Mapping Benthic Habitats Using Side Scan Sonar

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ABSTRACT

Detailed, but large scale habitat mapping is necessary if fisheries researchers are to investigate habitat-species distributions on spatial scales relevant to fisheries management and marine conservation, and identify essential fish habitats and the qualities that underlie their importance. The latter will include both the immediate structural qualities of a given area and the linkages among surrounding habitats. Knowledge of the underlying structure of habitat function should allow simple rules to be developed for future identification and protection of critical habitats. Despite over 40 years of concentrated academic investigation in the area of La Parguera, Puerto Rico, including geological mapping, there is no comprehensive habitat map suitable for large-scale biological studies. Developing such a map is now feasible using remote sensing and geographic information system (GIS). We are using side scan sonar (SSS) to develop a habitat map extending from the shoreline to the edge of the insular platform and covering over 20 nautical miles square (nm^2). SSS is advantageous over airborne remote sensing in its greater depth range and greater resolution. The SSS associated navigation equipment (computer, software, DGPS) and electric winch are mounted on a 22-ft vessel. A 300 kHz transducer is towed over 100-m wide paths to collect bottom images. To create larger views, georeferenced mosaics are generated from individual images using GIS technology. To date we have identified broad areas of habitat and located unknown patch reefs in otherwise soft-sediment areas. At 300 kHz, metal-frame fish traps were not detected, although evidence of their effect on corals were. Although SSS technology is valuable, its success requires proper logistical set-up, plus expertise in computers and electronics.

KEY WORDS: Habitat mapping, active sensors, side scan sonar

INTRODUCTION

The spatial distribution of benthic habitats and their complexity are key factors affecting fish distribution and abundance (McClanahan 1994). This relationship is especially noted in coral reef ecosystems (Choat and Bellwood

1991, Appeldoorn et al. 1997, Friedlander and Parrish 1998), where fish live and move among many different habitats (Coreless et al. 1997, Roberts 1997). Basic information on the distribution and complexity of benthic habitats is often unavailable for the majority of reef areas due to their large expanse and because it requires expensive and sophisticated equipment to map them. Remote sensing techniques offer a viable option to fill this gap for large areas, determining not only the location and amount of the distinct benthic habitats, but also how these habitats are distributed and for allowing, in some way, determination of habitat connectivity. However, in tropical regions, and specifically in coastal waters, the use of traditional optic sensors is very restricted because of rapid light absorption by the water column and phytoplankton, and the presence of colored dissolved organic matter, even in coral reef systems with relatively clear water. Active sensors, such as SSS, can solve this problem, offering a high resolution depiction of the bottom regardless of water transparency and depth.

Side scan sonar, first used in 1963, is now commonly employ in searching for shipwrecks, elaboration for nautical charts, and for seabed imaging worldwide (Fish and Carr 1990, Mazel no date). An example of extensive SSS use is the Gloria Project, which for more than 25 years was utilized to map geological features on the sea floor in all major oceans, including the U.S. Exclusive Economic Zone (U.S. Geological Survey 1987). However, Gloria is not a compact SSS. Few scientific works have made use of SSS in shallow waters. For example Siljestron et al. (1996) successfully mapped seagrass meadows of *Posidonia* and *Cymodocea* in Mediterranean waters. In Australia, Harris and Davis (1989) mapped submerged reefs using a 100-kHz SSS. SSS is also used in fish quantification (Pitched et al. 1996). In Puerto Rico, a section of the northeast shelf was mapped using SSS to determine distribution of sediment types (Rodriguez et al. 1998). Recently, work mapping benthic habitats was conducted in estuarine lagoons around San Juan Bay (Rivera, 1999). With the information collected from that project a detailed map of benthic habitats is being generated and will be available for multiple research purposes, especially fisheries research.

We are currently conducting a SSS survey of the insular shelf off La Parguera, Puerto Rico. The survey covers a 3-Nm wide section extending from the shoreline (Playita Rosada Isla west to Isla Cueva) out to the edge of the insular shelf. Despite over 40 years of concentrated academic investigation in the area of La Parguera, Puerto Rico, including geological mapping, there is no comprehensive habitat map suitable for large-scale biological studies. Our goal is to produce a map detailing the abundance and spatial distribution of benthic habitats. This includes both the immediate structural qualities of a given area and the linkages among surrounding habitats. Such information can be used to improve fish abundance surveys through habitat stratification, to identify and quantify potential fish habitats, and to study the relationship between habitat and their functional role in fisheries production. Knowledge of the relationship between habitat structure and function should allow simple rules to be developed for future identification and protection of critical habitats.

The purpose of this paper is to present how we have adapted methods and technology of SSS surveying, so that these can be applied to marine and estuarine coastal tropical regions. We illustrate this with preliminary results from the La Parguera survey.

METHODS

The study area is located off La Parguera (17°58'N, 67°02'W) in southwestern Puerto Rico (Figure 1). Collection of SSS imagery was done over a period of 40 days during 1998 and 1999.

A 22-ft fiberglass Privateer boat with a bow cabin and a four-cylinder inboard engine and stern drive was used to deploy the SSS and navigation systems. The boat is equipped with four gel cell 12V-103 amp batteries arrayed into two battery banks. Each bank is connected in series to supply 24V-DC. The 24V supply is connected to a Trace R/V inverter that outputs 120V AC power. Due to the creation of electromagnetic interference on SSS image, this inverter was exchanged with a Statpower Prosine™ 1000 inverter. The 120V power is supplied to the data acquisition computer and to a portable navigation computer when needed. However, 12V is supplied directly from one battery to the Differential Global Positioning System (DGPS) signal and to the 1000 nit liquid crystal display (LCD) connected to the SSS imagery acquisition computer. The 1000 nit LCD monitor increased imagery display visibility in daylight conditions and reduced power consumption. The battery banks are selected utilizing a battery bank selector switch. During daylight hours, two 12V-75watt, 4.5 amp solar panels connected in series and a charge controller provide recharging power to both battery banks. When the boat is ashore the Trace inverter, once connected to a 120V source, can also recharge both battery banks overnight.

Two additional lead acid 12V-103 amp batteries are connected into a 12V-DC bank. This bank provides the starting power for the boat engine and for the electrical winch, depth sounder, cabin lights, bilge pump and a cigarette plug adapter used to supply power to the navigation computer when needed as backup. The 12V bank also has a battery selector switch. These batteries are independent from the 24-DC battery bank. Once running, the engine alternator/battery charger provides recharging power for these batteries. The engine battery bank is independent of the SSS acquisition battery bank in order to avoid the possibility of introducing electromagnetic interference to the SSS imagery from the engine.

A 300-kHz Marine Sonic Technology Ltd. transducer (commonly known as the "fish") was towed over a 100-m wide swath. The fish was kept 3–5 m off the bottom on average to avoid collision with common bottom features such as patch reefs, hard bottom ledges, etc., that usually protrude 2-3 m off the bottom. Where the bottom topography was highly irregular, the fish was raised further from the bottom (7-8 m). Keeping the fish 3-5 m off the bottom also ensures the needed angle of view for the tranducer to reach its 50-m range on each channel side.

A NMEA 0183 navigation serial data output string with differential corrections is provided from a Magellan DGPS both to the navigation system software (Hypack V8.2) and to the SSS image acquisition software (Marine Sonics Technology Ltd., Sea Scan PC V5.18). This provides exact geo-referencing for the SSS images upon recording to hard disk. The offset between the DGPS antenna location and the fish location is not corrected for during real time data acquisition. This correction is usually accounted for in the post-processing of SSS imagery.

In Sea Scan PC, there are options to adjust the gain, to make corrections for the offset, to make annotations and to record depth information. Some filters, and analysis of the images, like estimations of areas and heights are also possible using the reviewing software, Sea Scan PC Review. Sea Scan PC automatically creates consecutive images of 1,000 by 512 lines that result in a image file of 1.2 megabytes in size with its respective navigation information, but the software does not offer the possibility to merge images into larger mosaics.

Prior to starting the survey, a detailed planning session was conducted using Hypack survey planning software in order to define the study area and the determine the transect lines to be followed with the SSS. As a result, 19 navigation files (Figure 1) were created. Each file covers a total of 1 Nm and includes 24 transect lines, 75 m apart. With this design, we have 12.5 m of overlap on both sonar channels (left and right), keeping a constant range of 50-m on each side. Vessel speed ranged between 2.8 – 3.8 knots, but much slower speed was required when depths were more than 21 m in order to reduce cable drag and lower the fish. A continuous log of the position was recorded in the navigation computer.

Available post-processing image filtering algorithms in Sea Scan PC Review were applied to improve the quality of the single images and eliminate electromagnetic interference when present. Commonly applied filters are spike (to eliminate random points), plus (to add brightness), minus (to reduce brightness) or expand (to enhance contrast).

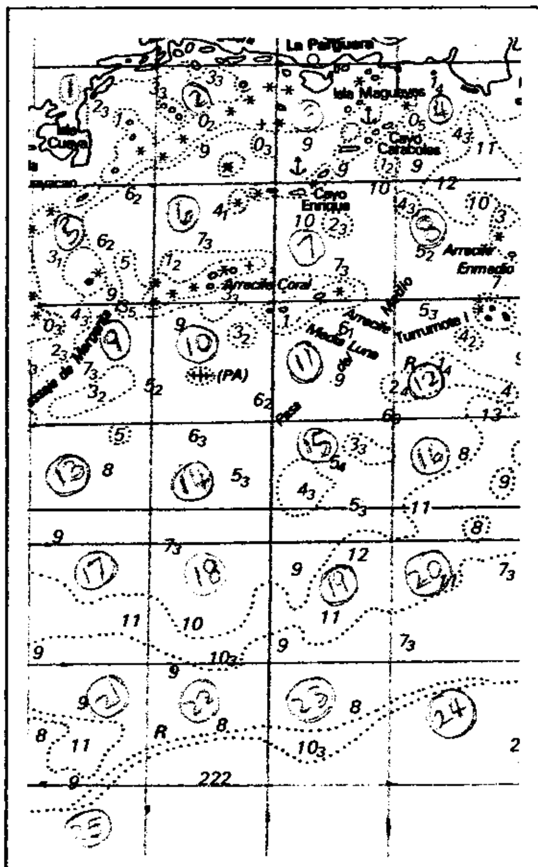


Figure 1. Area surveyed with SSS off La Parguera, southwest coast of Puerto Rico. Area extends from shore to shelf edge. Each square has 1 nm². Right most column was not included in the survey.

Further processing takes single images and merges these to form large mosaics. This is done using Caris V4.3.1, a GIS software from Universal, Ltd. This program has a special routine in its sonar module for processing Marine Sonic Technology (MST) images. The process starts by converting files from MST format into Caris format. Then, left and right channel images are joined by removing the water column and producing a geometrically correct bottom image. Mosaics were usually made by placing the brightest image on top when adjacent transects overlapped. The generated mosaic is then exported to the Caris - GIS module to make the initial visual interpretation of different sonar echo return signatures and to define polygons with similar echo return texture. These polygons are then related to habitat types based on interpreter experience and ground truthing information.

Ground truthing was used to check the accuracy of the interpretation and to revise the delimitation of the different polygons on the mosaic. Ground truthing is done using a tethered black and white underwater video camera in shallow or deep-water areas covered with sand, algae or grass. However, extensive ground truthing is also done by diving to get a general perception of the area and mosaic generation and reach areas in which the underwater video was not able.

The processing phase requires an additional computer with large memory (512 MB RAM) and hard disk storage capacity (>60 GB) due to the large amount of data collected and produced. For example, one file covering 1 Nm^2 and containing around 250 megabytes of raw imagery results in 1 gigabyte of processed information.

RESULTS

To date, 364 Nm of SSS transect lines have been surveyed out of a total of 442 Nm, representing 82% of the total study area. Of the 19 mosaics to be made, 63% have been processed.

At this moment, we have obtained around 4000 single images. Two examples are shown in Figures 2 and 3, where different types of bottom are clearly identifiable. Strong reflections produced by reef platforms, patch reefs or big isolated coral heads are easy to identify. Mixed coral-gorgonian areas are also possible to identify with more detailed observation. On sandy bottoms it is possible to observe ripple marks when present. Different densities of soft algae or the presence of silty-sand are also possible to detect. Reviewing bottom images at this scale has already revealed interesting features. We have routinely found uncharted patch reefs of a variety of sizes located in otherwise soft-bottom areas. The most interesting observation was the occurrence of deeper water (18 m) coral patches surrounded by halos of dense *Halophila decipiens* mixed with algae, primarily *Caulerpa racemosa* var. *macrophysa* and some *Udotea* sp. and *Dyctiota* sp. (Figure 2). Such halos have not been previously reported in the ecological literature. Figure 3 is from an area of high fish trapping activity and shows a coral reef area believed impacted by a fish trap or anchor drag. With such high quality definition, we found SSS technology useful for providing high resolution images of different types of benthic marine habitats. It also gave us information on structure and real size of those features. One disappointment has been our inability to distinguish the numerous fish traps in the area with the 300-kHz transducer. However, on occasion it was possible to observe the line attached to the trap. We believe using different sonar frequency can help identify spot fish traps more efficiently.

The large area views obtained from mosaics (Figures 4 and 5) complement the detailed single-image information with a view of the spatial distribution patterns among benthic habitats, which will allow us to establish the linkages between them. Onr factor interfering with the interpretation of the bottom images at this scale is the presence of the discrete parallel lines along the transect path due to surface reflection. These lines are located in variable positions over the bottom image and cannot be eliminated by available filters.

At present, we are defining all the possible identifiable features and will join them into a classification system of benthic habitats that can be applied to similar environments. As an example, we made gross estimations on percentage coverage of general features for some mosaics (Table 1). From this we can observe that on the La Parguera shelf, sand-algae is the most abundant habitat, covering 38.38% of the area analyzed. This percentage increases to 50.55% if we include the silty-sand and algal plains. Sometimes, fleshy algae form dense patches with a distinct dark pattern on SSS image, especially observed in intermediate depths. This type of habitat covered around 4.4% of the total area analyzed. In deeper waters (20 - 24 m), sand channels between extensive areas of hard bottom can be found close to the shelf edge (Figure 5).

Hard bottom habitat is second in abundance with 17.49%, mostly located close to shelf edge (Figure 5). Widely dispersed corals cover a total of 9.97% of the area (Figure 4). Overall percentage of coral habitats may increase after we acquire SSS images from the numerous emergent reefs present in the area. Hard bottom and corals are two related habitats that need to be delimited carefully based on detailed observations and intense ground truthing, in order to increase the accuracy of interpretation of the SSS imagery. Seagrass habitat (*Thalassia, Syringodium* and *Halophila*) is present in shallow and deep waters but they have lower percent cover (14.73%).

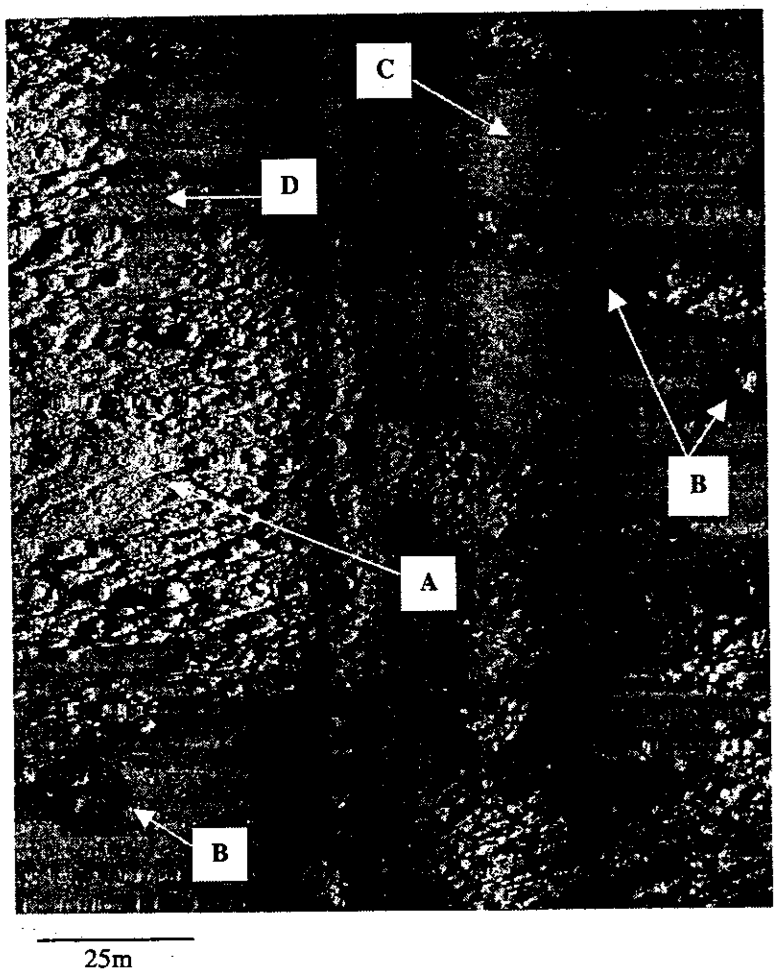


Figure 2. Edited single SSS image from 17°56'N, 67°03'W with water column removed. Surface echo has been edited out for easy interpretation. A. Strong rugose reflection shows coral reef habitat. B. Patch surrouned by halo of dense *halophila decipiens*. C. Smooth sand and algae plain. D. Sand ripple ridges.

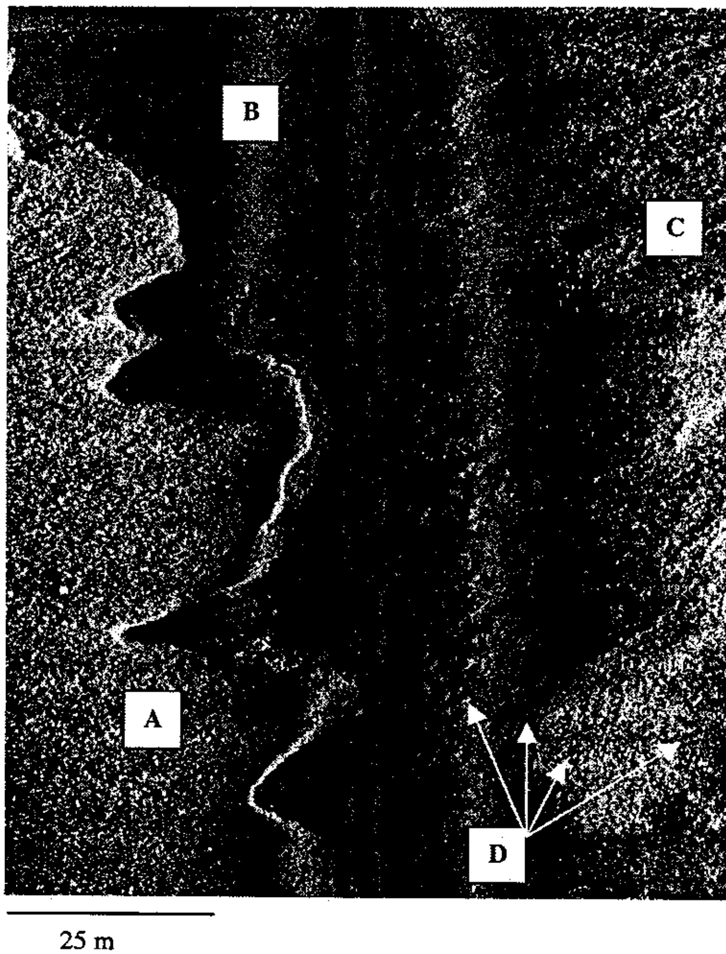
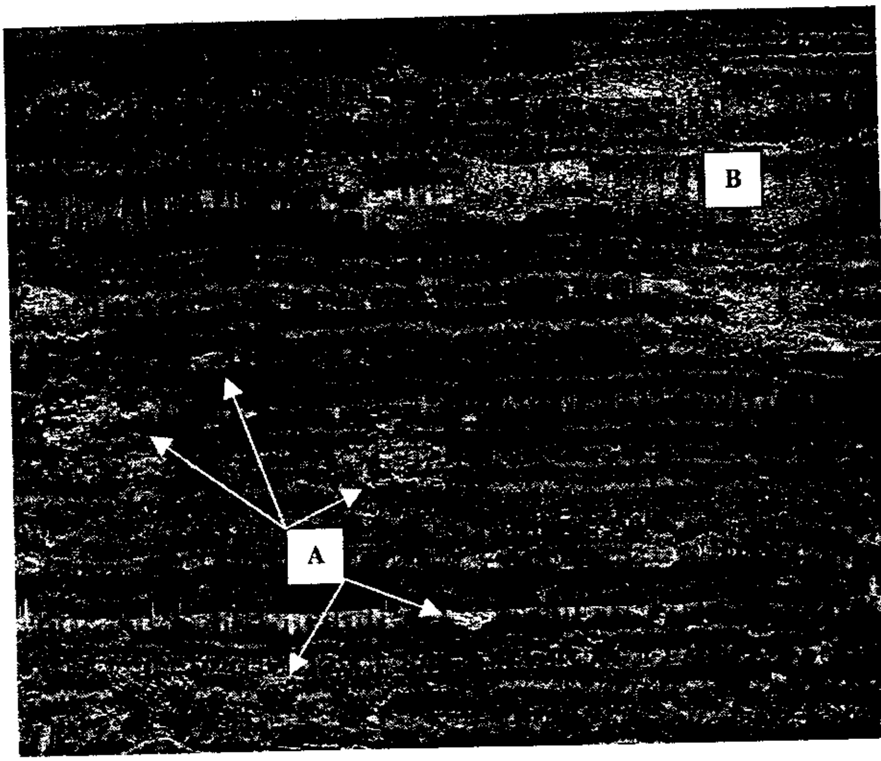


Figure 3. Edited single SSS image from 17°53'N, 67°04'W with water column removed. Surface return echo has been edited out for easy interpretation. A. Isolated coral colonies over hard bottom. This platform has 5 m height or relief. B. Sand and algae with small isolated corals. C. Coral reef formation. D. Coral reef area believed impacted by fish trap or anchor drag. Notice linear patterns on edge and at rieght of center. This area is known fish trap setting area.



100 m

Figure 4. Section of a mosaic No. 10 (center position 17°55'N, 67°03'W) in 18 - 20 m depth. A. Uncharted patch reefs in a variety of sizes on sandy bottom. B. Coral reef area.

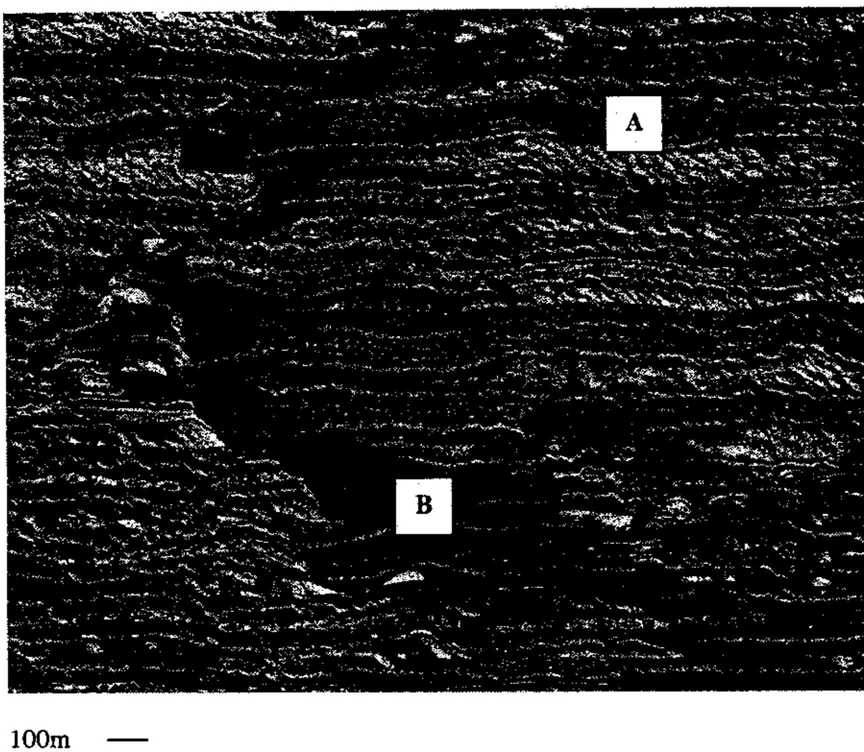


Figure 5. Sub-section of mosaic No. 22 (Center position 17°52'N, 67°03'W) in 20 - 24 m depth. A. Isolated coral and gorgonians on hard bottom. B. Sand channel.

CONCLUSIONS

Side scan sonar can be used successfully to describe and quantify marine habitats. Our preliminary results, show sand-algal plains as the dominant habitat, followed by hard bottom and corals.

Detailed information on habitat types using SSS technology allowed us to find abundant and uncharted coral reef patches over sand bottom. We also found unreported occurrence of patch reefs surrounded by halos of dense *Halophila decipiens*, which offer possibilities for new ecological research.

Despite our inability to detect fish traps, we were able to determine alterations on hard bottom recorded as a linear pattern on SSS images. These linear patterns are also observed in shallow seagrass areas where antropogenic effects such as anchor drags or prop scars are common.

Methods presented here involve a combination of different technologies, instruments, and software and require expertise in electrical and electronic techniques. It is very important to have trained personnel to facilitate efficient use and repair survey equipment.

Large area mosaics provide the basic information to establish patterns of spatial distribution of benthic habitats and how they interconnect. However, improvements in the processing techniques for building mosaics are needed to enhance the amount of information obtained and facilitate subsequent analysis of bottom features.

Considering that SSS image resolution is a function of frequency and range, fish traps probably can be detected using a higher frequency (e.g. 600 or 1,200-kHz) transducer. However, if the trap is built with plastic or other material with low sound reflectance, it will still be difficult to detect mesh. Furthermore, higher frequency transducers must be positioned closer to the bottom, which may reduce range of coverage (path width) and risk impact with bottom features.

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