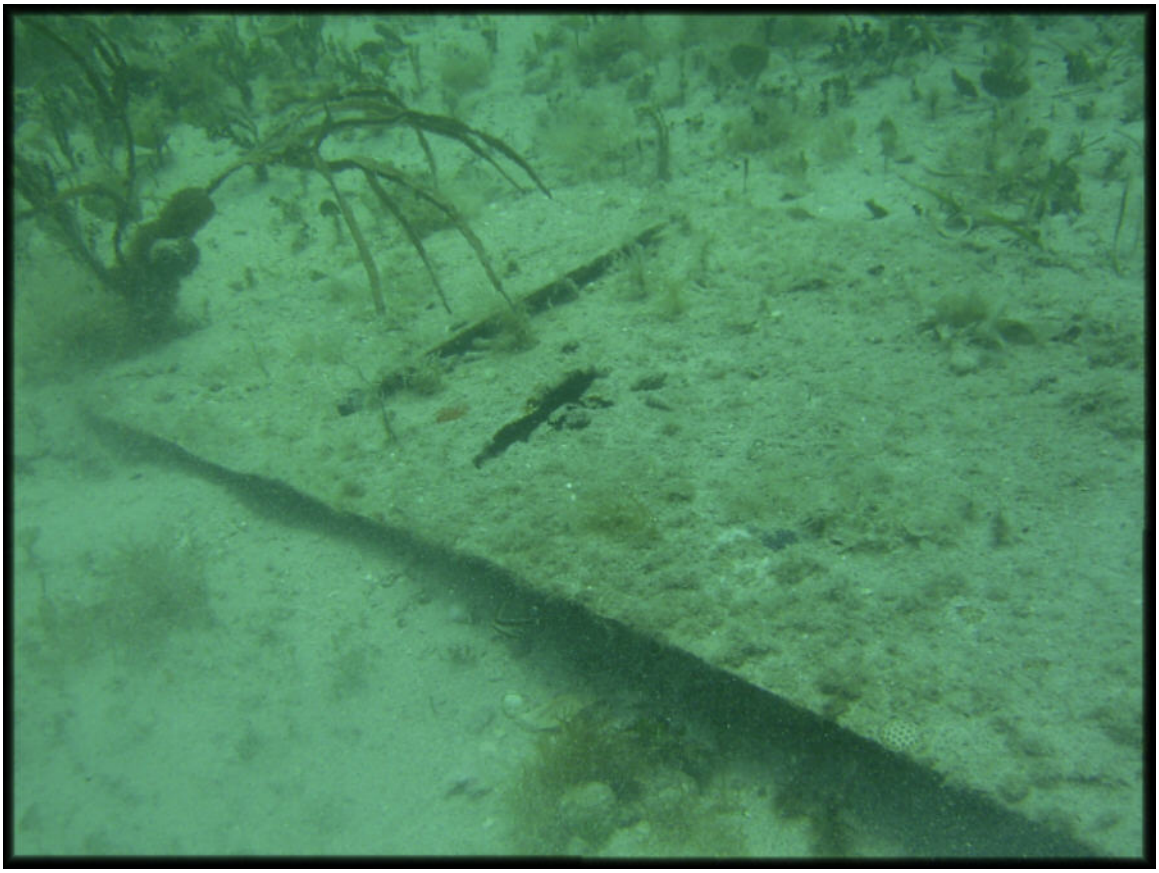

Figure 11. Image of metal sheet taken by diver with digital camera.

have been too great for the Sportscan sonar to properly image illegal reefs or no reefs may have been placed along the transect.

Targets identified as possible illegal reefs were detected in three general locations along transect 4. A curved shaped object detected by the Sportscan sonar at site 17 was initially overlooked as a possible target, but divers later confirmed the object as a metal car hood and functioned as an illegal reef. Car hoods are sometimes placed on the bottom to attract lobsters. Targets at site 18 were verified with video cameras and divers. The objects at site 18 were spread over a large area and consisted of several types of materials including corrugated sheets of metal, small concrete slabs which were probably crab trap weights, and flat aluminum sheets.

Three target sites were detected along transect 5 and classified as possible illegal reefs. One site was at the western end, and the two other sites were relatively close together at the eastern end of the transect. All three sites were in water approximately 12.2 m (40 ft) deep.

Data from the three transects perpendicular to bottom contours (transects 1, 3, and 4) were used to estimate illegal reef density and total number of illegal reefs over the entire study area. Data from these three transects were used for the estimate because the transects were spaced approximately equal distances apart across the study area and there was no prior knowledge of the number and distribution of illegal reefs in the area. Transect 2 (9.1 m bottom contour) contained biased data because information provided by the Florida Fish and Wildlife Conservation Commission suggested that illegal reefs were concentrated at this depth. The average number of suspected illegal reefs from the three transects was 2.43 ($s = 2.8711$) per km². When extrapolated to the entire study area of 602 km², this results in an estimated 1463 illegal reefs for the area. When data from transects 2 and 5 (roughly parallel to bottom contours) were used, even though the data from transect 2 are considered to be biased, the estimate changes only slightly to 1529 ($s = 2.0659$) illegal reefs over the entire study area.

Discussion

This project was performed primarily to determine if towed sidescan sonars, magnetometers, and video cameras could be used to detect and map locations of illegal artificial reefs and, secondly, to provide a preliminary estimate of the number of illegal reefs in the study area. Both sidescan sonars performed well. The SIS-1500 chirp sidescan sonar performed well for the first two transects and then ceased to function and was not used for the remainder of the survey. A loose screw in the circuitry was later found to have caused the system to fail. Advantages of the SIS-1500 sonar include its wider swath width and its overall quality imaging capability. Its disadvantages are that it is more costly ($65,000) than the Sportscan sonar, and it requires more training to operate. Its larger size and weight can also be considered a disadvantage when the unit is towed with smaller vessels.

The Sportscan sonar works well when towed near the bottom and is set on high frequency although it has a narrower swath than the SIS-1500. The lower cost of the unit and its associated software (approximately $7,000) and its simplicity of operation makes

it an ideal candidate detect illegal reefs especially if video imagery is simultaneously acquired to confirm the identify of targets. Both sonars imaged different types of materials (metal and concrete).

The magnetometer was not suitable for this type of effort. Although the instrument successfully detected iron plates used in the construction of some illegal reefs, it is not capable of detecting non-ferrous materials, and the numerous returns makes interpretation difficult.

Video cameras are useful at verifying some targets if they can be towed directly over the targets. They are most useful when towed with a sidescan sonar. Their limitations are that they need to be towed very near the bottom for clear pictures and their swath width is narrow because of their proximity to the bottom.

The divers had difficulty locating some of the targets. The instruments were referenced to the GPS location of the vessel and not to the locations of the instruments attached to the end of the tow cables. The targets were therefore not at the exact locations given by from the GPS coordinates. Follow-up studies with towed instruments should include inserting equipment with associated software that will reference the actual location of the towed instrument so that relocating targets for verification and removal will be easier.

Enumerating illegal reefs is difficult because of the variety of construction styles and materials used. Some illegal reefs consisted of metal or concrete plates arranged adjacent, and in close proximity, to each other. These reefs can be counted as a single unit, and a nearby arrangement can be counted as a second unit even though both may have been constructed by the same person(s). Other illegal reefs consisted of materials, such as metal sheets, scattered over a wide area. This type of illegal reef was counted as a single unit for this study.

Illegal artificial reefs are widespread in the study area north of the Florida Keys, as well as in areas outside the study area, and are found in a variety of depths (Figure 12). Materials used to form these reefs are varied. The number of reefs is estimated to be in the hundreds in the study area alone. These illegal reefs are thought to be placed in other areas near the Florida Keys as well. The impact of their use on the spiny lobster population is unknown as is their impact on bottom habitat. Further efforts are needed to more thoroughly and accurately map these reefs within and beyond the study area and to determine their impacts on bottom flora and fauna. Given the number of illegal reefs estimated within the study area from this effort, total number of illegal reefs in the entire Florida Keys waters could easily be in the thousands.

Illegal artificial reefs are a real and widespread problem inside and outside the FKNMS, not only because of the potential damage it causes lobsters, surrounding seagrasses, and corals, but also because they are a management problem of extreme proportions. Catching people in the act of placing and using these structures is extremely difficult because of the large area involved and because law enforcement officials are spread so thin on their patrols. One way of controlling this problem is to find the illegal reefs and remove, or otherwise, destroy them. This assessment project demonstrated that appropriate technology can be a cost-effective and efficient way to detect and map these illegal structures.

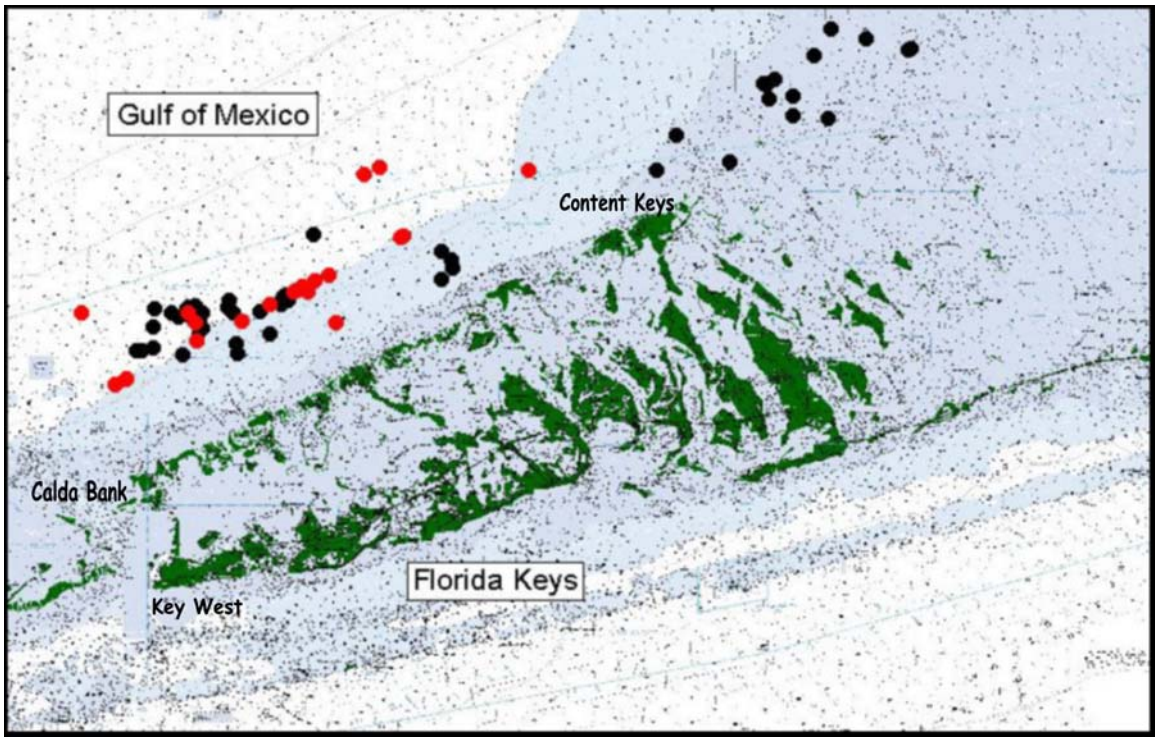

Figure 12. Sites of possible illegal artificial reefs found with sidescan sonars (red) combined with sites provided by the Florida Fish and Wildlife Conservation Commission (black).

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