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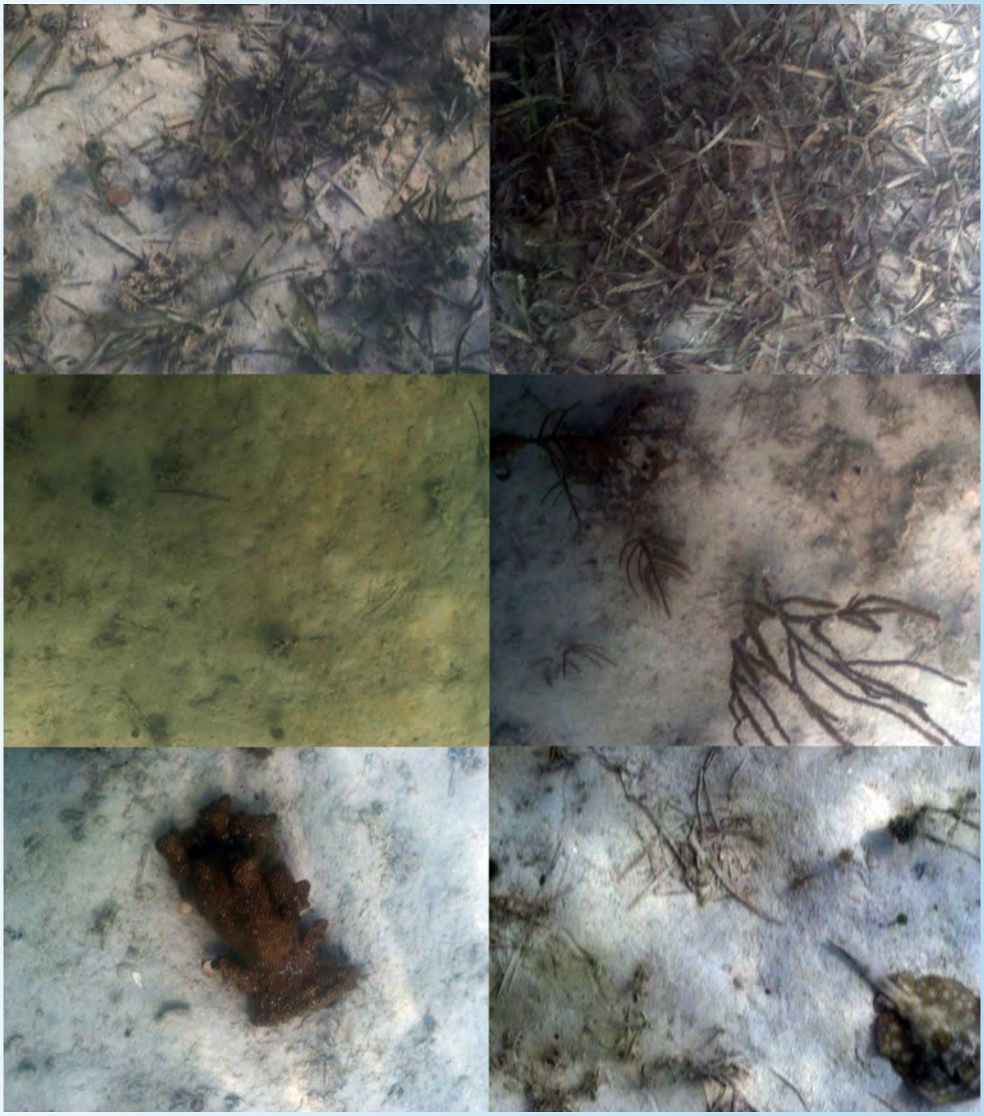
Benthic Habitat Classification in Lignumvitae Key Basin, Florida Bay, using the U.S. Geological Survey Along-Track Reef Imaging System (ATRIS)



Open-File Report 2011–1066

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Cover. **Bottom types classified in the ATRIS survey of Lignumvitae Key Basin.** (See figure 5.)

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

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Introduction

The Comprehensive Everglades Restoration Plan (CERP) funded in partnership between the U.S. Army Corps of Engineers, South Florida Water Management District, and other Federal, local and Tribal members has in its mandate a guideline to protect and restore freshwater flows to coastal environments to pre-1940s conditions (CERP, 1999). Historic salinity data are sparse for Florida Bay, so it is difficult for water managers to decide what the correct quantity, quality, timing, and distribution of freshwater are to maintain a healthy and productive estuarine ecosystem. Proxy records of sea-surface temperature (SST) and salinity have proven useful in south Florida. Trace-element chemistry on foraminifera and molluscan shells preserved in shallow-water sediments has provided some information on historical salinity and temperature variability in coastal settings, but little information is available for areas within the main part of Florida Bay (Brewster-Wingard and others, 1996).

Geochemistry of coral skeletons can be used to develop subannually resolved proxy records for SST and salinity. Previous studies suggest corals, specifically *Solenastrea bournoni*, present in the lower section of Florida Bay near Lignumvitae Key, may be suitable for developing records of SST and salinity for the past century, but the distribution and species composition of the bay coral community have not been well documented (Hudson and others, 1989; Swart and others, 1999). Oddly, *S. bournoni* thrives in the study area because it can grow on a sandy substratum and can tolerate highly turbid water. *Solenastrea bournoni* coral heads in this area should be ideally located to provide a record (~100–150 years) of past temperature and salinity variations in Florida Bay.

The goal of this study was to utilize the U.S. Geological Survey's (USGS) Along-Track Reef Imaging System (ATRIS) capability to further our understanding of the abundance, distribution, and size of corals in the Lignumvitae Key Basin. The study area was subdivided into four areas whereby corals and other benthic habitats were classified based on ATRIS imagery.

Setting

Lignumvitae Key Basin is located in the middle Florida Keys near Lower and Upper Matecumbe Keys in the south part of Florida Bay (fig. 1). The basin was surveyed from

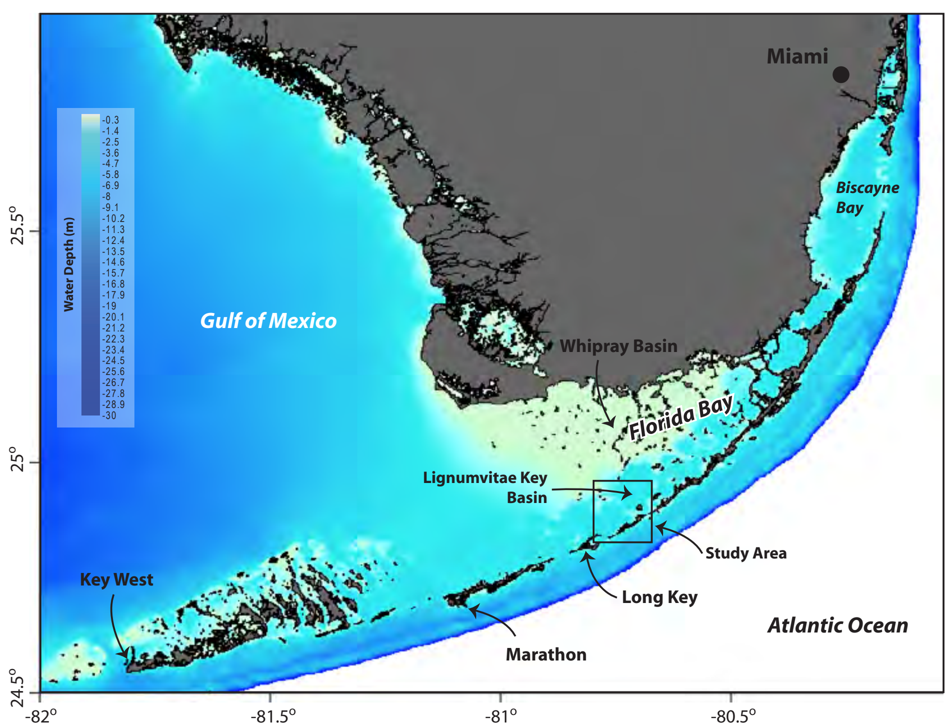

Figure 1. Location of Florida Bay and study area in south Florida.

September 14 to 17, 2009. Two of the surveys were conducted near the Peterson Keys, one north of Lignumvitae Key, and the other along the north shore of Lower Matecumbe Key. These sites were chosen because of previous records of coral heads that were either cored or were large enough to be cored for potential paleo-environmental purposes (Hudson and others, 1989; Swart and others, 1999).

Surface waters of the south part of Florida Bay are subject to tidal mixing with the Gulf of Mexico and Atlantic Ocean. During the rainy season, June through October, freshwater flowing in from the Everglades, approximately 25 kilometers (km) to the north, can lower the salinity at the study site from an average of 36 practical salinity units (psu) to near 27 psu (data from the National Oceanic and Atmospheric Administration, NOAA, Coastal-Marine Automated Network, C-MAN, station LONF1; fig. 2). Conversely, surface waters in this region can also escalate to above 40 psu due to evaporative effects. Salinity has been reported as high as 70 psu in the isolated basins of central Florida Bay (for example, Whipray Basin, fig. 1) and near 0 psu along the border of the Everglades and in the northern bay (Lee and others, 2006). Surface-water temperatures are also subject to drastic annual swings. Average water depth in Florida Bay is approximately 1 m. The shallow waters have the capacity to get quite warm in the summer (~34 °C) and cool quickly during the passing of winter cold fronts (~8 °C; fig. 2). Because of the collocation of mixing waters from Everglades drainage and Gulf of Mexico and Atlantic Ocean waters, records from large coral heads in the Lignumvitae Key Basin should record annual swings in temperature and salinity patterns over the past ~100 years.

Methods

The USGS developed the ATRIS imagery system to support mapping activities and to ground-truth remotely sensed data, such as acoustic, lidar, and satellite imagery of submerged coastal environments (Brock and Zawada, 2006). Two configurations are available for surveying benthic environments: (1) shallow, between 0 and 10 meters (m) and (2) deep, between 10 and 25 m. The shallow-ATRIS setup used in this study was operated from the 7.6-m-long USGS vessel R/V *Halimeda* (fig. 3). The shallow-water system houses a sensor package containing a gigabit Ethernet digital camera affixed to the submerged portion of an adjustable fiberglass pole. Attached directly above the camera at the top of the pole is a Global Positioning System (GPS) antenna. An Ashtech receiver collects GPS positioning from the antenna, which allows for accurate geo-location of the imagery. Each image was geo-located to within 5 m in real time, but after differential corrections, accuracy improved to ~50 cm. To improve the boat GPS data, a base station was established at the Keys Marine Laboratory on Long Key (fig. 1). The base station consisted of an Ashtech kinematic GPS receiver and antenna, identical to that used on the R/V *Halimeda*, and fixed at the same location throughout the study period. The base station GPS data were used to differentially correct each of the image locations. Camera-to-seafloor range and vessel-heading data were also collected for each image. Field conditions (water clarity and sea state) for much of the study limited the collection rate of imagery to 4 frames per second (fps; maximum of 20 fps). Approximately 20 linear km were surveyed

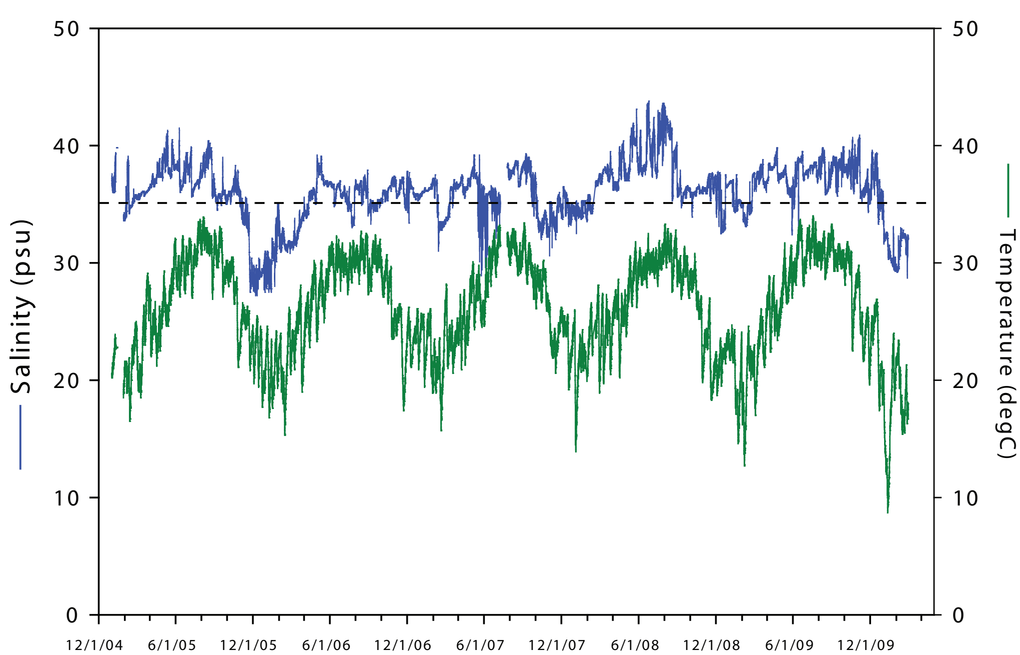

Figure 2. Salinity (blue) and temperature (green) from January 2005 to February 2010. Note the consistent warm summer high temperatures and declining winter low temperatures during the 5-year record. Salinity also varies from a low of near 27 psu up to 44 psu (normal marine salinity is 35 psu, dashed line). Data were recorded hourly from the C-MAN (NOAA) station LONF1 located in Florida Bay near Long Key, FL. [psu is practical salinity units]

each day at a boat speed of 4–5 km per hour (kph). The camera angular field-of-view in the x and y directions is 29° and 22°, respectively. Images were displayed in real time and were written to a Level 1, mirrored redundant array of independent disks (RAID), enabling simultaneous storage and backup.

The ATRIS Data Analysis and Processing Tool (ADAPT) was utilized for post-processing of the imagery dataset. ADAPT allows for interactive geographic browsing, scaling, and extraction of specific substratum images for further quantitative analysis, as well as a classification tool that allows the user to define and classify the substratum in each image (fig. 4). The images for each of the surveyed areas were viewed in the ADAPT software and every third image classified, due to substantial overlap between frames. Five

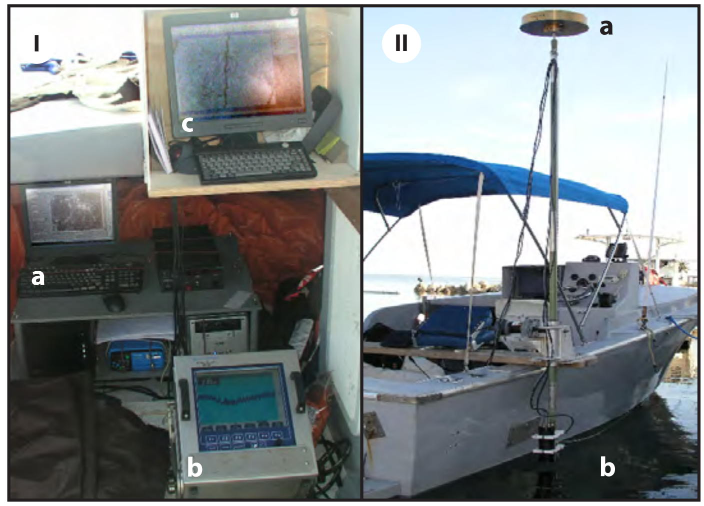

Figure 3. ATRIS system setup aboard the R/V *Halimeda*. (I) Photograph displaying the (a) Along-Track Reef Imaging System (ATRIS) computer package and monitor showing real-time images, (b) depth sounder, and (c) computer screen showing navigation and boat track line. (II) Photograph of the R/V *Halimeda* with pole attached to side of boat. The pole has a GPS antenna mounted on top (a) and camera affixed to the bottom (b).

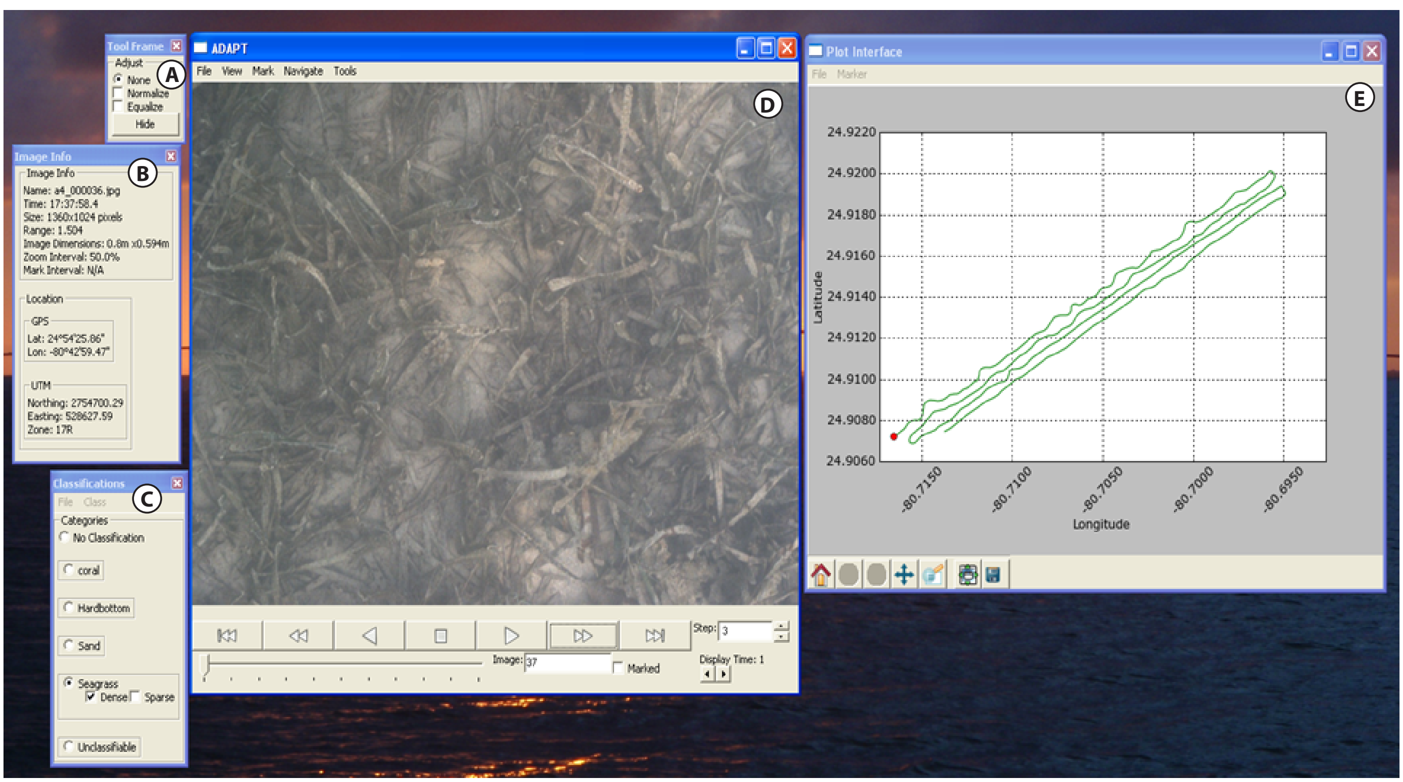

Figure 4. Screen-capture image of the ATRIS Data Analysis and Processing Tool (ADAPT) classification process. Various screens are displayed when classifying images: (A) Tool screen is used to help adjust the color or contrast of the image; (B) Image information screen displays the image number, time and date of acquisition, range of camera off the seafloor, and image dimensions; (C) Classification screen contains selectable buttons for possible bottom types; (D) Image screen; (E) Plotting screen shows the location of each image (red dot) along the boat track line.

categories were used in classifying the benthic habitats: seagrass (subcategories, dense and sparse), sand, hardbottom, coral, and unclassifiable. The classification files were merged with other data files that contained latitude, longitude, water depth, camera range, boat heading, and bottom type. This merged file was used to create benthic habitat products presented in this report.

Currently, progress is being made to increase the rate at which images can be viewed and classified. In the future, ATRIS images will be viewed in a Geographical Information System (GIS)-based format, allowing the scientist to view all images on a map, zoom in to particular areas, and potentially classify benthic habitats within the ArcGIS software. Within the ArcGIS program, world files (*.tfw) are generated from GPS, compass, and depth data associated with each image. The resulting world files are then used by the ArcGIS program to georeference, orient, and scale the images. The final step is to utilize an ArcGIS Image Server, which permits interactive browsing, dynamic mosaicking, and zooming within a given geographic region. The ATRIS images reside on a single GIS layer, making it easy to integrate with other geospatial data.

Results and Summary

We collected 363,960 seafloor images during the shallow-ATRIS survey from September 14 to 17, 2009. The 85-line-km survey over the 4 days revealed representative examples of Florida Bay bottom types. The bottom-type classifications used for this study are seagrass (subcategories, dense and sparse), sand, hardbottom, coral, and unclassifiable (fig. 5). Surveys did not cover areas near mud banks because the objective was to document areas likely to support coral growth (specifically, *S. bournoni*). In addition, *S. bournoni* occurrence was noted during classification of bottom types. Figure 6 shows survey areas 1, 2, and 4 in Lignumvitae Key Basin and area 3 along the north shore of Lower Matecumbe Key. The highlights of each survey area are discussed below.

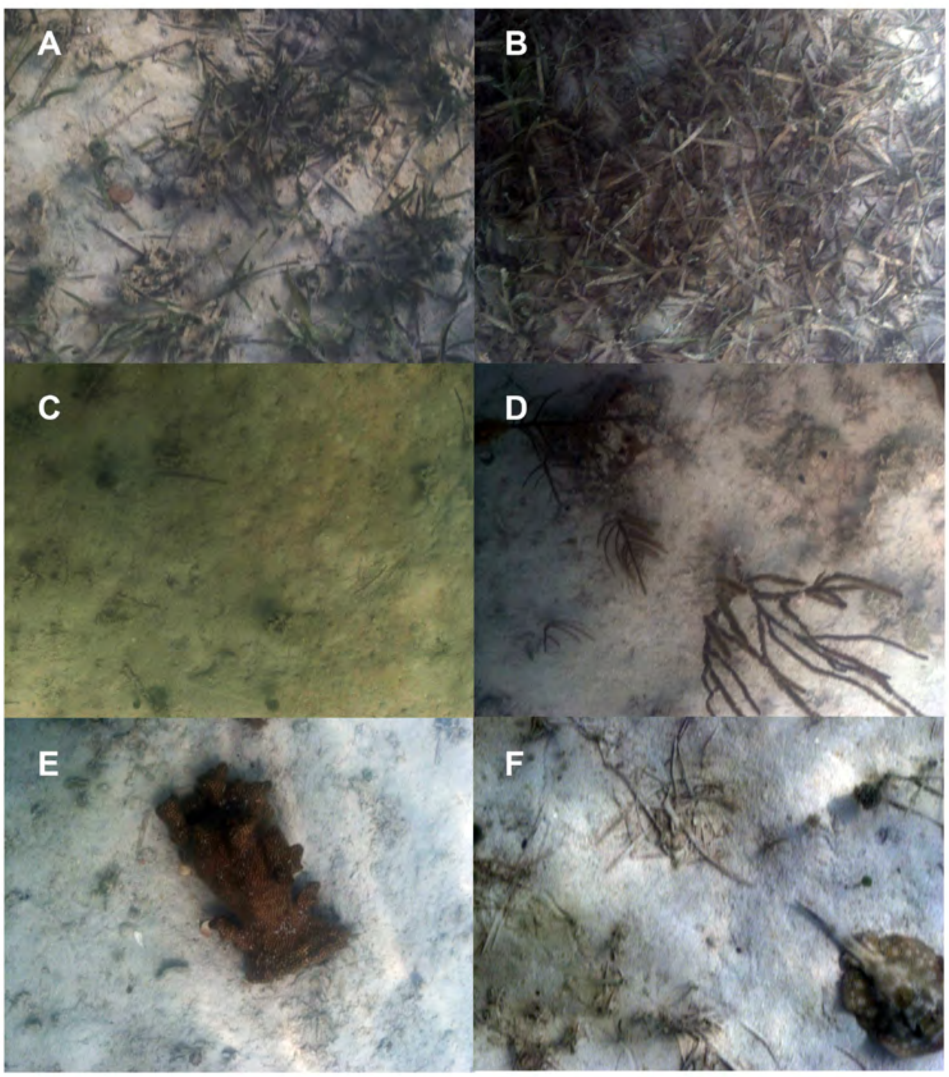

Figure 5. Bottom types classified in the ATRIS survey of Lignumvitae Key Basin: (A) sparse seagrass, (B) dense seagrass, (C) sand, (D) hardbottom, and (E) coral. Other possible organisims observed included algae, invertebrates (lobster, crabs), and larger animals such as fish and stingrays (F).

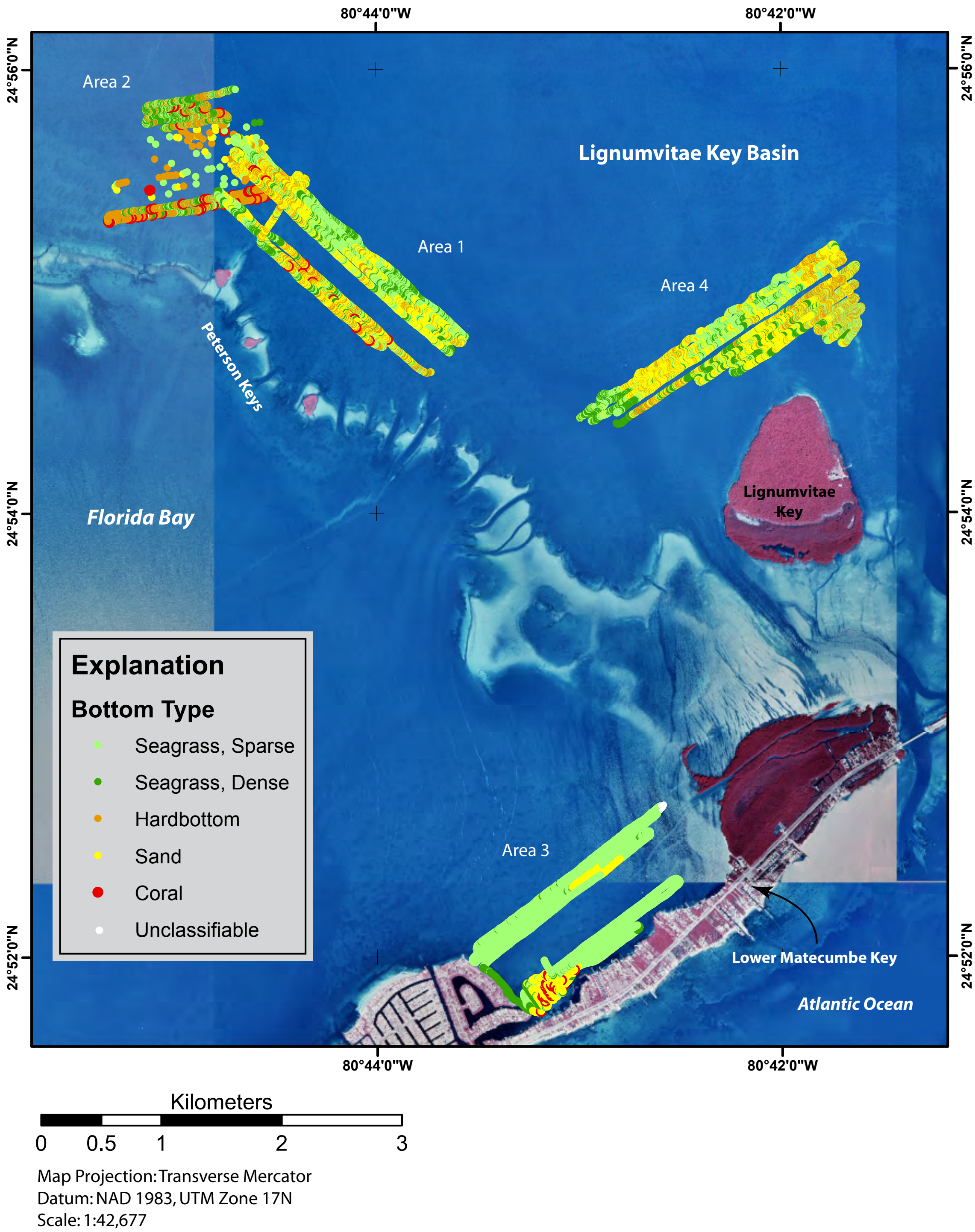

Figure 6. Bottom-type map showing all surveyed areas in Lignumvitae Key Basin and Lower Matecumbe Key.

Area 1

Area 1 is located to the east of the Peterson Keys in Lignumvitae Key Basin and is the site where Hudson and others (1989) cored a *S. bournoni* coral head. Water depth ranged from 4.4 to 7.1 m. Area 1 was surveyed over a 2-day period (fig. 7). No large (>1 m) coral heads were observed in this region even though a detailed survey of the area surrounding the Hudson coordinates was conducted (inset, fig. 7). However, numerous small coral heads were observed ranging in size from 5 to 30 cm in diameter. The majority of area 1 was found to be seagrass (sparse and dense) and with interspersed sand. Sandy areas contained *Penicillus* sp., the predominate sediment-producing alga, and burrow mounds constructed by burrowing shrimp (*Callianassia* spp.). Hardbottom areas typically had a veneer of sediment, but were noticeable because they supported various species that require hardbottom habitat including gorgonians, primarily sea whips, small scleractinian corals (*Siderastrea radians*, *Solenastrea bournoni*, *Porites porites*), and occasionally hydrocorals (*Millepora* spp.).

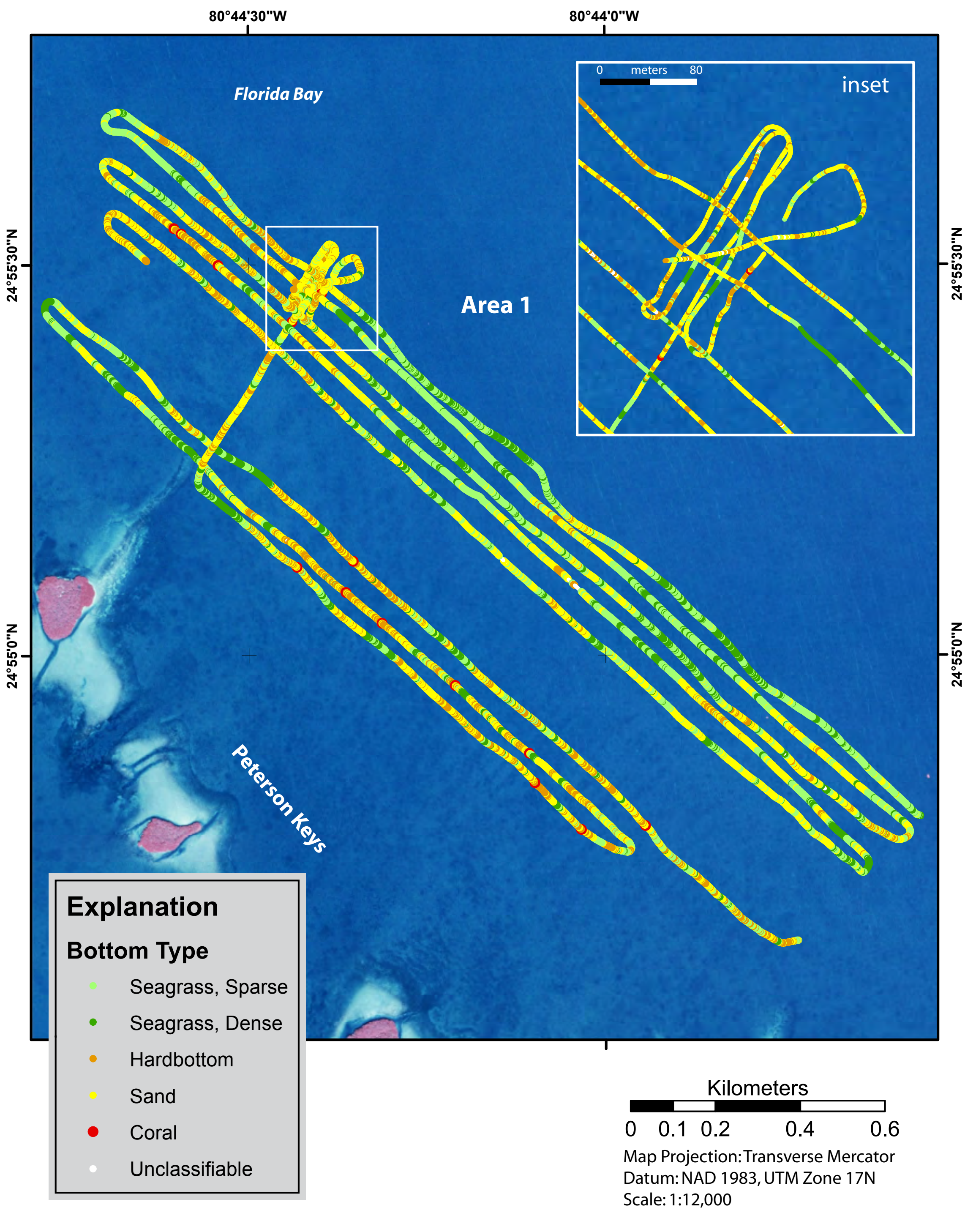

Figure 7. Bottom-type map for area 1. Inset in upper right corner is the area where Hudson and others (1989) cored a *Solenastrea bournoni* coral head. (See fig. 6 for area 1 location.)

Area 2

Area 2 is north of the most northerly Peterson Key and overlaps the north end of area 1. Water depth ranged from 4.4 to 5.9 m. The area was dominated by hardbottom and seagrass (fig. 8). Numerous small corals (5–10 cm) were found in this area, but due to low-visibility water conditions resulting in blurry images, some of those corals on the map may have been misinterpreted and may in fact be the orange clionid sponges. There were also computer problems during the processing of the images that resulted in the omission of numerous classified images in the central section of the survey line.

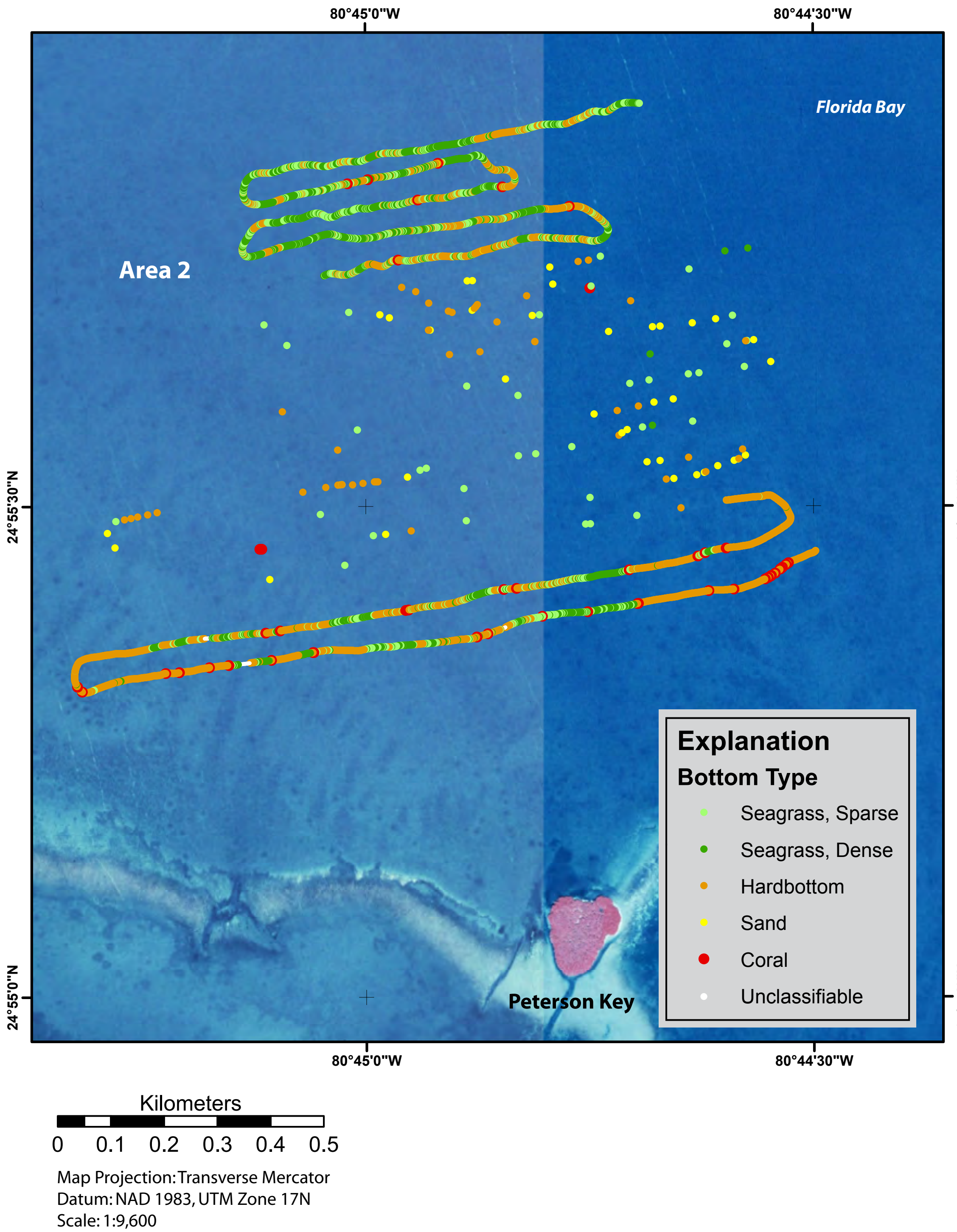

Figure 8. Bottom-type map for area 2. The absence of continuous data in the middle section of the survey line was the result of computer-related issues during the classification process. (See fig. 6 for area 2 location.)

Area 3

Area 3 is located along the Florida Bay side of Lower Matecumbe Key. Area 3 was surveyed because of information that implied moderate to large coral heads were present (Harold Hudson [retired NOAA, Florida Keys National Marine Sanctuary], oral commun., 2008). Water depth ranged from 4.3 to 5.7 m. Four track lines were run offshore, but after noting that most of the area was seagrass, the survey lines were moved closer to the coastline of Lower Matecumbe Key (fig. 9). A 400-square-meter area of hardbottom and sand was discovered in the lower southwest corner of the survey area, coinciding with the presence of numerous (~33) *S. bournoni* corals (inset, fig. 9). *Solenastrea bournoni* corals were concentrated in this small area and ranged in size from 10 cm to 70 cm. The water was exceptionally clear during the survey, and numerous small corals were observed from the boat.

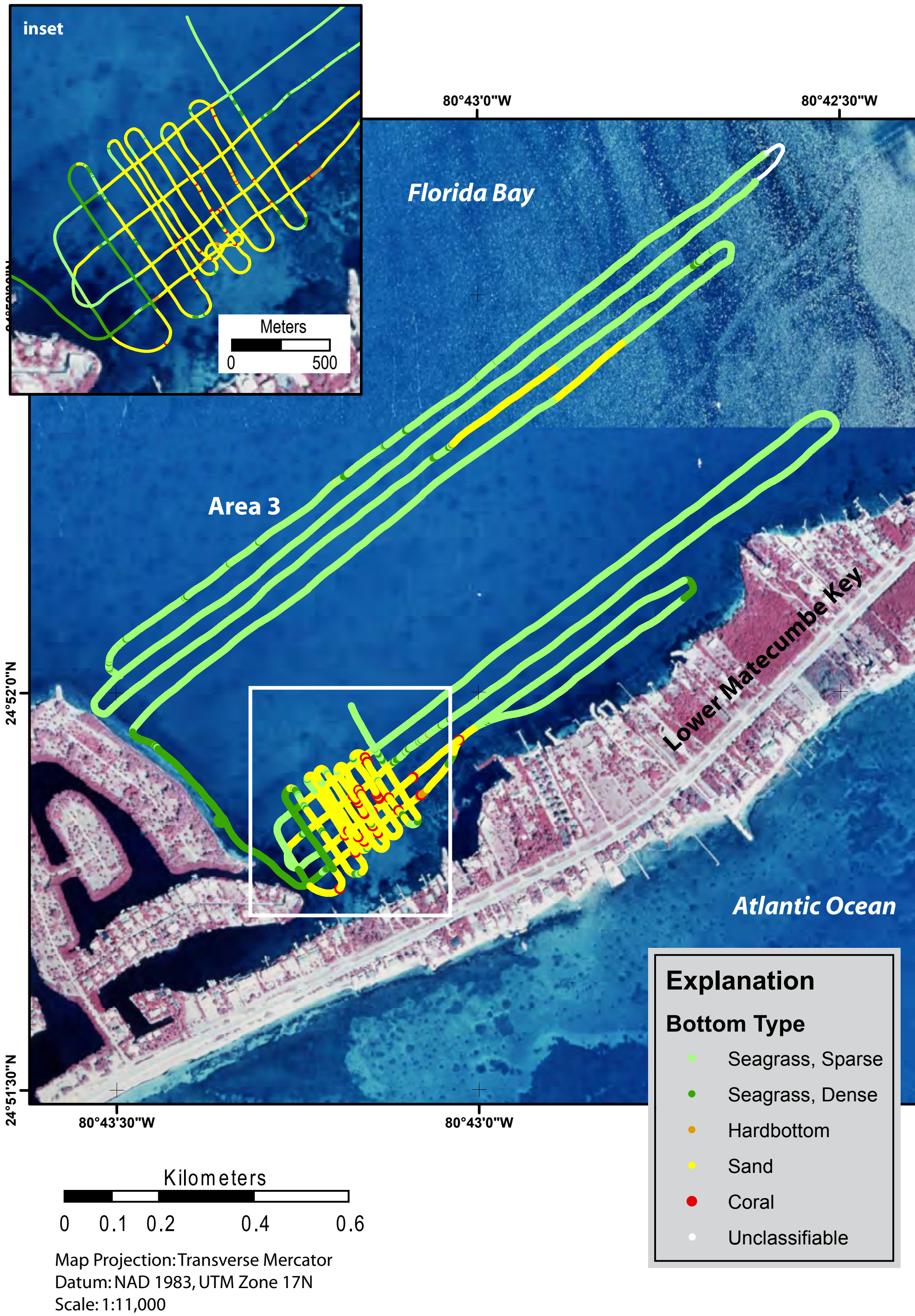

Figure 9. Bottom-type map for area 3. Majority of area 3 in this cove of Lower Matecumbe Key is sparse and dense seagrass. Inset in the figure shows an enlarged area in the elbow of the survey area characterized by sand and hardbottom. This area contained numerous small- (10 cm) to medium-sized (70 cm) *Solenastrea bournoni* coral heads. (See fig. 6 for area 3 location.)

Area 4

The area 4 survey was conducted north of Lignumvitae Key. Water depth ranged from 4.8 to 6.1 m. Interpretation of aerial photography and results published by Prager and Halley (1997) indicated that this area was primarily hardbottom and sandy substratum and had high potential for the occurrence of *Solenastrea* sp. corals (fig. 10). A shallow-water ridge of hardbottom was discovered along the east part of the survey area. Lush gorgonians and numerous small (<10-cm-diameter) corals were revealed in this region. Overall, area 4 showed gradation from seagrass at the west end to hardbottom and sand along the east survey boundary. To help clarify the zonal patterns, an interpolation map, or Thiessen polygon (fig. 11), was created for a portion of area 4. This map helped visually identify and isolate those regions of dense and sparse seagrass as well as areas of sand and hardbottom. The combination of the contour map and high-resolution aerial photography

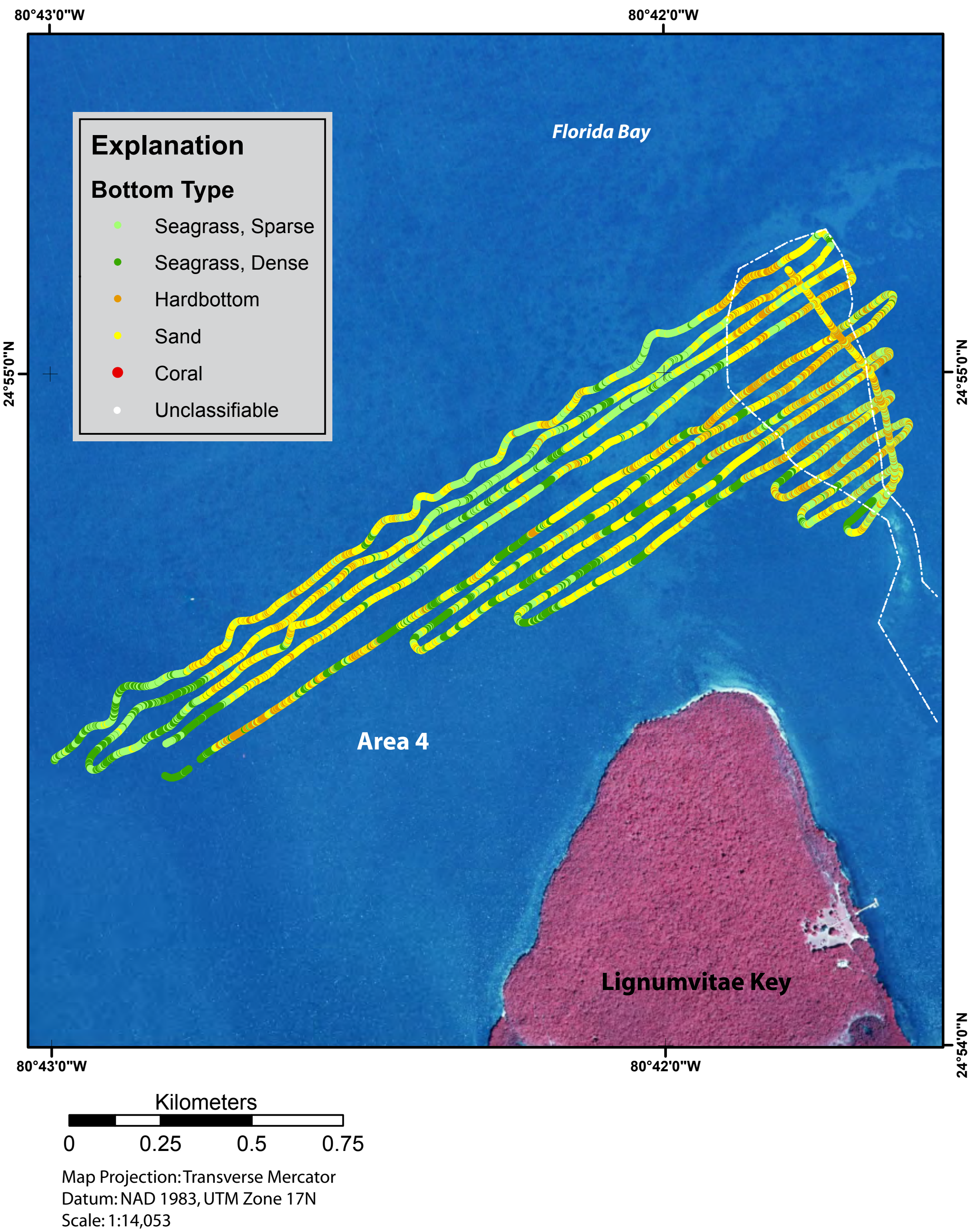

Figure 10. Bottom-type map for area 4 near Lignumvitae Key. The aerial photograph shows a ridge (dotted line) along the northeast section of the survey that corresponds to a region of hardbottom species, such as gorgonians and small corals. (See fig. 6 for area 4 location.)

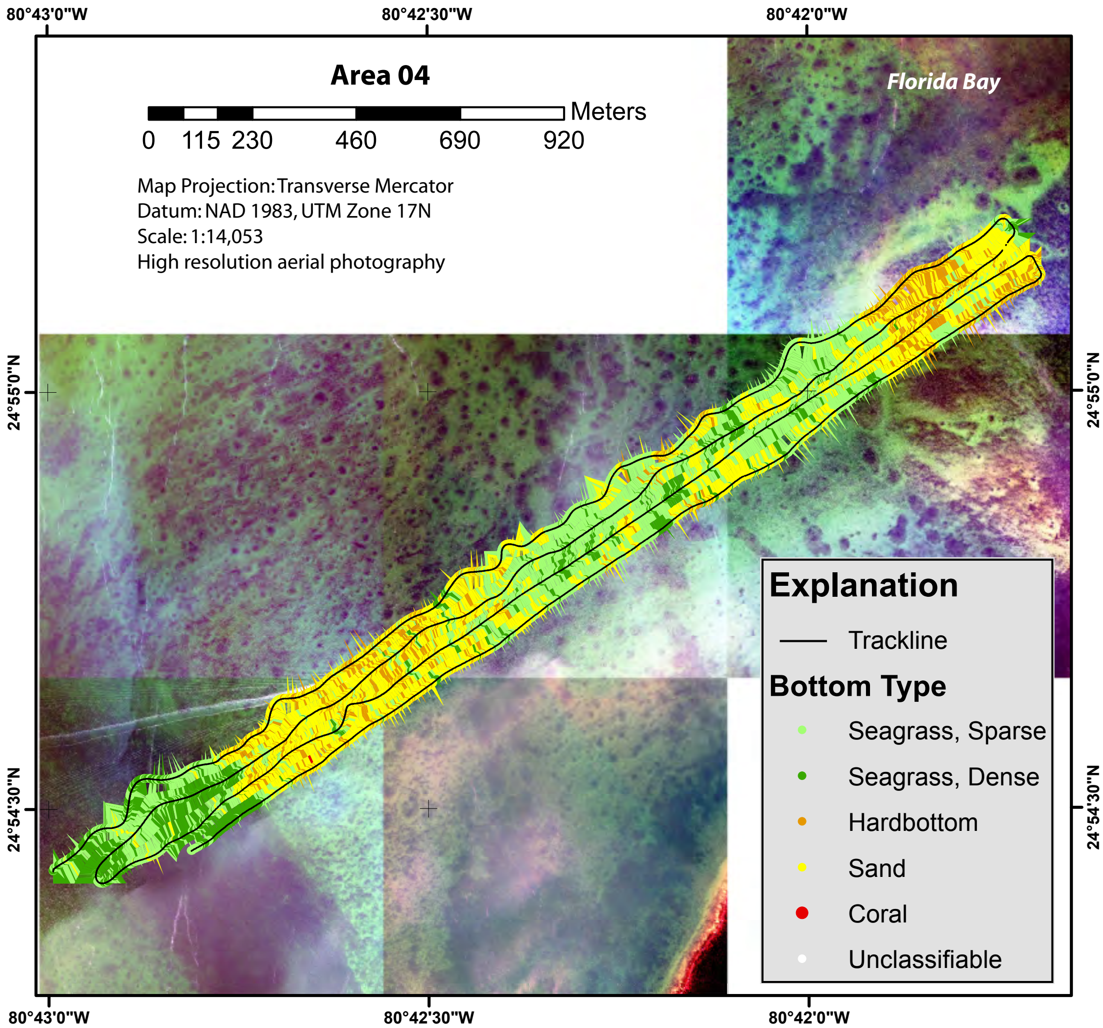

Figure 11. Interpolation (Thiessen polygon) map of the survey data for a portion of area 4 near Lignumvitae Key overlaid on high-resolution aerial photography. The interpolation plot reveals the zonation of seagrass, sand, and hardbottom types. Jagged edges result from the interpolation process during the Thiessen polygon creation.

showed how spatially variable the benthic habitats can be in Florida Bay. The numerous, small seagrass patches and sand-bottom types can be difficult to discern from hardbottom areas in the imagery. Without the aid of ATRIS, area 4 could have been interpreted as sand and seagrass. It is important to include multiple in-situ observations and ground-truthing when interpreting benthic habitats from aerial photography.

Prager and Halley (1997) interpreted much of Lignumvitae Key Basin as hardbottom based on limited visual (diver) interpretation and bottom grab samples. Results show that the area is much more heterogeneous than shown in the results published by Prager and Halley (1997), as seen in figure 12.

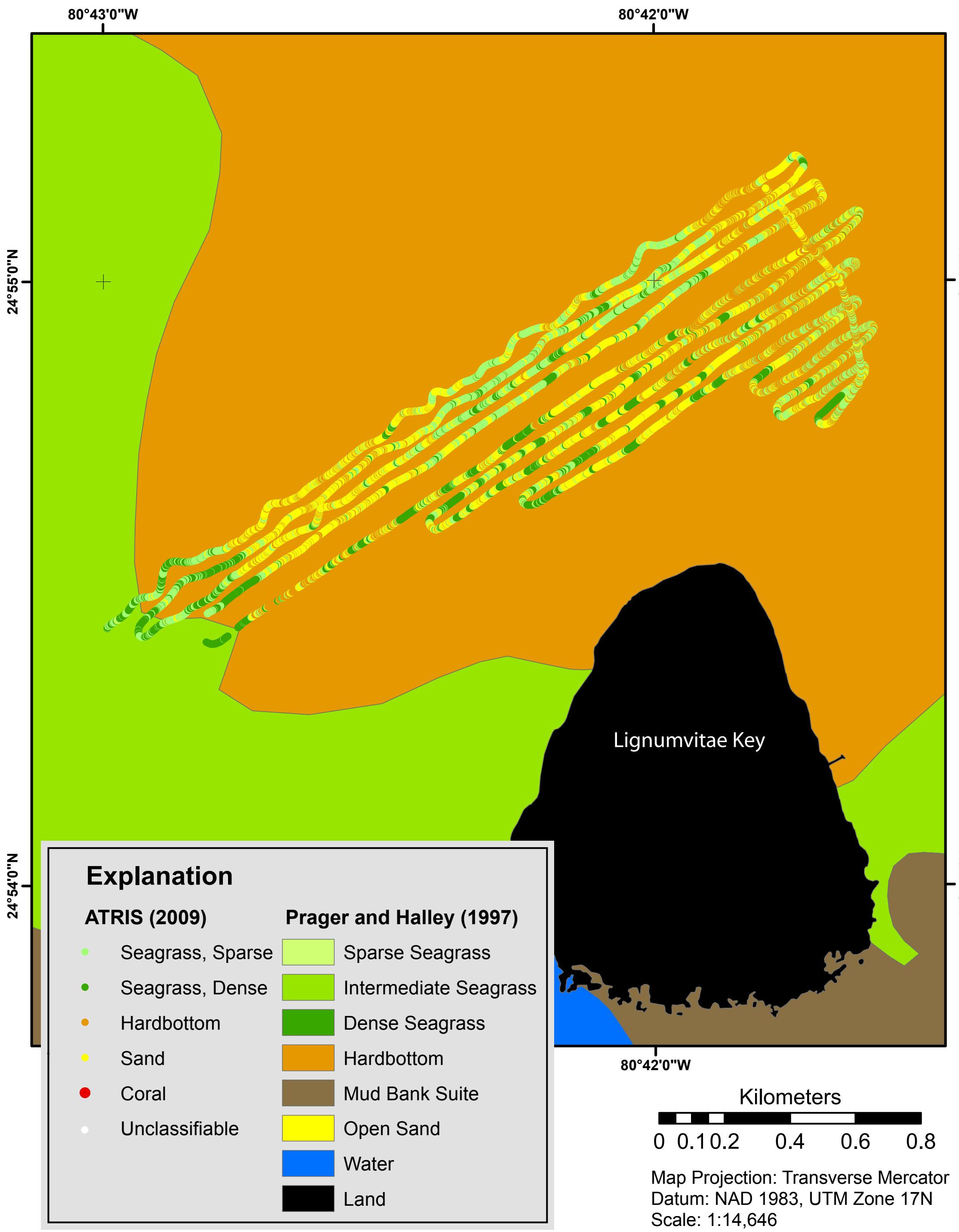

Figure 12. Area 4 classified bottom-type map near Lignumvitae Key superimposed on bottom-type map of Prager and Halley (1997). ATRIS results show high variability in benthic types in a small area when compared to large-scale benthic habitat surveys.

Conclusions

Numerous corals were located during the ATRIS surveys in Florida Bay. Whereas the *Solenastrea* sp. corals were widespread across the areas surveyed, there were no corals of significant size (>1 m) along our track lines that would provide historical records of surface-water salinity or temperature reaching beyond instrumental records from Florida Bay. However, ATRIS proved to be a productive tool for developing high-resolution benthic habitat maps. In addition to producing detailed habitat maps, ATRIS has potential as a valuable monitoring tool, as for example, for monitoring seagrass recovery from propeller scars or storm damage or for mapping expansion or contraction of seagrass beds. The post-processing of hundreds of thousands of images is time consuming, but the products of the system are highly detailed and provide important information on benthic habitat.

Acknowledgments

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