Final Report

Development of GIS maps for Southeast Florida Coral Reefs

DEP AGREEMENT NO. G0098

Produced by Grantee: Florida Fish and Wildlife Conservation Commission
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FLORIDA FISH AND WILDLIFE CONSERVATION COMMISSION
FISH AND WILDLIFE RESEARCH INSTITUTE

(In coordination with subcontract to
Nova Southeastern University Oceanographic Center)

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Executive Summary:
The present report outlines the results of an integrated mapping project undertaken to provide habitat maps of the shallow Palm Beach County seafloor between the 6m and 35m contours. This study is a continuation of a similar mapping study undertaken in Broward County, and results were produced such that a seamless and fully compatible mapping product is now available for both counties. The study area stretched from 26.4429^o (E. Linton Blvd) in the south to 26.9590^o (Jupiter Inlet) in the north. Compatibility with other, in particular NOAA, mapping products was also assured. Data types used in this mapping effort included Laser Airborne Depth Sounder (LADS) bathymetry, and single-beam acoustic seafloor discrimination, as well as ecological assessments and groundtruthing. The method used for acoustic seafloor discrimination was based on the first echo and its associated tail, and on the second echo returns of a 38 kHz and a 420 kHz signal. The survey system employed was an at-source-logging Biosonic transducers and Biosonics recording software. Data analysis used QTC Impact software and a suite of in-house custom-developed algorithms that allowed development of an acoustically-based biomass model for gorgonians, algae and barrel sponges (*Xestospongia muta*). A series of controlled experiments and field verifications verified that it was possible to acoustically distinguish between different scattering classes correlated to different seafloor types and different biomasses of scattering organisms.

Two sets of mapping products were produced. In Phase I, polygons were produced by visual interpretation of LADS bathymetry and input of the acoustic ground discrimination. Phase I maps were based on original habitat definitions by the NOAA biogeography program as previously adapted for the Broward County habitat mapping program. The final map showed a well-developed linear reef complex, which is a continuation of the outer reef of Broward County. Also, the middle reef of Broward County was observed in the southern part of Palm Beach County as a linear reef feature. In the northern area of Palm Beach County, a series of hardground ridges, likely a drowned headland, had no equivalent to any structures observed in the other counties. The majority of the area was covered by sand. Distinctions between linear reef, spur and groove, and colonized pavement were based on benthic cover as suggested by acoustic seafloor discrimination and geomorphology. The outer linear reef was subdivided into four habitats: aggregated patch reef, spur and groove, linear reef and deep colonized pavement. The area east of the outer linear reef consisted of a patchy environment with large patches of reef interspersed amongst the deep sand. These were more prevalent close to the reef and tapered off eastward, becoming more sandy. The spur and groove, linear reef, and deep colonized pavement comprised the outer reef and were separated mainly based on geomorphology. The outer reef was separated from the middle linear reef by a wide sand plane (deep sand).

Underwater video drop cameras aided in the refinement of the mapping categories. Accuracy assessment of an independent grid of target points showed the Phase I map to have a Users Accuracy of between 85%

and 93% and a Producers Accuracy of 89%. These accuracies compare to NOAA published map accuracies.

In Phase II, remote ground discrimination based on 38 and 420 kHz acoustic signals was used to map spatial complexity as well as biomass of indicator taxa (gorgonians, macroalgae, barrel sponges). Biomass models of Phase II had accuracies of 79.6% for gorgonians, 61.7% for macroalgae, and 86.1% for barrel sponges (*Xestospongia muta*). The biomass model derived from the 420 kHz signals agreed with spatial complexity derived from the 38 kHz E1/E2 parameter. The maps show distinct areas of higher biomass alternating with areas of lower biomass within the same habitats. Biomass frequently, but not always, correlated with acoustically derived spatial complexity, which agreed with diving observations and demonstrates the validity of the acoustic ground discrimination.

In conclusion, maps of the Palm Beach County's submarine habitats, with regards to geomorphological zonation and distribution of benthic biomass of certain indicator groups (gorgonians, algae barrel sponges), were produced that were satisfactorily accurate .

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OVERVIEW

Under DEP Agreement G0057 and NOAA Award NA160Z2440, the Florida Fish and Wildlife Research Institute (FWRI), with the assistance of Nova Southeastern University, was required to map the coral reefs and other benthic habitats found off Palm Beach County, FL. The area to be mapped extends from the 6m to the 35m contour and includes roughly 110 km^2. It was not specified whether the entire county was to be mapped due to the large area. However, excellent progress was made and the entire county was surveyed and mapped.

The overall aim of the project was to fill gaps in coverage of knowledge and monitoring of coral reef ecosystems and thus complemented the nationwide goals of the Coral Reef Conservation Act, NOAA, Executive Order 13089, and the National Action Plan.

The produced digital maps are to be included in the South Florida Electronic Area Contingency Plan that FWRI is developing jointly with the US Coast Guard to help support oil spill response and planning.

The Coral Reef polygons have been provided to NOAA charting division for inclusion into the nautical charts. The previous charts did not show any coral reef habitats.

The maps will also support state and county permitting activities related to sand mining and the minimization of impacts by submarine construction and excavation, such as pipeline routings.

Data will also be included in large-format maps to be shown on a future Palm Beach County Boating and Angling Guide, which is to be produced by FWRI. Such guides are to include extensive information about marine resources, their protection and conservation.

Benthic data will be added to the SEAMAP Bottom Mapping Project, which consists of various GIS data layers produced by the Atlantic States Marine Fisheries Commission and the States of North Carolina, South Carolina, Georgia, and Florida. The aim of the GIS data is to identify essential fish habitat.

Finally, the maps will be used for local and state-sponsored monitoring programs to assist in optimal site-selection.

In order to provide a product that is compatible with these goals, the following approaches were taken:

(1) Data were acquired from available sources.

(2) A complete bathymetric and acoustic seafloor discrimination survey based on single-beam sonar was run at 75m line-spacing over the entire area of Palm Beach County.
(3) Different survey systems (acoustic ground discrimination, LADS) were used for map production.
(4) Phase I maps were produced from visual interpretation of LADS bathymetry and are directly comparable to the previous Broward County mapping product.
(5) Phase II maps were produced from acoustic ground discrimination surveys and represent biomass density models for the dominant biotic classes: gorgonians, macroalgae, and barrel sponges (*Xestospongia muta*).
(6) The final mapping product includes results from both phases.

Stipulated and provided products were:

- Geo-referenced maps depicting classified benthic habitats.
- Habitat classification compatible with other NOAA mapping products.
- Geo-referenced maps of the distribution of benthic indicator category biomass for gorgonians, algae and barrel sponges biomass
- Production of GIS data layers.

The surveys and the survey team were structured as follows:

PI and overall responsibility: Bernhard Riegl
Responsible for inception of the survey, financial management, choice of survey hardware, oversight of surveys, quality control, submission of final report.

GIS, Phase I mapping and reporting: Brian Walker
Responsible for collation of all existing data types, development and maintenance of LADS GIS, development of operator-driven habitat mapping techniques, production of technical part (Phase I) of report, collation of final GIS product and production of metadata for submission.

Hydrographic Surveys, GIS and Phase II mapping and reporting: Greg Foster
Responsible for planning and execution of hydrographic surveys, building of survey hardware, maintenance of survey hard- and software, acoustic data processing, development of biomass model, development of biomass GIS, production of technical part (Phase II) of report.

PHASE I – INTERPRETATION OF BENTHIC HABITATS FROM HIGH-RESOLUTION BATHYMETRY

1.1 PHASE I - INTRODUCTION

The benthic mapping was divided into two phases of work, Phase I- visual interpretation of the bathymetric and photograph data and Phase II- hydrographic surveys for acoustic ground discrimination and their analysis. Phase I utilized high resolution bathymetric data for visual discrimination of bottom features. The acoustic ground discrimination data from Phase II provided spatially explicit data regarding the distribution of benthic fauna and flora as well as their biomass. It also allowed the discrimination of different substrata due to their physical properties as recorded in the acoustic signal. Both approaches thus supplement each other and provide strong synergy. Video groundtruthing aided in the classification of the habitats in both Phases I and II.

For the production of the Phase I maps, a bottom-up approach was taken (Hewitt et al., 2004). The high resolution LADS bathymetry was used to map reef geomorphology; acoustic data from the ground-discrimination surveys were used to aid definition of the geomorphologic features into habitat types; and a waterproof drop video camera from a boat was used as groundtruthing tool to confirm substrate type. The entire area mapped was roughly 254 square-kilometers. The shallow inshore seafloor from the ~0m to -6m contour was mapped using a combination of assimilated data types including aerial photography and high-resolution bathymetry and the deeper seafloor habitats, from the -6m to the -35m contour, were mapped using high-resolution LADS bathymetry and acoustic ground discrimination. The result produced a seamless GIS benthic habitat classification of the entire nearshore reef system in Palm Beach County.

1.2 PHASE I - BATHYMETRIC MAP CREATION

The bathymetric survey that produced the data used in visual seafloor interpretation was conducted by Tenix LADS Corporation of Australia, using the LADS system with a sounding rate of 900 Hz (3.24 million soundings per hour), a positioning accuracy of 95% at 5 m circular error probable (CEP), a horizontal sounding density of 4m x 4m, a swath width of 240 meters, area coverage of 64 Km^2/hr, and a depth range of up to 70m, depending on water clarity. This survey encompassed North Broward County, all of Palm Beach County, and southern Martin County, approximately 75 km in shoreline length, and from the shore eastward to depths of ~40m. The entire survey area covered approximately 254 square kilometers of marine habitat. The bathymetric data were gridded by triangulation with linear interpolation, sun-shaded at a 45° angle and azimuth, and mosaicked with aerial photography of the land. This final image was used as the foundation for mapping.

1.3 PHASE I FINAL MAPPING CATEGORIES

Similar to the Broward habitat mapping effort (Report on DEP Agreement No G0057, NOAA Award NA160Z2440), the final map polygons conformed to the NOAA hierarchical classification scheme used in Puerto Rico and the U.S. Virgin Islands NOAA Technical Memorandum NOS NCCOS CCMA 152 (Kendall et al., 2001), with some modification. All data were mapped in ArcGIS 9x and polygons were drawn at a scale of 1:6000 with a one acre minimum mapping unit (MMU). The most notable modification was in the mapping of different zones. The Puerto Rico mapping effort classified the polygons into nine reef zones according to the features' relationship along the shore (i.e. lagoon, back reef, fore reef, bank/shelf, etc.). These categories were useful because the NOAA effort mapped everything from land and intertidal out to the bank/shelf escarpment. However, many of these mapped zones did not apply in South Florida. The absence of an emergent reef in South Florida precluded mapping zones such as lagoon, back reef, and reef crest. Also our effort was confined to depths between 6m and 35m, which excluded the land. The intertidal zone was not distinguished in this project. Thus, all features mapped in this project reside within the Bank/Shelf, Fore Reef, or Bank/Shelf Escarpment zones.

Benthic habitats were made compatible to the NOAA Puerto Rico mapping effort with slight modification and the previous Broward County mapping effort as closely as possible. The most notable change was the omission of submerged vegetation from Phase I (the basemap layer) due to the inability to detect seagrass and macroalgae from bathymetry alone. Thus, the detection of these habitat types was conferred to Phase II of this project. Groundtruthing showed that much of the deeper sand contained macroalgal mats and sparse sea grass beds (*H. decepiens*).

The hierarchical classification scheme for the Palm Beach County mapping effort is as follows:

Coral Reef and Hardbottom
    Coral Reef and Colonized Hardbottom
        - Linear Reef
            Outer*
            Middle*
        - Spur and Groove
        - Individual Patch Reef
        - Aggregated Patch Reef
        - Colonized Pavement
            Deep*
            Shallow*
        - Ridge*
            Deep*

        Shallow*
      - Deep Ridge Complex*
- Unconsolidated Sediments:
  - Sand
    - Deep*
    - Shallow*
- Other Deliniations:
  - Artificial
  - Inlet Channel*
  - Sand Borrow Areas*
  - Unknown

1. 4. PHASE I - DESCRIPTION OF MAPPED REEF HABITATS

All definitions are NOAA definitions as described in Technical Memorandum NOS NCCOS CCMA 152 (Kendall et al 2001) and on their web site (http://biogeo.nos.noaa.gov/products/benthic/htm/ descrip.htm) unless otherwise noted by an asterisk (*). The here described categories are also fully compatible to those previously used for the mapping of Broward County benthic categories.

Coral Reef and Hardbottom: Hardened substrate of unspecified relief formed by the deposition of calcium carbonate by reef building corals and other organisms (relict or ongoing) or existing as exposed bedrock.

> **Coral Reef and Colonized Hardbottom:** Substrates formed by the deposition of calcium carbonate by reef building corals and other organisms. Habitats within this category have some colonization by live coral.
>
> > **Linear Reef:** Linear coral formations that are oriented parallel to shore or the shelf edge. These features follow the contours of the shore/shelf edge. This category is used for such commonly used terms as fore reef, fringing reef, and shelf edge reef.
> >
> > > **Linear Reef-Outer*:** This category included essentially only the reef crest of the outer reef.

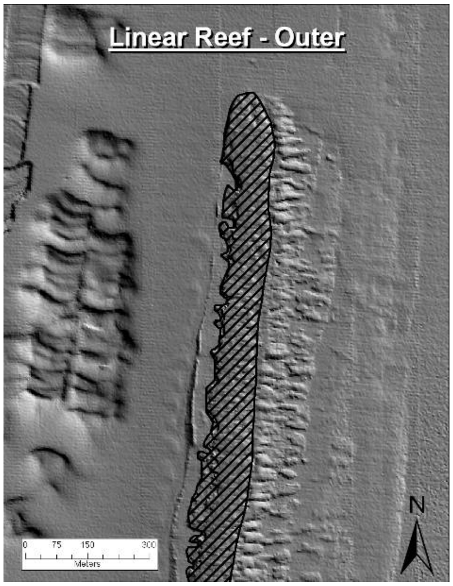


Figure 1.1: *Illustration of bathymetric features interpreted as Linear Reef - Outer.*

Linear Reef-Middle*: Since the middle reef exhibited much less clear morphological differentiation than the outer reef, it was not practical to subdivide it into several units. It is therefore encompassed in one single category, "linear reef". This category is given a unique color identifier since the acoustic roughness measures suggest a largely distinct community structure from hardgrounds, shallow reef and outer reef.

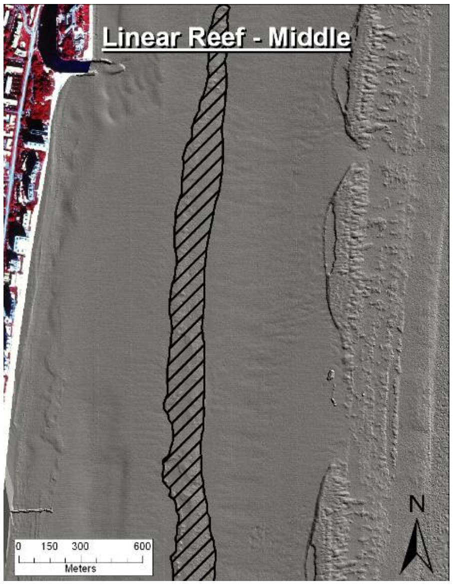


Figure 1.2: *Illustration of bathymetric features interpreted as Linear Reef - Middle.*

Spur and Groove: Habitat having alternating sand and coral formations that are oriented perpendicular to the shore or bank/shelf escarpment. The coral formations (spurs) of this feature typically have a high vertical relief compared to pavement with sand channels and are separated from each other by 1-5meters of sand or bare hardbottom (grooves), although the height and width of these elements may vary considerably. This habitat type typically occurs in the fore reef or bank/shelf escarpment zone.

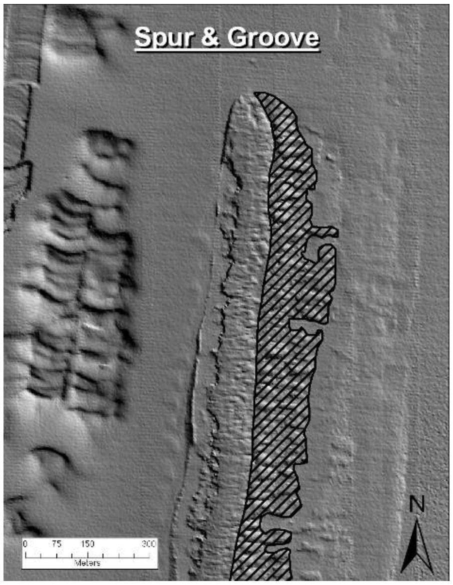


Figure 1.3: *Illustration of bathymetric features interpreted as Spur and Groove.*

Patch Reef: Coral formations that are isolated from other coral reef formations by sand, seagrass, or other habitats and that have no organized structural axis relative to the contours of the shore or shelf edge. A surrounding halo of sand is often a distinguishing feature of this habitat type when it occurs adjacent to submerged vegetation.

Individual Patch Reef: Distinctive single patch reefs that are equal to or larger than the minimum mapping unit (MMU).

Aggregated Patch Reef: Clustered patch reefs that individually are too small (smaller than the MMU) or are too close together to map separately

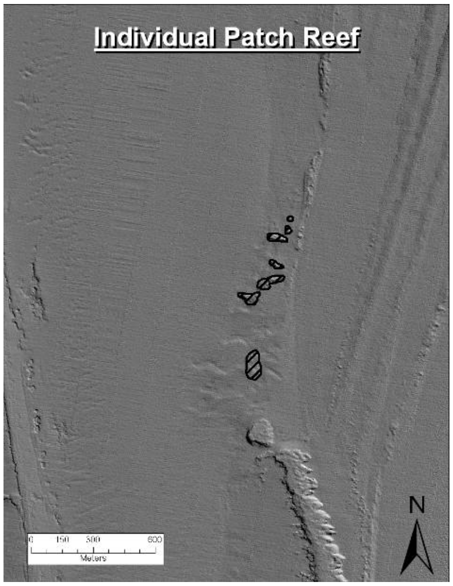


Figure 1.4: *Illustration of bathymetric features interpreted as Individual Patch Reef.*

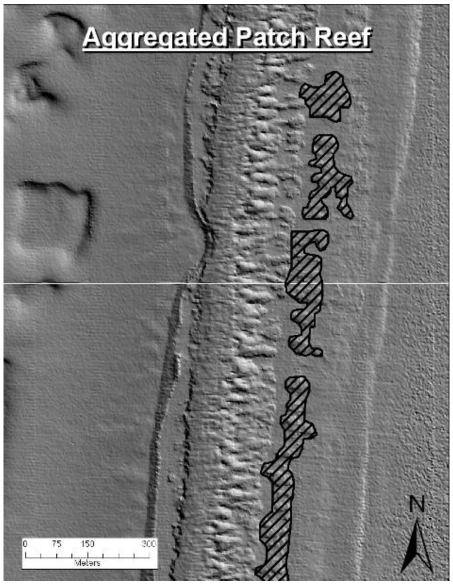


Figure 1.5: *Illustration of bathymetric features interpreted as Aggregated Patch Reef.*

Colonized Pavement: Flat, low-relief, solid carbonate rock with coverage of macroalgae, hard coral, gorgonians, and other sessile invertebrates that are dense enough to partially obscure the underlying carbonate rock.

> **Colonized Pavement-Deep*:** This category includes a transition zone from colonized pavement to colonized rubble. Since much of the rubble in the lee of the outer reef is at least partly consolidated, the differentiation between colonized pavement and rubble would be somewhat artificial.

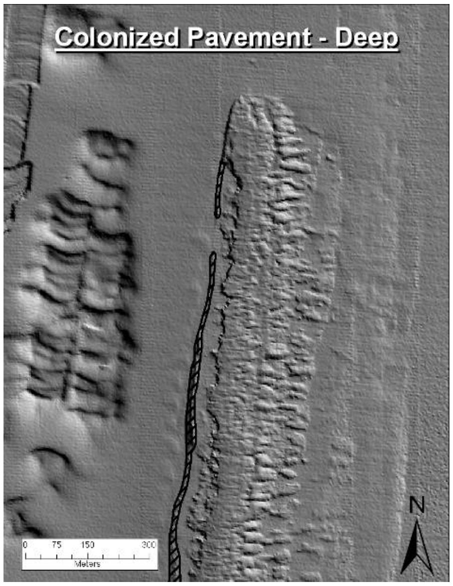


Figure 1.6: *Illustration of bathymetric features interpreted as Colonized Pavement - Deep.*

Colonized Pavement-Shallow*: This category includes flat, low-relief hardbottom and rubble. This habitat was limited in Palm Beach to the extreme nearshore. This habitat can have variable sand cover, which shifts according to wave-energy in response to weather. Thus, some of the colonized pavement will always be covered by shifting sand and the density of colonization will be highly variable and likely linked to temporal changes.

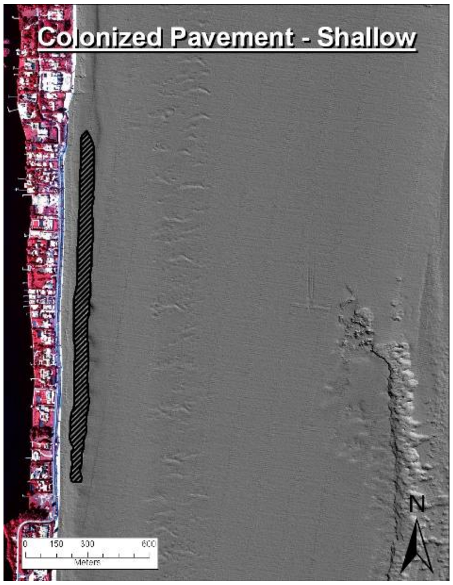


Figure 1.7: *Illustration of bathymetric features interpreted as Colonized Pavement – Shallow.*

Ridge*: Linear, shore-parallel, low-relief features that appear to be submerged cemented beach dunes. Presumably, they are the foundation upon which the Linear Reefs grew and consist of early Holocene beachrock ridges, however, verification is needed. The biological cover is similar to that of colonized pavement-a coverage of macroalgae, hard coral, gorgonians, and other sessile invertebrates that are dense enough to partially obscure the underlying carbonate rock.

> **Ridge-Deep*:** While the geological provenance of the structure is not clear, its morphology suggests it to be a ridge of older age than the outer reef, possibly the structure on which the outer reef initiated. It consists of hardground with variable and shifting sand cover and benthic communities.

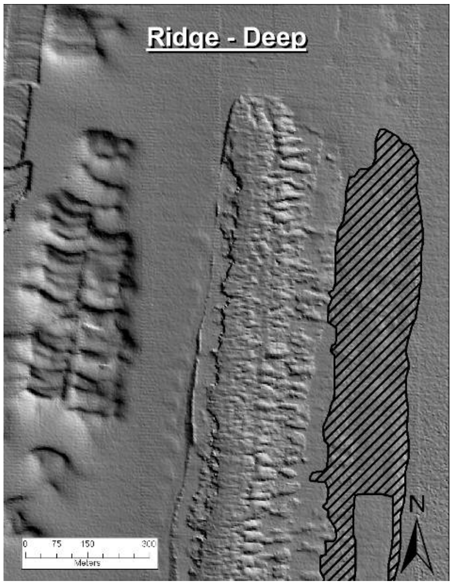


Figure 1.8: *Illustration of bathymetric features interpreted as Ridge – Deep.*

Ridge-Shallow*: Ridges found in shallow water near shore which are geomorphologically distinct, yet their benthic cover remains similar to the shallow colonized pavement communities on the surrounding hard-grounds. They presumably consist of early Holocene beachrock ridges with possibly some *Acropora* framestones however verification is needed.

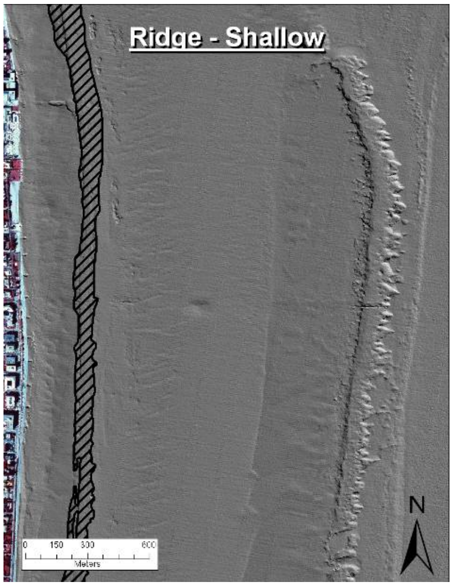


Figure 1.9: *Illustration of bathymetric features interpreted as Ridge – Shallow.*

Deep Ridge Complex*: A complex of ridges found in deep water in northern Palm Beach County. These features reside in depths from 20 to 35m and are presumed to be of cemented beach dune origin. Most of this habitat consists of low cover, deep communities dominated by small gorgonians, sponges, and macroalgae, but denser areas exist, especially near areas of higher relief.

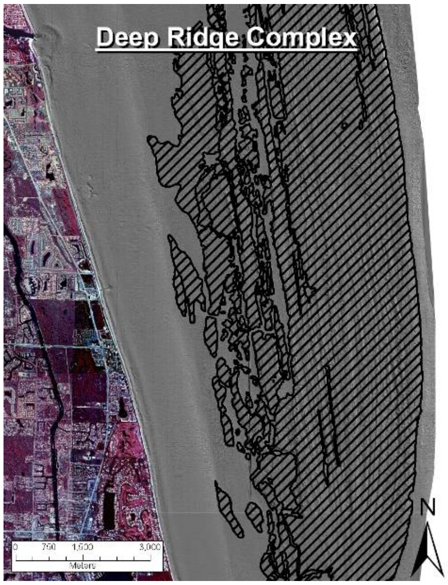


Figure 1.10: *Illustration of bathymetric features interpreted as Deep Ridge Complex.*

Unconsolidated Sediments: Unconsolidated sediment.

Sand: Coarse sediment typically found in areas exposed to currents or wave energy. This was arbitrarily split into deep and shallow to account for infaunal biological differences.

Sand–Deep*: Sand habitat primarily deeper than the 25 m contour.

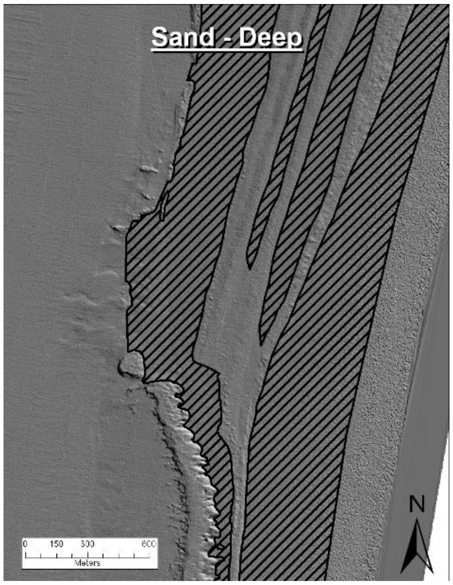


Figure 1.11: Illustration of bathymetric features interpreted as Sand – Deep.

Sand–Shallow*: Shallow sand is generally highly mobile. Large, mobile sand pockets are generally found between consolidated hardgrounds. It is believed that the sand movement is a deciding factor in the generation of benthic patterns.

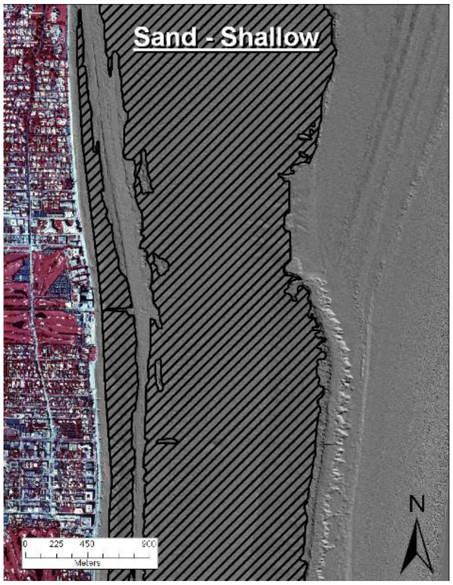


Figure 1.12: Illustration of bathymetric features interpreted as Sand – Shallow.

Other Delineations:

Artificial: Man-made habitats such as submerged wrecks, large piers, submerged portions of rip-rap jetties, and dredge spoil. The example below illustrates several submerged ships and piles of concrete placed there as part of Palm Beach County's artificial reef program.

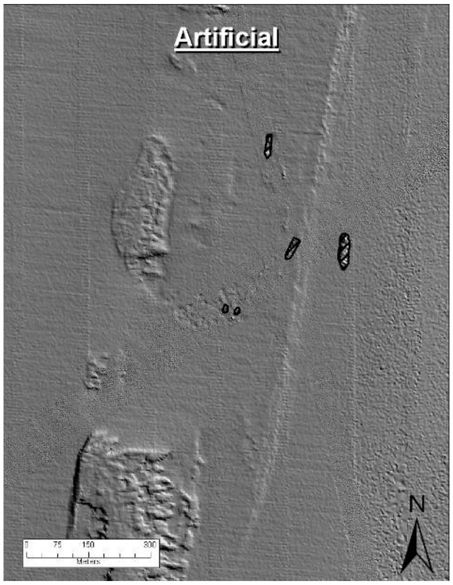


Figure 1.13: *Illustration of bathymetric features interpreted as Artificial.*

Unknown*: Features which have not yet been identified. This was mainly an area in the north at the 60ft contour that appeared to be sand-draped outcrops.

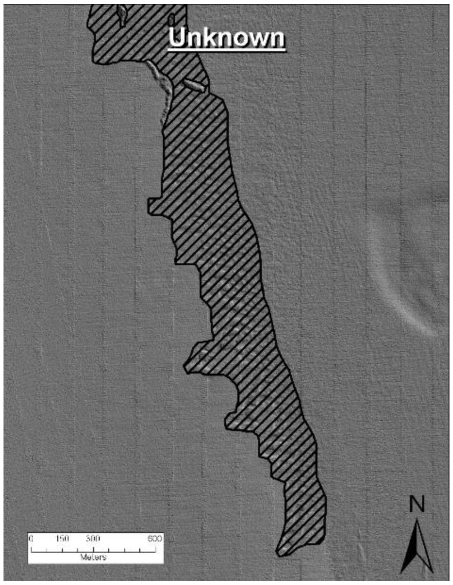


Figure 1.14: *Illustration of bathymetric features interpreted as Unknown.*

Inlet Channel*: Palm Beach Harbor inlet channel.

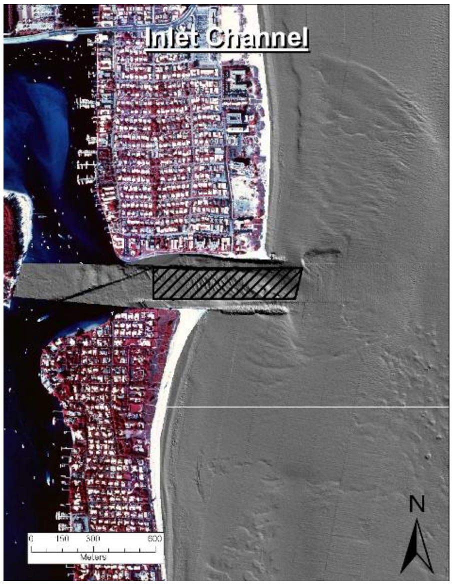


Figure 1.15: *Illustration of bathymetric features interpreted as Inlet Channel.*

Sand Borrow Areas*: Several borrow pits from previous dredging projects are found throughout the survey area. While they are all found in sandy areas, at the bottom many of them expose limestone and thus small ridges or patch reefs are formed that can harbor a strongly localized and patchy, but sometimes dense, benthic fauna.

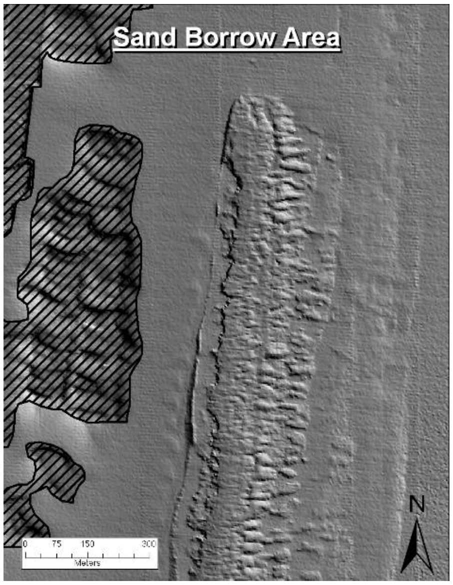


Figure 1.16: *Illustration of bathymetric features interpreted as Sand Borrow Area.*

1. 5. PHASE I - GROUNDTRUTHING METHODS

For groundtruthing assessment, eight linear corridors, perpendicular to the shoreline and equally spread throughout the county were chosen. Within these corridors videos of the seafloor were collected for several minutes per area in different targeted locations. These videos allowed for the clear characterization of habitat on the bottom. A total of 334 points were collected. These videos were used in the groundtruthing of both Phases I and II and the accuracy assessment of Phase I.

In Phase I, approximately half of the videos (a total of 187) were used for groundtruthing to help decide how data classes should be interpreted during the mapping process (Figure 1.17). Each video location was plotted in GIS and described according to its content. These locations were color-coded according to their video descriptions and overlaid on the Phase I habitat map. The groundtruthing transects thus spanned many different habitats and were ideal to detect habitat transition zones. All groundtruthing points were included in the final GIS and linked to a table including their relevant information. There was high agreement with the habitat map and the groundtruthing points therefore minimal changes were required.

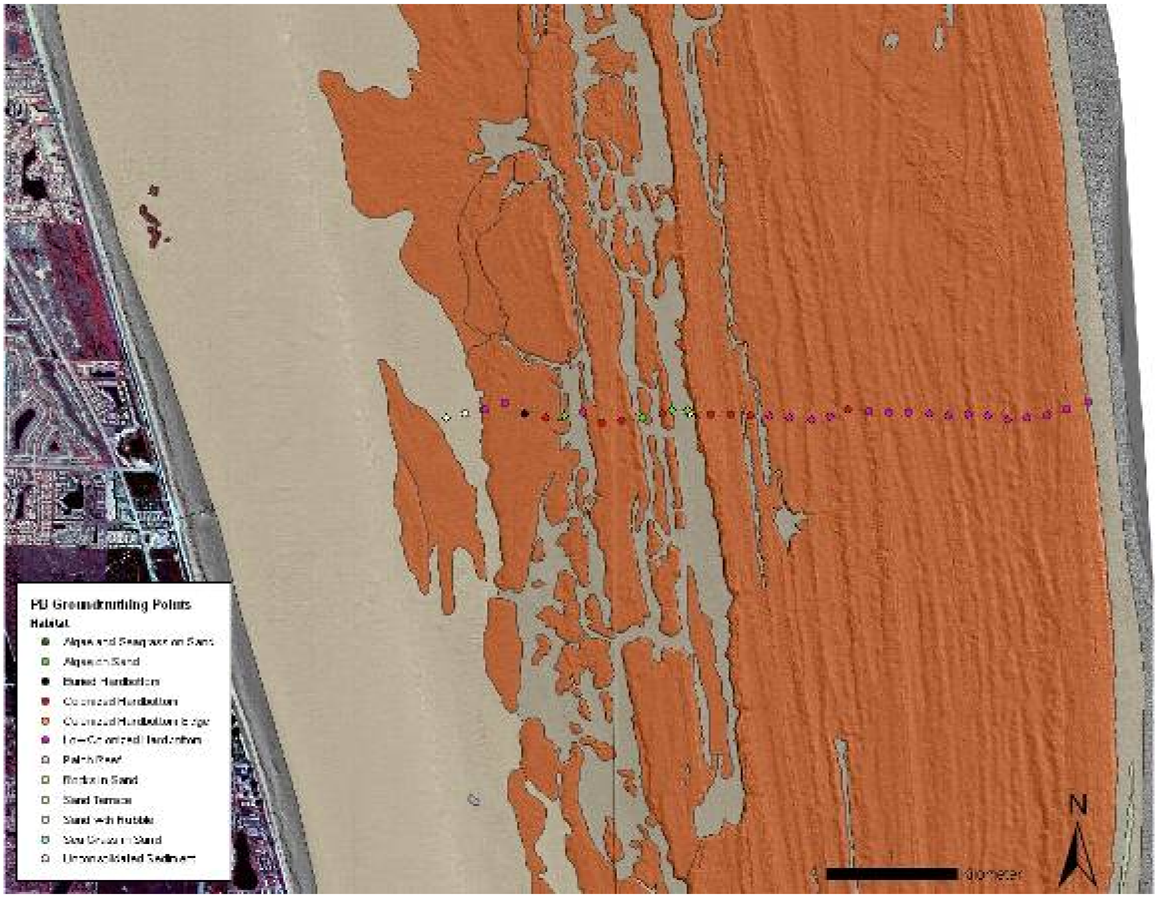


Figure 1.17: *Example of a groundtruthing transect offshore in northern Palm Beach County. The points are colored according to their habitat characterization from the video.*

1.6. PHASE I - ACCURACY ASSESSMENT METHODS

The remainder of the videos (a total of 147) was used for accuracy assessment of the Phase I map by confusion matrix approach (Ma and Redmond 1995). After the map polygons were drawn and classified using the acoustic discrimination systems, groundtruth points, and LADS bathymetry, the accuracy assessment point locations were imported into the GIS to compare actual vs. mapped habitats (Figure 1.18).

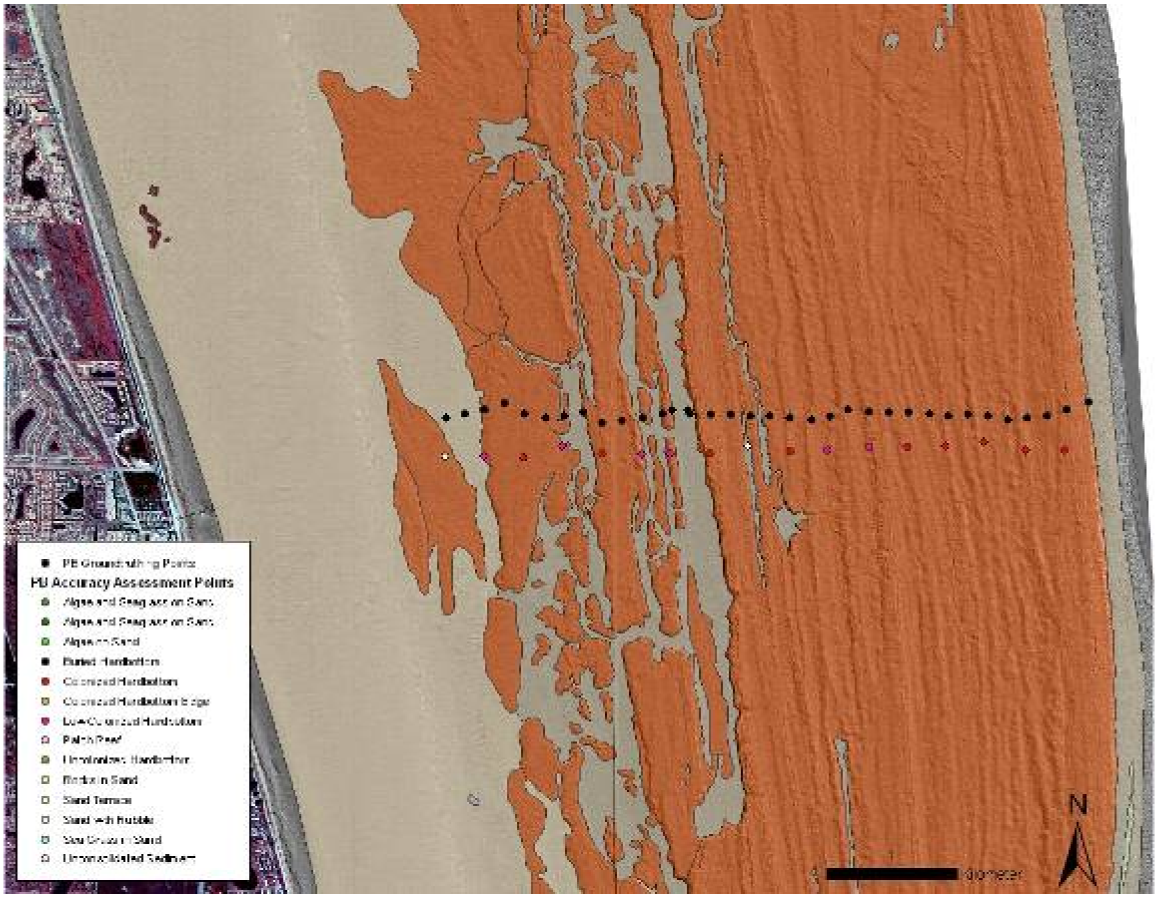


***Figure 1.18**: Example of the accuracy assessment transect in northern Palm Beach County. The black dots are the groundtruthing points and the colored points are the accuracy assessment locations.*

1.7. PHASE I ACCURACY ASSESSMENT RESULTS

The results of the accuracy assessment yielded a high level of accuracy (Figure 1.19). Total map accuracy was 89.2%, equaling the total map accuracy for the Broward maps (Report on DEP Agreement No G0057, NOAA Award NA160Z2440). User's and producer's accuracies were similar as well. Accuracy assessment showed good user's and producer's accuracies for all categories. The lowest accuracy was noted in the user's accuracy for Coral Reef/Hardbottom. Of the 58 total points counted for this class, 9 of them were incorrectly mapped as Unconsolidated Sediment (84.5%). This is not surprising due to the ephemeral nature of some of the low relief hardbottom areas. These sites area often covered and uncovered by sand movement during large storms. In fact much of the nearshore hardbottom south of Palm Beach Inlet evident in the LADS data was buried by sediment two years ago during hurricane season (FWRI SECREMP report).

These results are also consistent with accuracy assessments using other mapping methods. Kendall et al (2001) reported a user's accuracy of 86% and producer's accuracy of 97% for Unconsolidated Sediments in the NOAA Puerto Rico and Virgin Island mapping effort. These results are similar, albeit slightly higher than the Palm Beach County mapping effort's user's (93%) and producer's (89%) accuracies for Unconsolidated Sediments. For Coral Reef/Hardbottom, Kendall et al (2001) reported user's accuracy of 97% and producer's accuracy of 85% whereas the Palm Beach County mapping yielded a slightly lower user's accuracy (85%) and slightly higher producer's accuracy (89%). The NOAA total mapping accuracy was high due to 100% accuracy of mapping submerged vegetation. When this category was removed, their maps showed similar accuracies as report here (91%).

		Reference Data			
		Unconsolidated Sediments	Coral Reef/ Hardbottom	Row Totals	User's Accuracy
Mapped Classes	Unconsolidated Sediments	75	6	51	92.6%
	Coral Reef/ Hardbottom	9	49	58	84.5%
	Column Total	84	55	139	
	Producer's Accuracy	89.3%	89.1%		89.2%
					Total Map Accuracy

Po = 89.2%
T = 77.6% (95CI's for T are 67.0% and 88.3%)

Figure 1.19*: Confusion matrix for the Phase I generalized mapped classes.*

1.8. PHASE I - HABITAT MAPPING RESULTS & DISCUSSION

The results from the bathymetric surface creation showed a seamless hillshaded surface of the seafloor of the entire county from 0 to ~40m depth mosaicked with coastal imagery (Figure 1.20). Many seafloor features were evident in the surface, thus this surface was also used to plan the acoustic surveys to ensure maximum coverage of coral reef resources. Visual interpretation of this surface in GIS yielded a habitat characterization of the bathymetric layer (Figure 1.21). The characterization of habitats allowed the calculation of habitat areas countywide (Table 1.1). A summary of these data showed that of the ~254 Km² mapped, 35% was Coral Reef and Colonized Hardbottom and 64% was unconsolidated sediment. The estimation of Coral Reef and Colonized Hardbottom is probably slightly overestimated because it included the entire area of Aggregated Patch Reef into its calculation and this habitat is composed of a mixture of sand and reef habitat. The Deep Ridge Complex included the largest amount of Coral Reef and Colonized Hardbottom habitat comprising 29% of the total mapped area in Palm Beach County, approximately 74 Km². The Outer Linear Reef (LR-Outer, CP-Deep, and Spur & Groove combined) occupied the next biggest area of Coral Reef and Colonized Hardbottom contributing >5Km² to the total mapped area (~2%). As in the Broward mapping effort (Report on DEP Agreement No G0057, NOAA Award NA160Z2440), the outer reef was separated by geomorphology into deep colonized pavement (drowned back reef), linear reef outer (drowned reef crest), and spur & groove (drowned). This allowed for the characterization of the entire reef structure or its individual parts. These different areas were demarcated as different habitats under the assumption that differences in topographic complexity between the features will create slightly different habitats. Unconsolidated Sediments (Sand-Shallow, Sand-Deep, and Sand Borrow Areas combined) were the dominating seafloor feature in Palm Beach County contributing 162 Km² to the total mapped area (64%). Vegetation was seen inhabiting some areas of unconsolidated sediments, especially in the fringes of the Outer Linear Reef. This was not captured in the Phase I mapping but was modeled during Phase II.

Several differences from Broward County were evident in Palm Beach County. The most notable was the inclusion of a new category, the deep ridge complex. This is an expansive area of many ridges in the northern half of the county that extends from about 20m to 35m depth (Figure 1.22). Groundtruthing showed that most of this feature contained a similar habitat throughout so it was decided to make it one large area in the Phase I map. There were notable areas of increased biological communities within this feature which were captured in the acoustic mapping (Phase II).

Another clear difference between the two counties was the near-absence of near-shore, shallow-water reef communities (<20m) in Palm Beach. Broward habitat mapping found ~33 Km² of this type of habitat between the shallow ridge, shallow colonized pavement, and inner reef along a much shorter coastline (~40

Km for Broward vs. ~73 Km for Palm Beach County). The communities on this habitat in Broward contain some of the highest scleractinian coverage of any habitat and are host to a large diverse assemblage of fishes (Ferro et al 2005). This habitat is almost absent in Palm Beach County (~1 Km²).

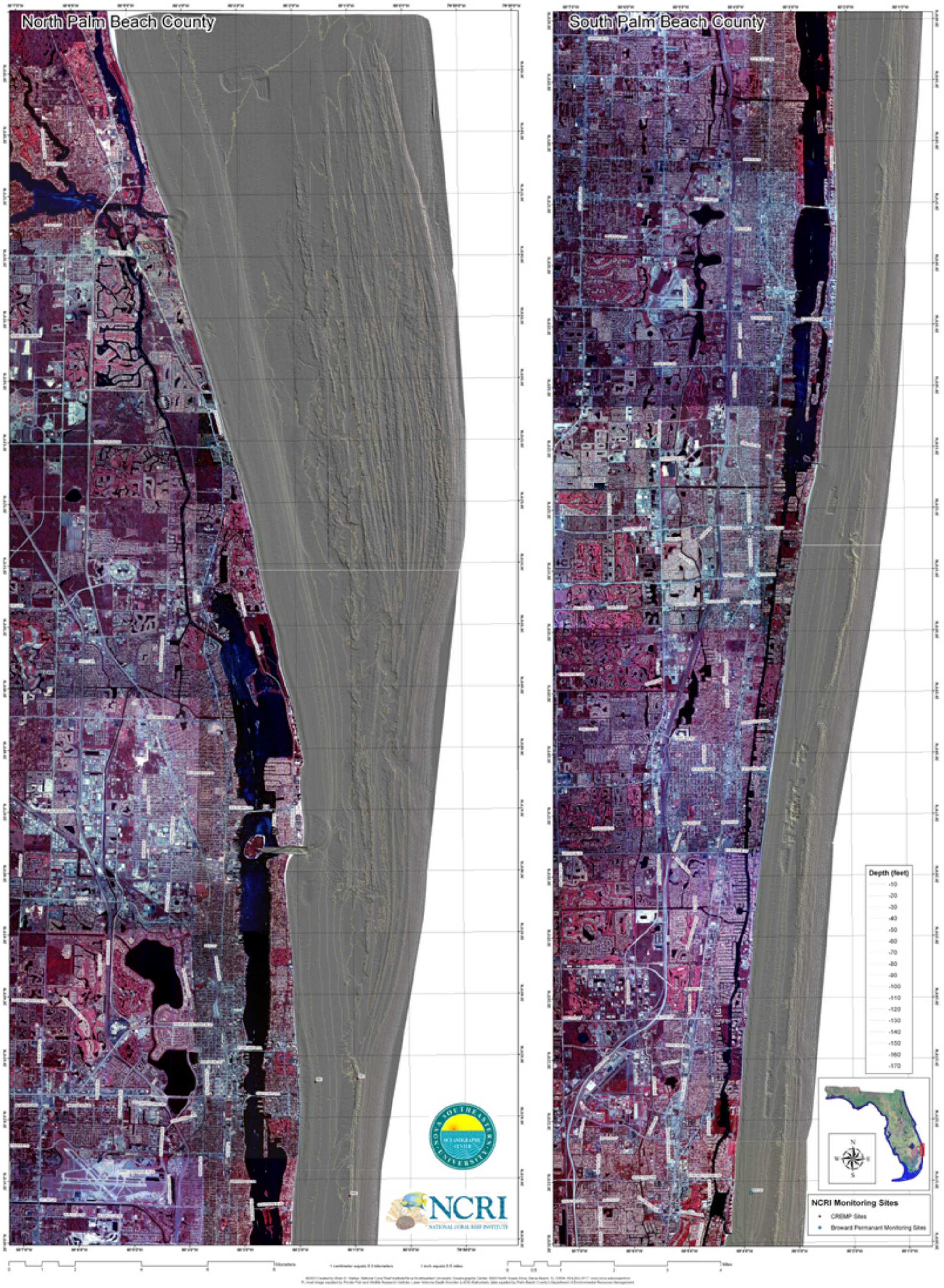


Figure 1.20. *Map of the bathymetric base-layer used in the Phase I mapping and to plan the surveys in Phase II. The grey surface is the hillshaded seafloor from 0 to ~40m depth.*

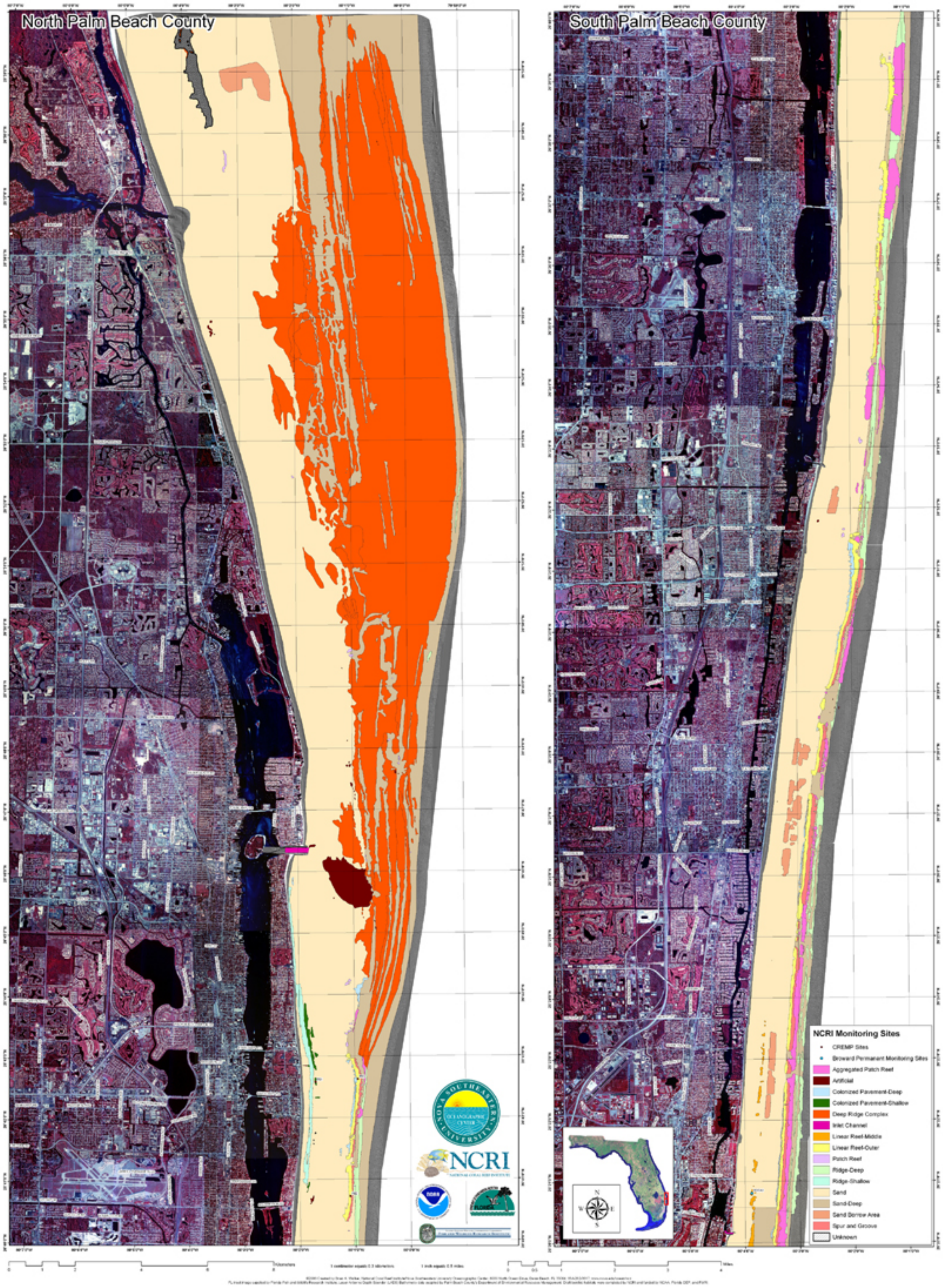


Figure 1.21. *Benthic habitat map of Palm Beach County after Phase I. The colors correspond to habitats discerned from the bathymetric layer and confirmed with video groundtruthing.*

Habitat	Type	Modifier	Area (Km²)	% of Total
Coral Reef and Colonized Hardbottom	Colonized Pavement	Shallow	0.32	0.13%
		Deep	0.52	0.20%
	Deep Ridge Complex		74.20	29.25%
	Patch Reef		0.16	0.06%
	Linear Reef	Outer	3.20	1.26%
		Middle	0.18	0.07%
	Spur & Groove		1.82	0.72%
	Aggregated Patch Reef		3.65	1.44%
	Ridge	Shallow	0.88	0.35%
		Deep	3.91	1.54%
Unconsolidated Sediment	Sand	Shallow	120.42	47.48%
		Deep	39.10	15.42%
Other Delineations	Sand Borrow Area		2.63	1.04%
	Artificial		1.49	0.59%
	Inlet Channel		0.11	0.04%
	Unknown		1.07	0.42%
Total			253.66	100.00%

Coral Reef and Colonized Hardbottom	88.83	35.02%
Unconsolidated Sediment	162.16	63.93%
Other Delineations	2.67	1.05%

Table 1.1. *Areas of habitats occupied in Palm Beach County.*

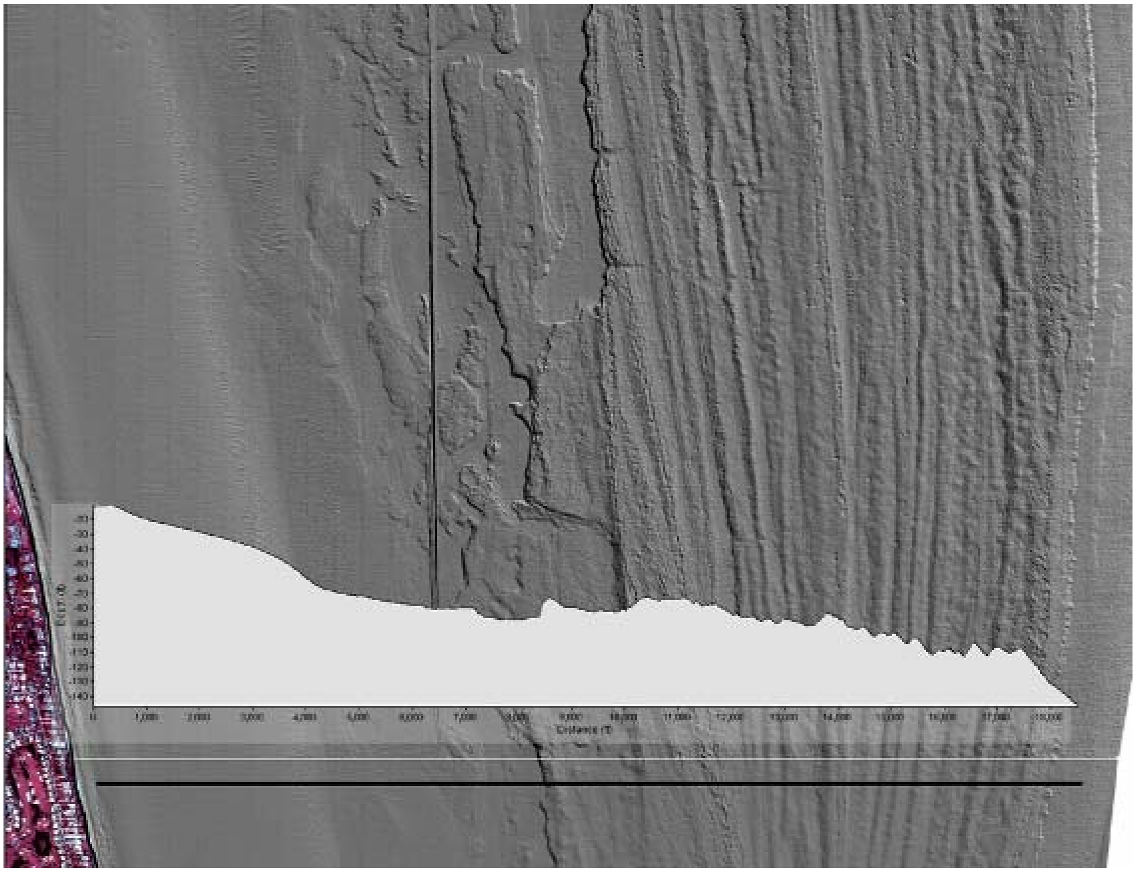


Figure 1.22. *Reef profile of the Deep Ridge Complex. The thick black line under the graph corresponds to the topographic data in the graph. This shows that the entire ridge complex is below 20m depth and the series of ridges extending eastward do so with increasing depth. The inshore 20m sand draped escarpment corresponds to the Middle Linear Reef Depth that extends throughout Broward County further south.*

PHASE II – ACOUSTIC SURVEYS FOR DISCRIMINATION OF BENTHIC HABITATS AND BIOMASS

2.1. PHASE II - INTRODUCTION

The main objective of the acoustic survey was to describe the abundance and the spatial distribution of biota occurring on the benthic habitats of Palm Beach County, FL. Since bathymetry-based mapping was not able to resolve all biomass and submerged aquatic vegetation issues, an acoustic approach was used to specifically map the distribution of biota. The primary acoustic target was to be foliose gorgonians, but new post-processing techniques developed during this project also allowed for mapping of the abundance and spatial distribution of macroalgae and areas dominated by large colonies of the barrel-sponge *Xestospongia muta*. Ultimately, the patterns of within- and between-reef abundance of biota supplement the Phase I LADS bathymetry and habitat classifications for identification of areas most suitable for management.

The extent of the acoustic survey ranged from a latitude of 26.4429^o in the south to 26.9590^o in the north (Figure 2.1). From the southern boundary of the survey to the point at which the outer reef terrace terminates near Palm Beach Lakes Blvd (26.7240^o), the survey extended from the seaward slope of the outer reef terrace (approx. 35 m) to a minimum depth of approximately 2 m (which exceeds the minimum depth stipulated in the contract: 6m). From Palm Beach Lakes Blvd to the northern boundary of the county, where the prominent bathymetric features are a series of ridges running parallel to shore, the survey extended from the seaward slope of the outermost ridges (35-40m) to the nearshore hardbottom. To complete the survey within the allotted time and due to the increasingly wide area of shelf within the specified survey depth, it was necessary to move the nearshore boundary progressively offshore as the survey progressed northwards. The acoustic survey was completed between the months May 6th-July 10th, 2006. Ground-truthing was performed at the end of the survey by deploying a weighted video camera overboard and recording 20 second video files for later review and classification. A total of 334 ground-truthing samples, arranged along eight east-west corridors, were collected in this manner.

The survey was conducted along pre-planned north-south lines, spaced 75 m apart, using a BioSonics DT-X echosounder and two multiplexed, single-beam digital transducers operating at frequencies and full beam widths of 38 kHz/10^o and 418 kHz/6.4^o, respectively. It was thus possible to cover essentially the entire county with survey lines, which exceeds original specifications that only expected the southern part of the county to be mapped. Positioning was provided by a Trimble® differential GPS receiver that provided an integrated NMEA GGA string to the navigational software. Positioning accuracy was differentially corrected against coast guard beacons and WAAS signal, thus resulting in positioning accuracies of <1m error. The 38 kHz acoustic data was post-processed using BioSonics Visual Bottom Typer (BioSonics Inc.) software to produce values of E1/E2, which is related to the spatial complexity and hardness of the seafloor. The 420 kHz acoustic data was post-processed using QTC Impact (Quester Tangent Corporation) software, and subjected to further post-processing to produce biomass estimates of gorgonians, macroalgae, and colonies of the barrel sponge *Xestospongia muta*.

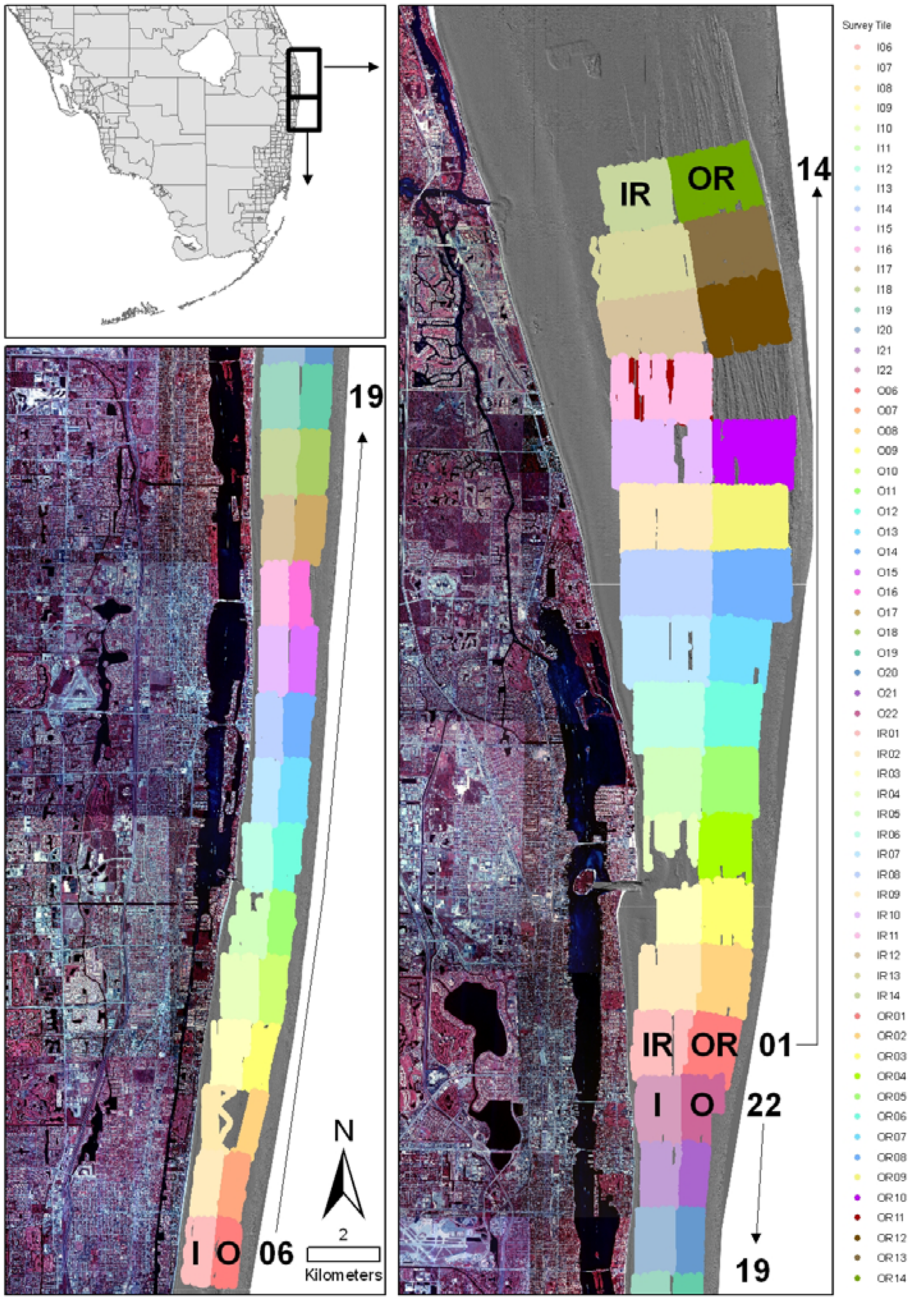


Figure 2.1. *Palm Beach County acoustic survey tiles. The extent stretched from southern Palm Beach County (right) to northern Palm Beach County (left). The survey lines completed by NSU are superimposed in color. The southern tiles were labeled I (Inner) and O (Outer) while the northern tiles were labeled IR (Inner Ridge) and OR (Outer Ridge).*

2.2. PHASE II METHODOLOGY

2.2.1. Survey Area

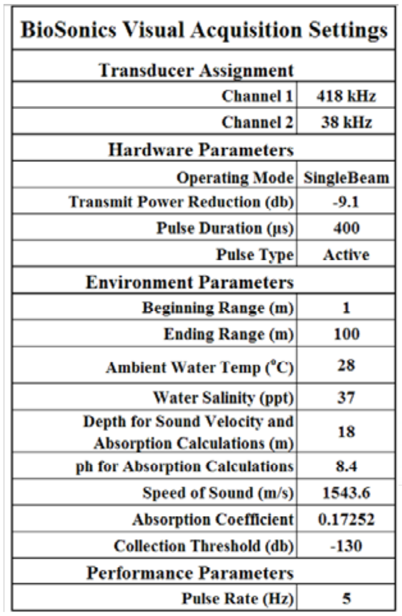
The extent of the acoustic survey ranged from a latitude of 26.4429^o (E. Linton Blvd) in the south to 26.9590^o (Jupiter Inlet) in the north (Figure 2.1). The survey area was subdivided into tiles comprised of 11 to 36 pre-planned survey lines oriented along the bathymetric isocline (generally north-south) and spaced 75 m apart. Overall, 62 tiles encompassing an area of 155.9 km^2 were acoustically surveyed. From the southern boundary of the survey to the point at which the outer reef terrace terminates near Palm Beach Lakes Blvd (26.7240^o), the survey extended from the seaward slope of the outer reef terrace (approx. 35 m) to a minimum depth of approximately 2 m. These southern tiles were labeled I (Inner) and O (Outer), referring to their position relative to the shoreline. From Palm Beach Lakes Blvd to the northern boundary of the county, where the prominent bathymetric features are a series of ridges running parallel to shore, the survey extended from the seaward slope of the outermost ridges (35-40m) to the nearshore hardbottom. To complete the survey within the allotted time, it was necessary to move the nearshore boundary progressively offshore as survey moved northwards, from 6 m at Palm Beach Lakes Blvd to 18 m at northernmost extent of the acoustic survey. These northern tiles were labeled IR (Inner Ridge) and OR (Outer Ridge).

2.2.2. Survey Equipment

The survey was conducted from a 7.5 m v-hull boat equipped with a swing-arm onto which the two transducers were mounted front (38 kHz) to back (418 kHz), with the GPS antennae mounted directly above, for optimal integration of acoustical and positional data strings (Figure 2.2). The BioSonics Visual Acquisition v. 5.0.4 software provided a real-time display of the raw echo envelopes, which allowed for precise control of survey speed to prevent contamination of the acoustic signal resulting from turbulence at the transducer face. Turbulence-induced signal contamination was visible as a rolling oscillation through the raw echo envelope of the 38 kHz transducer, which was located forward of the 420 kHz transducer and was thus more prone to disturbance. Survey speed was adjusted as necessary to remain safely under the onset of turbulence-induced signal contamination, which commonly resulted in greatly disparate speeds due to prevailing currents as the survey vessel transitioned between southerly and northerly directions. The typical net survey speed (vessel + current) was approximately 4.5 knots.

Global positioning data were collected with a Trimble Ag132 dGPS system that used either coast-guard differential beacon corrections or WAAS ground reference station corrections to achieve real-time horizontal positioning accuracies of mostly less than 0.9 m horizontal dilution of precision. Data were logged as an NMEA-GGA string, which encodes the horizontal accuracy of each position to allow for assessment of quality control standards. Pre-planned survey lines were drawn over the LADS bathymetric image in Hypack Max© navigational software. The maps in this report utilize the same LADS imagery. The dGPS signal was interfaced with HypackMax© to provide real-time monitoring of vessel position with respect to the aerial images and pre-planned survey lines.

Sonar signals were generated using a BioSonics DT-X digital echosounder system and two multiplexed, single-beam digital transducers operating at frequencies and full beam widths of 38 kHz/10^{o} and 418 kHz/6.4^{o}, respectively. The ping rate and pulse duration was set at 5 kHz and 0.4 ms respectively for both the 38 and 418 kHz transducers. The Transmit Power Reduction (-9.1 db) option within the BioSonics Visual Acquisition software was used throughout the survey, as it useful for preventing saturation of the acoustic signal at shallow depths. Complete settings for the BioSonics Visual Acquisition software are displayed in Figure 2.2



BioSonics Visual Acquisition Settings	
Transducer Assignment	
Channel 1	418 kHz
Channel 2	38 kHz
Hardware Parameters	
Operating Mode	SingleBeam
Transmit Power Reduction (db)	-9.1
Pulse Duration (µs)	400
Pulse Type	Active
Environment Parameters	
Beginning Range (m)	1
Ending Range (m)	100
Ambient Water Temp (°C)	28
Water Salinity (ppt)	37
Depth for Sound Velocity and Absorption Calculations (m)	18
ph for Absorption Calculations	8.4
Speed of Sound (m/s)	1543.6
Absorption Coefficient	0.17252
Collection Threshold (db)	-130
Performance Parameters	
Pulse Rate (Hz)	5

Figure 2.2. *BioSonics Visual Acquisition software settings used with BioSonics DT-X echosounder (Table). Swing-arm in traveling position with 420 kHz (top) and 38 kHz (bottom) transducers and Trimble antennae (Upper Image). Inside V-Berth of survey vessel with (left-to-right) BioSonics DT-X echosounder, Trimble receiver, and acquisition PC (Lower Image).*

2.2.3. 420 kHz Post-Processing in QTC Impact

The 420 kHz survey data were post-processed using QTC Impact software, version 3.20. Processing the BioSonics ".dt4" files in QTC Impact requires adjustment of the 'BioSon_BaseGain' parameter (in increments of 1/64), in the "impact.cfg" file to achieve the proper amplification of the raw echo waveform. The objective is to balance the amplification of waveforms (waveform resolution increases as amplification increases) against the percentage of acoustic records that must be filtered-out due to over-amplification.

The criterion within QTC Impact used to evaluate the adequacy of the value of the 'BioSon_BaseGain' was the number of records greater than a Signal Strength of 99%. In QTC Impact, waveforms with a Signal Strength greater than 99% are "clipped" (or flat-topped) and are problematic for proper classification of acoustic data. A subset of the Palm Beach survey data was processed in QTC Impact at several different values of 'BioSon_BaseGain' to determine the proper value, which was found to be 3/64. At the final 'BioSon_BaseGain' of 3/64, the Signal Strength of 4.1% of the records in the survey subset were greater than 99% (Figure 2.3).

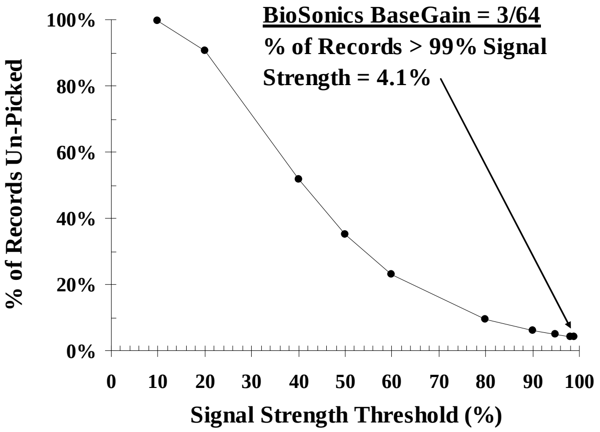


Figure 2.3. *The percentage of QTC Impact FFV records flagged and removed (un-picked) from further processing (y-axis) at increasing Signal Strength Thresholds (x-axis), at a BioSon_BaseGain setting of 3/64 (Impact.cfg file). The Signal Strength Threshold used in this survey was 99%, which un-picked 4.1% of survey records.*

The next step was the creation of Full Feature Vector (FFV) records, in which the raw sonar and navigation data are merged into a single file and features are extracted from the bottom picked waveforms. One FFV record was generated from a stack of five consecutive waveforms. Five filters available within the QTC Impact software were used to flag poor quality records and exclude them from processing, referred to as 'un-picking'. The first filter un-picked any records with a Signal Strength greater than 99%, as explained above. The second filter un-picked any FFV records in which any of the five waveforms were recorded at depth picks shallower than 5.0 m. In the initial evaluation of survey data, it was found that depth contamination of the acoustic signal became pronounced at depths less than 5 m. The third filter un-picked any FFV records in which any of the five waveforms were recorded at depth picks greater than 35.0 m. The fourth filter un-picked FFV records in which any of the five waveforms within a stack were collected more than 3,000 ms apart, preventing asynchronous and hence geospatially isolated records from being stacked together. The fifth filter un-picked FFV records in which any of the five waveforms were collected at recorded depths more than 0.3 m apart. The primary purpose of this filter was to identify records taken at times during which the depth-pick was unstable. Any remaining records of dubious quality were removed manually.

Before the filtered FFV records could be sorted into acoustic classes it was necessary to create a catalogue, comprised of a subset of survey FFV records, to which all other FFV records were compared. In QTC Impact software, the echoes comprising the catalogue are digitized, subjected to a variety of analyses (cumulative amplitudes and ratios of cumulative amplitudes, amplitude quantiles, amplitude histograms, power spectra, wavelet packet transforms) by the acquisition software (Preston et al., 2001, 2004). After being normalized to a range between 0 and unity, they are subjected to Principal Components Analysis (PCA) for data reduction. The first three principle components of each echo are retained (called Q values), according to the assumption that these explain the majority of variability in the data set (Quester Tangent Corporation, 2002). Data points are then projected into pseudo-three-dimensional space along these three components, and subjected to cluster analysis using a Bayesian approach (Quester Tangent Corporation, 2002). The user decides on the number of desirable clusters and also chooses which cluster is split how often. Clustering decisions are guided by three statistics offered within the program; the "CPI" (Cluster Performance Index), "Chi^2" and "PCA Total Score" statistics. The PCA Total Score decreases to an inflection point, which is 'a strong indication of best split level' (Quester Tangent Corporation, 2002). While CPI generally increases without bound with more cluster splitting (Kirlin and Dizaji, 2000; Freitas et al., 2003b), the maximum rate of increase tends to coincide with the optimal split level (Quester Tangent Corporation, 2002). Chi^2 decreases with more cluster splitting, reaching maximum/minimum values at optimal split level (Quester Tangent Corporation, 2002).

There are two basic approaches the user can take for selecting FFV records for inclusion into the catalogue. In the unsupervised approach all survey FFV records are merged into a single file and decimated, typically by a factor of 10-20. The aforementioned clustering procedure is then conducted to a logical conclusion, e.g. an optimal split to the inflection point of the CPI, or to a desired number of classes. This approach defines acoustic diversity on the basis of the entire survey area, and thus may not isolate desired acoustic classes, or produce acoustic classes outside of the area of interest for the particular survey. In the supervised approach, FFV records representative of the desired classes are handpicked for inclusion into the catalogue, and as in the unsupervised approach, split to a logical conclusion. Based on previous experience, the supervised approach to catalogue creation was utilized. After creating the supervised catalog, all catalog FFV records, minus those that filtered or manually de-selected, were classified.

2.2.4. Creation of 420 kHz Biomass Models

The QTC acoustic classifications of the supervised catalog were then subjected to additional post-processing to create models for estimating the biomass of gorgonians, macroalgae, and colonies of the barrel-sponge *Xestospongia muta*. The first step was to create moving 20-record blocks of acoustic class membership by calculating the percentage of records belonging to each acoustic class for each moving block of 20 records. This is illustrated for the hypothetical case of 3 QTC acoustic classes in Figure 2.4. The rationale for this approach is that complicated benthic habitats, such as gorgonians on a reef, cannot be adequately described by a single acoustic class, but rather are defined by the relative distribution of multiple acoustic classes, some of which can be expected to be common to other habitat types. For the example of gorgonians on a reef, the individual habitat components could be sparse-dense gorgonians, uncolonized hardbottom, widely spaced sponges, and sand channels.

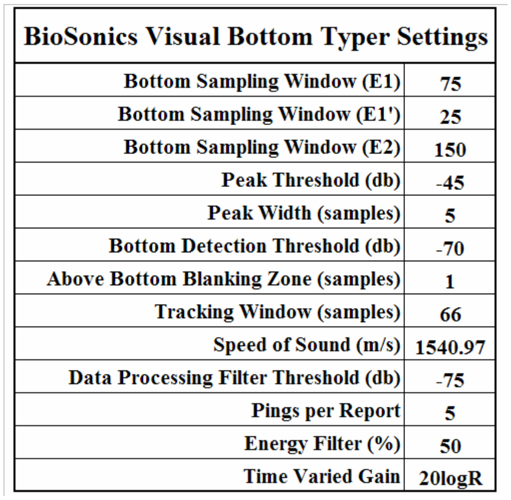
		QTC Class				QTC Class			
	QTC	1	2	3	Total	1	2	3	Total
Record	Class	#	#	#	#	%	%	%	%
1	1								
2	3								
3	1								
4	2								
5	2								
6	1								
7	2								
8	3					Acoustic Class Membership			
9	2								
10	1	10	6	4	20	50%	30%	20%	100%
11	1								
12	1								
13	2								
14	1								
15	3								
16	3								
17	1								
18	1								
19	2								
20	1								

Figure 2.4. *Example calculation of Percent Acoustic Class Membership using moving 20-record block for example of 3 classes (12 in actual survey). Tally QTC Classes from Record 1 to Record 20 (Class1=10, Class2=6, Class3=4) and calculate Percent Acoustic Class Membership as simple ratio of '# per Class/20'. It is a moving block, so next Record calculated in this example is Record 11, tallying from Record 2 to Record 21.*

The values of QTC percent acoustic class membership (and depth) were submitted as independent variables to three simple linear regression analyses (one regression for gorgonians, one for macroalgae, and one for *Xestospongia muta*). In each of the three regression analyses, the dependent variable was a measure of biomass obtained by estimating the areal coverage and canopy height (gorgonians and macroalgae) or counting the number of colonies per meter (*X. muta*) in each of the supervised catalog videos. All survey records, minus those that were filtered or manually de-selected, were transformed into estimates of biomass using the three aforementioned regression models.

2.2.5. 38 kHz Post-Processing

The 38 kHz survey data were post-processed using BioSonics Visual Bottom Typer software, version 1.10, to produce values of E1/E2. The value of E1/E2 is calculated as the ratio of area under the second half of the first echo (E1) to the area under the complete second echo (E2) and generally relates to the spatial complexity and hardness of the sea floor. The values of the user-defined parameters within the Visual Bottom Typer software are displayed in Table 2.1.



BioSonics Visual Bottom Typer Settings	
Bottom Sampling Window (E1)	75
Bottom Sampling Window (E1')	25
Bottom Sampling Window (E2)	150
Peak Threshold (db)	-45
Peak Width (samples)	5
Bottom Detection Threshold (db)	-70
Above Bottom Blanking Zone (samples)	1
Tracking Window (samples)	66
Speed of Sound (m/s)	1540.97
Data Processing Filter Threshold (db)	-75
Pings per Report	5
Energy Filter (%)	50
Time Varied Gain	20logR

Table 2.1. *BioSonics Visual Bottom Typer software settings used to process 38 kHz sonar data.*

2.2.6. Creation of 420 kHz Biomass Maps and 38 kHz E1/E2 Maps

Ordinary point kriging, a geostatistical method based on the spatial autocorrelation inherent in landscape patterns, was used to produce spatially continuous habitat maps for the model-predicted biomass estimates of gorgonians, macroalgae, and *Xestospongia muta* colonies. Kriging is not ordinarily the method of choice for categorical data, such as the discrete classes produced by QTC cluster analysis (Davis, 2002; Riegl and Purkis, 2005), since fractional classes, such as those produced by kriging, are often nonsensical. However, transforming the categorical QTC classes into continuous biomass estimates circumvented this requirement for using kriging. Each kriged contour feature was then clipped to the perimeter of the area traversed within each survey tile, i.e. the boundaries of the contour maps do not extend beyond the area of acoustic sampling. Ordinary point kriging was also employed to produce spatially continuous maps of the continuous E1/E2 values obtained from the 38 kHz signal.

2.2.7. Ground-Truthing

Ground-truthing was conducted immediately following completion of the acoustic survey by deploying a weighted video camera overboard and recording 10-20 seconds of sonar and video with the vessel at idle speed. The dGPS coordinates of each ground-truthing location were recorded from the BioSonics .dt4 sonar files. A total of 334 ground-truthing samples were taken along eight pre-planned east-west corridors spanning both the latitudinal and longitudinal extent of the survey, amounting to a total traverse of 4,527 m (Appendix A). The spatial locations of ground-truthing samples are displayed over the LIDAR bathymetry for the example of gorgonian biomass (Appendix B). For each ground-truthing sample the biomass and substrate-class was estimated over the 10-20 second sampling period. The biomass of gorgonians and macroalgae was estimated as the product of percent areal cover and canopy height. For both gorgonians and macroalgae, the areal cover was divided into 5 categories; 1 = 0-12.5%, 2 = 12.5-25%, 3 = 25-50%, 4 = 50-75%, and 5 = 75-100%. Gorgonian canopy height was divided into three categories; 1 = 0.25m<, 2 = 0.50m<, and 3 = >0.5m. Macroalgae canopy height was divided into four categories; 1= Turf, 2 = 3cm<, 3 = 6cm<, and 4 = >6cm. *X. muta* biomass was estimated as the number of colonies observed in the video divided by the meters traversed during the sample, as calculated by the starting and ending dGPS coordinates. Each ground-truthing record was also classified into one of four bottom-type categories (Flat, Low, Medium, and High) based on the composite rugosity observed throughout the video. The Flat category corresponds to areas of thick sand cover, where no underlying carbonate structure is apparent. With a few exceptions, this category was exclusive to the nearshore areas at depths less than 14 m. The Low rugosity category corresponds to areas of flat hardbottom, typically with sand cover, where the underlying carbonate structure is apparent as slight undulations. This category typically occurred on the seaward edge of the outer reef terrace and in areas between patch reefs. The Medium and High rugosity categories correspond to elevated reef structures, the High category being distinguished by features of greater spatial complexity, typically old dead corals. Many of the samples were of mixed bottom-type categories, as the sample traverses often included different bottom types, such as when passing over a patch reef.

2.3. PHASE II - RESULTS

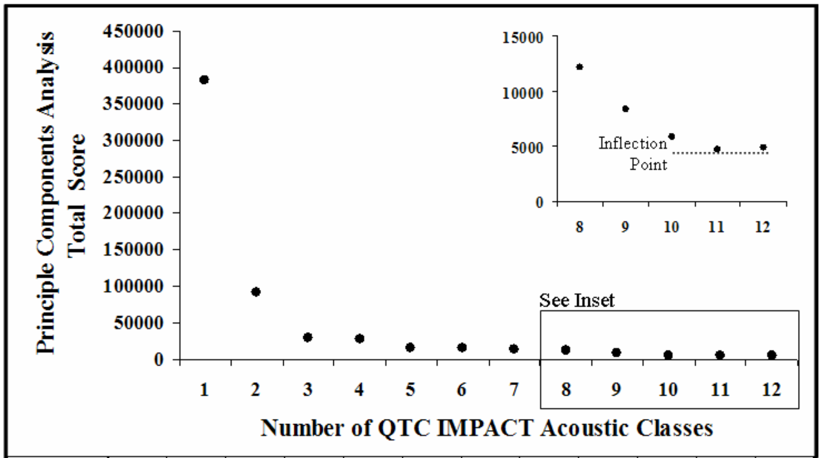
2.3.1. Creation of the 420 kHz Biomass Models

To create the supervised catalogue 108 sonar samples totaling 104 minutes were collected over the extent of the survey area. The catalog samples belonged to the nine general categories shown in Figure 2.5. Multiple sonar samples were collected for each category to help ensure that the catalog would be valid across the extent of the survey area.

Catalog Category	# Sonar Files	Rugosity			MacroAlgae Cover			Gorgonian Cover		
		Sand	Low	High	Low	Med	High	Low	Med	High
1	23	x								
2	11		x		x			x		
3	11		x			x		x		
4	15		x				x	x		
5	11		x		x					x
6	8			x	x			x		
7	11			x			x	x		
8	6			x	x				x	
9	12			x	x					x

Figure 2.5. *General categories of video and sonar samples collected to create supervised acoustic catalog.*

The 108 individual catalog files were merged into a single QTC FFV file and filtered by 1.) Signal Strength > 99% (2.5% of records un-picked), 2.) Depth < 5m (2.15% of records un-picked), 3.) Depth > 35m (3.85% of records un-picked), 4.) TimeSpan > 3000 ms (2.20% of records un-picked), and 5.) DepthSpan > 0.3m (0.35% of records un-picked). The remaining FFV records in the supervised catalogue were then submitted to the QTC Impact clustering routine and ultimately split into twelve classes, using the inflection point of the Total PCA score as the guideline for determining the proper number of classes (Figure 2.6). The decision of which class to isolate during each split was based on the class with the highest chi^2 score. The decision of which axis to split (Primary/Secondary/Tertiary) was made by a trial & error, judging by the lowest resultant PCA Total Score.



Split	1	2	3	4	5	6	7	8	9	10	11	12
Axis	P	S	T	T	T	P	P	T	P	S	P	P
Class			1	1	1	4	2	6	7	1	6	9

Figure 2.6. *Sequence of clustering (splitting) during creation of supervised catalog in QTC Impact. 12 splits resulted in a total of 12 acoustic classes. Clustering was ended at the inflection point of the Principle Components Analysis Total Score (see inset). The axis of each split is indicated; P(rimary), S(econdary), T(ertiary) as well as acoustic class.*

The arrangement of the twelve QTC acoustic classes in PCA hyperspace is displayed in Figure 2.7. Significantly, the trail of acoustic classes can be seen to move through all three axes of PCA hyperspace. This is a desirable outcome for cataloging as it implies a high level acoustic diversity within the catalog.

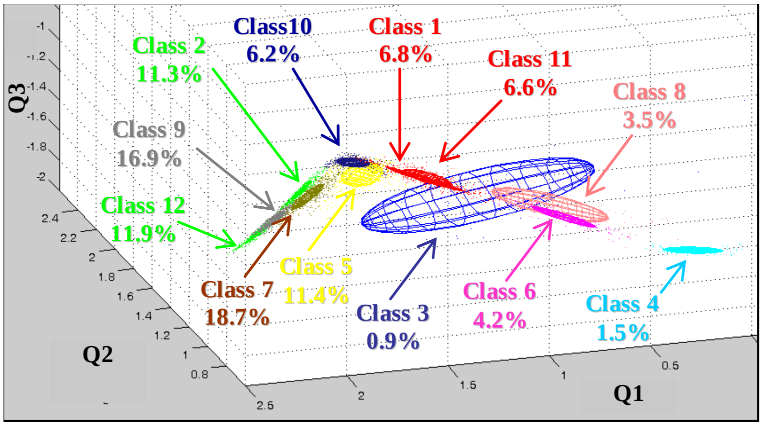


Figure 2.7. *Final clustering of 420 kHz supervised catalog in QTC Impact, displayed in the three axes of pseudo-three-dimensional PCA hyperspace (Q-Space), and percentages of records within each of the 12 acoustic classes.*

The individual QTC acoustic classifications of the supervised catalog records were then grouped into 20-record blocks and the percent acoustic class membership of each catalog record was calculated (Figure 2.4). As a demonstration of how acoustic class membership can be used to produce a model for detecting gorgonians, the average acoustic class membership for three selected habitat types from the supervised catalog are presented in Figure 2.8a. The three habitat types selected for this demonstration are; 1) Gorgonians Present on Reef/Hardbottom (n=18), 2) Gorgonians Absent on Reef/Hardbottom (n=8), and 3) Gorgonians Absent on Hardbottom (n=25). All records were taken from depths ranging from 13-19 m, averaging 16 m. As can be seen in the standard error bars of Figure 2.8a, clear distinctions exist between the acoustic class memberships of these example habitat types.

In addition to acoustic class membership, the biomass regression models require the inclusion of depth as an additional independent variable (Figure 2.8b). In this example, the distributions of acoustic class membership move along to the right in the projected PCA hyperspace (Figure 2.7) as depth increases from 16m to 22m. Depth contamination of the QTC signal was reported in the Broward County survey, and while the exact cause is as yet unknown, it can be addressed by the additional post-processing method of regression analysis as described in this report.

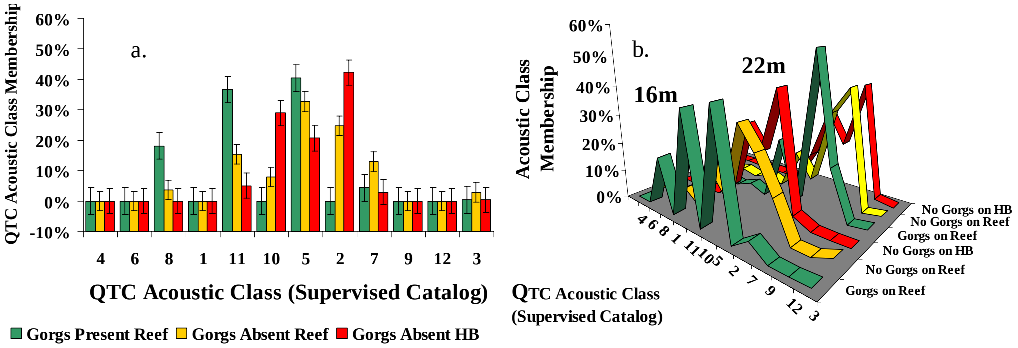


Figure 2.8. ***(a)*** *Percent acoustic class membership of three categories from the 420 kHz supervised catalog; Gorgonians Present on Reef (green), Gorgonians Absent on Reef (yellow), Gorgonians Absent on Hardbottom (red). Average depth = 16m. Error bars = Standard Error. Arrangement of QTC Acoustic Classes (x-axis) in same order as in PCA hyperspace.* ***(b)*** *Same categories as in (a), demonstrating how acoustic class membership shifts through hyperspace with changing depth.*

The 20-record percent acoustic class memberships for the twelve QTC classes, along with depth, were submitted to three separate regression analyses to produce biomass models for gorgonians, macroalgae, and colonies of *X. muta*. The dependent variable in each of the regression analyses was the quantitative biomass estimate obtained from careful review of the catalog videos (Appendix A). The biomass of gorgonians and macroalgae was estimated as the product of percent areal cover and canopy height. For both gorgonians and macroalgae, the areal cover was divided into 5 categories; 1 = 0-12.5%, 2 = 12.5-25%, 3 = 25-50%, 4 = 50-75%, and 5 = 75-100%. Gorgonian canopy height was divided into three categories; 1 = 0.25m<, 2 = 0.50m<, and 3 = >0.5m. Macroalgae canopy height was divided into four categories; 1= Turf, 2 = 3cm<, 3 = 6cm<, and 4 = >6cm. *X. muta* biomass was estimated as the number of colonies observed in the video divided the meters traversed during the sample, as calculated by the starting and ending coordinates. After each regression, any non-significant x-coefficients were removed from the dataset and the regression analyses were repeated until all x-coefficients were statistically significant. The final forms of the regression models are shown in Table 2.2.

		Gorgonians		MacroAlgae		*X. muta*	
r^2		0.663		0.427		0.551	
n		3508		3508		3508	
units		ArealCover*Height		ArealCover*Height		#Colonies/meter	
X-Coeff		Slope	P-Value	Slope	P-Value	Slope	P-Value
(m)	depth	-0.3944	2.46E-92	-0.0975	0.022465	0.0052	1.07E-10
QTC Acoustic Class Membership (%)	4	-7.1606	1.25E-58	-2.2825	0.001585	0.0350	0.004236
	6	-7.3502	4.21E-74	-1.3762	0.024589	0.0260	0.013159
	8	n/a	n/a	n/a	n/a	n/a	n/a
	1	-6.3789	1.09E-86	-1.7403	0.000581	n/a	n/a
	11	3.6425	8.66E-21	n/a	n/a	0.3501	2.2E-132
	10	-6.0289	1.24E-106	-1.5772	0.000691	-0.0506	5.89E-09
	5	6.6320	1.06E-138	-1.3983	0.02968	0.2129	4.47E-86
	2	-3.2085	1.21E-60	7.1002	2.56E-59	-0.0440	2.91E-06
	7	4.1325	3.77E-69	5.9525	1.1E-17	-0.0864	4.9E-08
	9	n/a	n/a	5.9445	1.55E-25	-0.0493	8.49E-05
	12	5.0335	1.12E-70	10.7223	6.47E-29	-0.0982	1.88E-06
	3	n/a	n/a	10.3672	1.23E-10	-0.3094	1.9E-21
		Intercept	P-Value	Intercept	P-Value	Intercept	P-Value
		9.3408	4.58E-98	2.7631	3.05E-05	-0.0636	8.1E-12

Table 2.2. *Results of the regression analyses constituting the biomass prediction models for gorgonians, macroalgae, and colonies of X. muta.*

The supervised catalog records were then submitted to the three regression models to produce estimates of gorgonian, macroalgae, and *X. muta* biomass, as estimated by the product of areal cover and canopy height for gorgonians and macroalgae and as the number of colonies per meter of video transect for *X. muta* (Figure 2.9). The gorgonian model works generally well across the range of estimated biomass, but the model predictions for macroalgae and *X. muta* begin to plateau at the upper ends of the ground-truthed biomass. Given the great differences between macroalgae and colonies of *X. muta* as acoustic targets, one being low-lying and evenly distributed and the other relatively large and unevenly distributed, it is unlikely that a single explanation exists for plateau effect. Regardless, the effect is relatively minor and unimportant, as these high biomasses constituted only a small fraction of observations in the field.

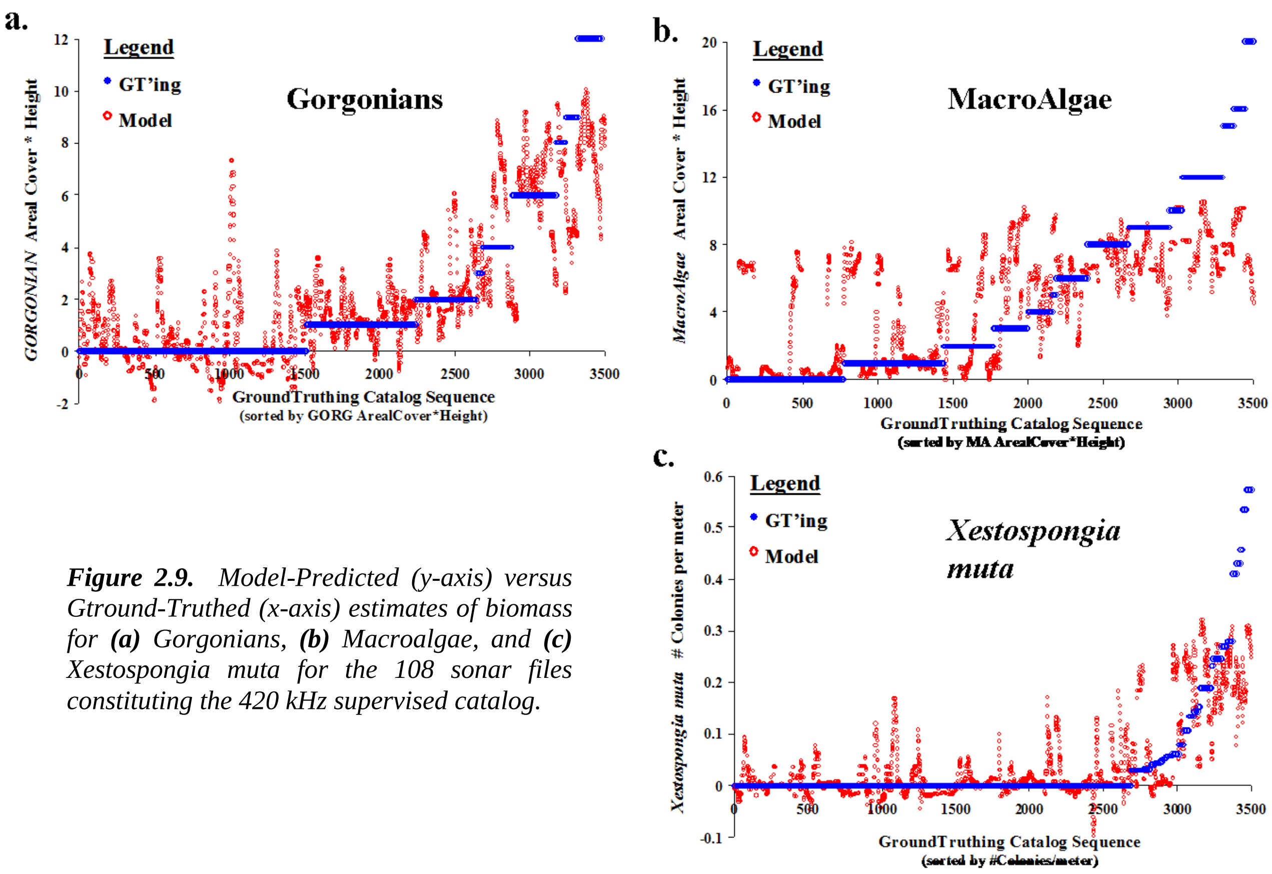


Figure 2.9. *Model-Predicted (y-axis) versus Gtround-Truthed (x-axis) estimates of biomass for **(a)** Gorgonians, **(b)** Macroalgae, and **(c)** Xestospongia muta for the 108 sonar files constituting the 420 kHz supervised catalog.*

2.3.2. Creation of 420 kHz Biomass Maps

Ordinary point kriging, a geostatistical method based on the spatial autocorrelation inherent in landscape patterns, was used to produce spatially continuous habitat maps for the model-predicted biomass estimates of gorgonians, macroalgae, and *X. muta* colonies (Appendices C-E). The biomass of gorgonians and macroalgae was estimated as the product of percent areal cover and canopy height. The biomass of *X. muta* colonies was estimated as the number of colonies observed in the video divided by the meters traversed during the sample, as calculated by the starting and ending dGPS coordinates. Prior to creating the maps, the 0.5 and 99.5 percentiles of the model-predicted biomass estimates were removed from the gorgonian, macroalgae, and *X. muta* survey datasets to prevent an undue influence of outliers on the presentation of the kriged biomass contour plots. Each kriged contour plot was then clipped to the perimeter of the area traversed within each survey tile, i.e. the boundaries of the contour maps do not extend beyond the area of acoustic sampling.

2.3.3. Assessing Predictive Accuracy of 420 kHz Biomass Models

For the purpose of assessing predictive accuracy, the continuous model-predictions of biomass were grouped into coarse abundance categories. The gorgonian and macroalgae biomass estimates were grouped into ‘Bare’, ‘Sparse’, and ‘Abundant’ categories, and the *X. muta* biomass estimates were grouped into ‘Present’ and ‘Absent’ categories (Figure 2.10a-c). These category breaks are displayed as the solid vertical bars in Figure 2.10a-c. For the example of gorgonians, ‘Abundant’ was defined as a ground-truthing biomass greater than 9 (percent areal cover * height, see Appendix A for definitions), ‘Sparse’ as a ground-truthing biomass greater than 3 and less than 9, and ‘Bare’ as a ground-truthing biomass estimate less than 3. The average model-prediction ± 1 standard deviation of each coarse ground-truthing category was then calculated from the entire ground-truthing dataset of 334 sonar files. The quantitative split between each category was then calculated as the mid-point of the overlap between the $+1\sigma$ of the lower-abundance category and the -1σ of the adjacent higher-abundance category. For the example of gorgonians, the split between ‘Bare’ and ‘Sparse’ categories was calculated as a model-prediction value of 3.25, and the split between ‘Sparse’ and ‘Abundant’ categories as a model-prediction value of 6.34.

Three confusion matrices were produced to compare the acoustic predictions of biomass with the values estimated by ground-truthing (Table 2.3). Overall, the acoustically predicted biomasses agreed well with the ground-truthing estimates of biomass. The overall accuracy for the three classes (Bare/Sparse/Abundant) of biomass was 79.6% for gorgonians and 61.7% for macroalgae, compared to the three-class pure-chance prediction of 33.3%. The overall accuracy for the two classes (Absent/Present) of *X. muta* was 86.1%, compared to the two-class pure-chance prediction of 50%. The user’s accuracies for all three biotic types indicate that the biomass models are conservative, i.e. the models generally under-predict biomass. Using the gorgonian model as an example, the user’s accuracy for the Bare category was 95.2%. There were no instances in which the model-prediction of a Bare ground-truthing record was classed as Abundant. The user’s accuracy for Sparse and Abundant gorgonian categories was 31.5% and 22.6%, respectively, with the majority of the model-predicted “misses” erring on the low side of biomass cover. The user’s accuracy of the Sparse and Abundant categories could have been increased by decreasing the model-prediction splits discussed in the preceding paragraph, but this would have resulted in the less-desirable situation of false-positive biomass model predictions.

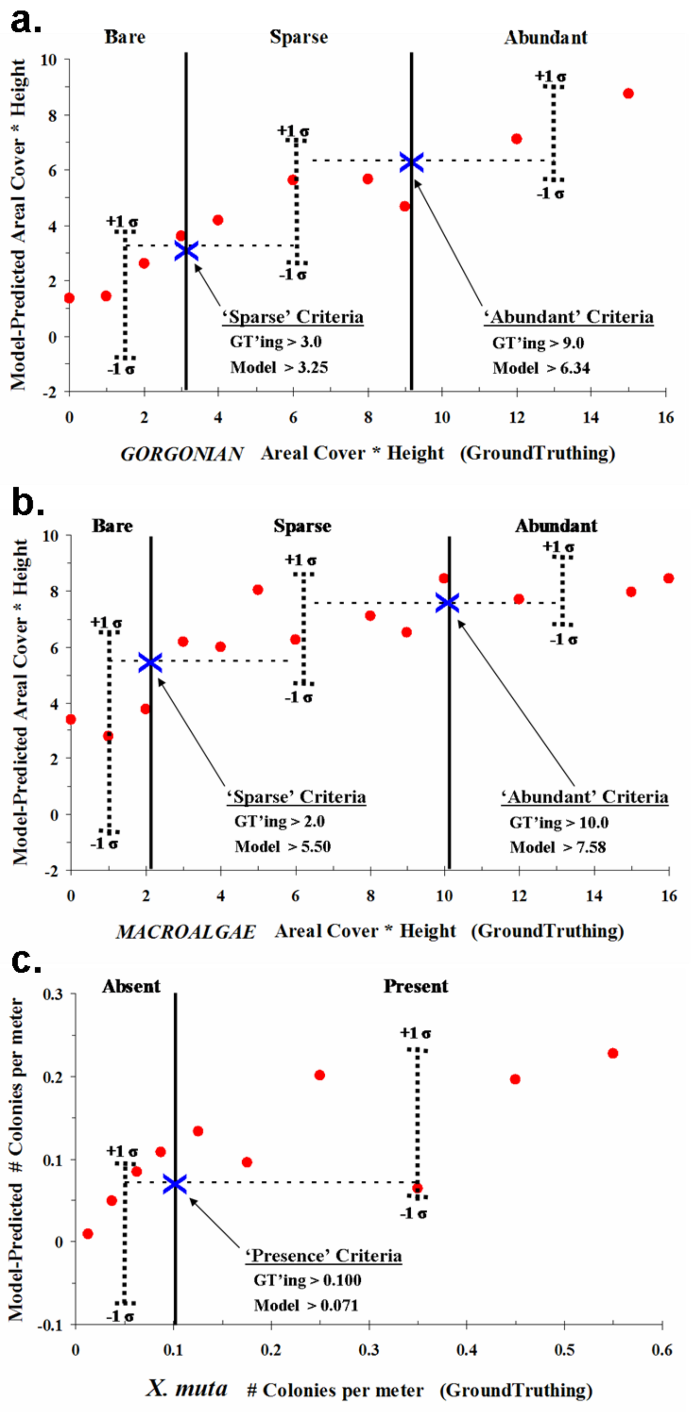
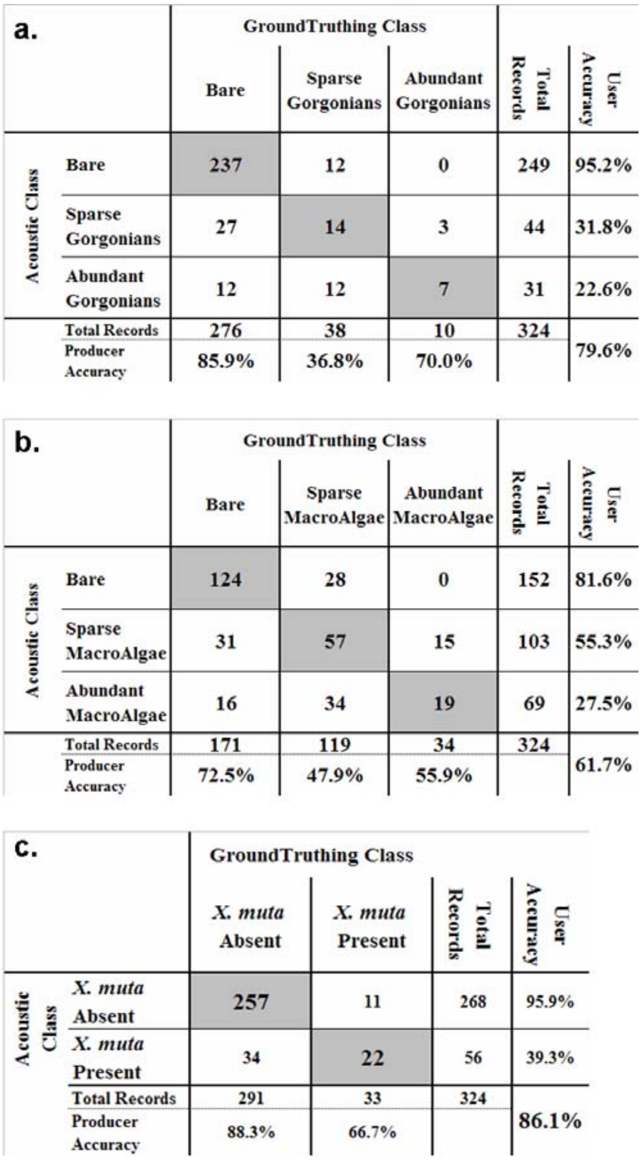


Figure 2.10. *Establishment of abundance categories using statistics taken from all 334 sonar files constituting the ground-truthing dataset (Bare/Sparse/Abundant for gorgonians and macroalgae, Present/Absent for X. muta). Within each abundance category, the model-predicted average ± 1σ was calculated. The quantitative split between each category is the mid-point of the overlap between the +1σ of the lower-abundance category and the -1σ of the adjacent higher-abundance category (blue X).*



a.

Acoustic Class	GroundTruthing Class: Bare	GroundTruthing Class: Sparse Gorgonians	GroundTruthing Class: Abundant Gorgonians	Total Records	User Accuracy
Bare	237	12	0	249	95.2%
Sparse Gorgonians	27	14	3	44	31.8%
Abundant Gorgonians	12	12	7	31	22.6%
Total Records	276	38	10	324	79.6%
Producer Accuracy	85.9%	36.8%	70.0%		

b.

Acoustic Class	GroundTruthing Class: Bare	GroundTruthing Class: Sparse MacroAlgae	GroundTruthing Class: Abundant MacroAlgae	Total Records	User Accuracy
Bare	124	28	0	152	81.6%
Sparse MacroAlgae	31	57	15	103	55.3%
Abundant MacroAlgae	16	34	19	69	27.5%
Total Records	171	119	34	324	61.7%
Producer Accuracy	72.5%	47.9%	55.9%		

c.

Acoustic Class	GroundTruthing Class: *X. muta* Absent	GroundTruthing Class: *X. muta* Present	Total Records	User Accuracy
X. muta Absent	257	11	268	95.9%
X. muta Present	34	22	56	39.3%
Total Records	291	33	324	86.1%
Producer Accuracy	88.3%	66.7%		

Table 2.3. *Class-by-class error matrix for the biomass prediction models of (a) gorgonians, (b) macroalgae, and (c) colonies of Xestospongia muta.*

2.3.4. 38 kHz Post-Processing

The value of E1/E2 is calculated as the ratio of the area under the second half of the first echo (E1) to the area under the complete second echo (E2), and generally relates to the spatial complexity and hardness of the sea floor. The 38 kHz survey data were post-processed using BioSonics Visual Bottom Typer software, version 1.10, to produce values of E1/E2.

2.3.5. Creation of 38 kHz E1/E2 Maps

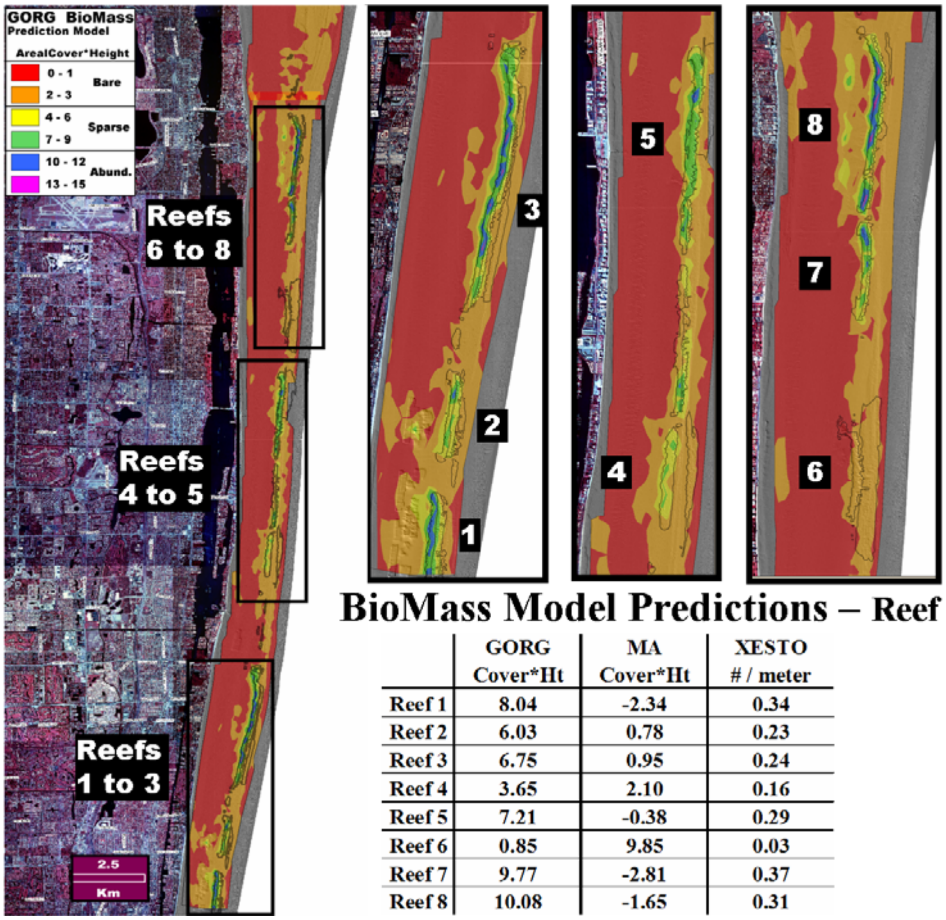
Ordinary point kriging, a geostatistical method based on the spatial autocorrelation inherent in landscape patterns, was used to produce spatially continuous maps for the 38 kHz values of E1/E2 (Appendix F). Prior to creating the maps, values of E1/E2 greater than 5,000 were removed for the survey dataset to prevent an undue influence of these outliers on the presentation of the E1/E2 contour plots. This eliminated 0.31% of the total E1/E2 survey records. Each kriged contour plot was then clipped to the perimeter of the area traversed within each survey tile, i.e. the boundaries of the contour maps do not extend beyond the area of acoustic sampling. The contour plots of E1/E2 were used a supplement to the decision-making process in the assignment of Phase I habitat classes.

2.4 PHASE II DISCUSSION

2.4.1. 420 kHz Biomass Models

The primary objective of the acoustic survey was to describe the abundance and the spatial distribution of biota occurring on the marine habitats of Palm Beach County, FL. As can be seen in the contour plots of predicted biomass, the models did predict between- and within-reef variations of gorgonian, macroalgae, and biomass models (Appendices C-E). Between-reef variations of biomass were quantified by querying the model-predictions for eight individual sections of the outer reef tract located in the southern portion of Palm Beach County (Figure 2.11). The eight areas to which the model-predictions were constrained are displayed as the black outlines in the three close-up maps of Figure 2.11, and correspond to the following Phase I habitat categories; Linear Reef, Spur and Groove, Individual Patch Reef, and Aggregate Patch Reef (see Phase I Final Mapping Categories section in this report). As can be seen in the table of Figure 2.11, there was considerable variations in the model-predicted biomasses of gorgonians, macroalgae, and colonies of *X. muta*. Of particular interest is the observation that Reefs 4 and 6 (numbers of reefs can be seen in Figure 2.11), both of which have low values of predicted biomass of gorgonians and *X. muta*, but have an unusually high biomass of macroalgae. Correspondingly, Reefs 1, 7, and 8 have high predicted values of gorgonian and *X. muta* biomass and relatively low predicted values of macroalgae biomass. Further confirmation of the between- and within-variations of model-predicted biomass would require additional ground-truthing in the form of along-reef transects across the model-predicted contour features.

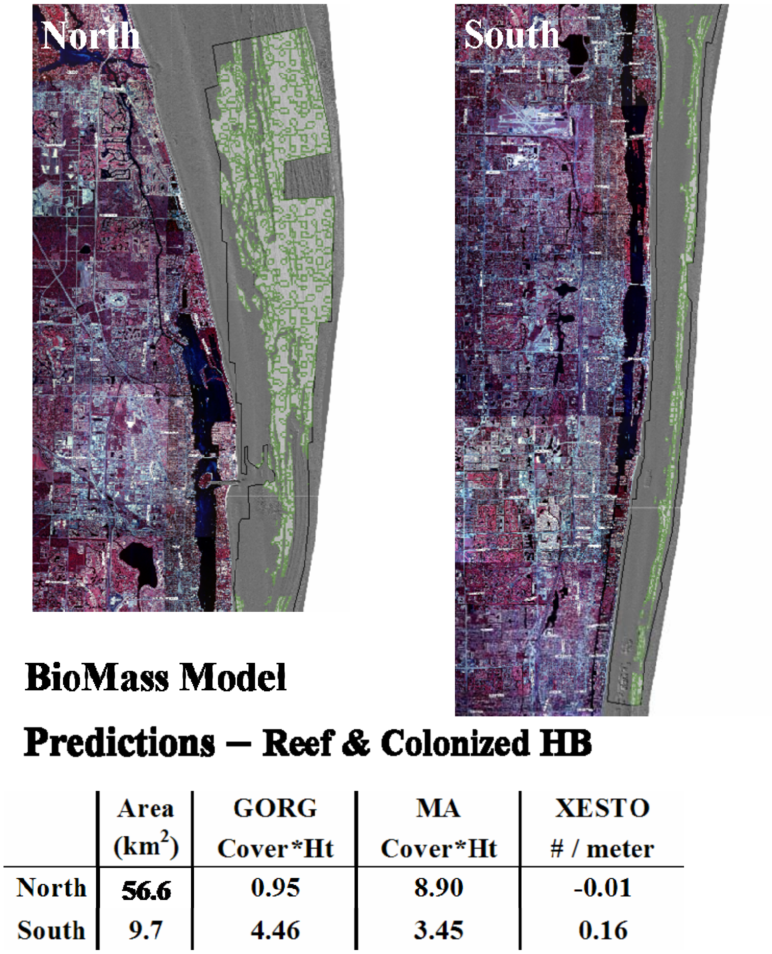
A similar analysis comparing the predicted biomass of the northern and southern regions of Palm Beach County is displayed in Figure 2.12. In this analysis, the biomass model-predictions were constrained to the general Phase I habitat category of Coral Reef and Colonized Hardbottom. The main feature in the southern region is the outer reef terrace, which terminates near Palm Beach Lakes Blvd., whereas the main feature in the northern region is a series of ridges running parallel to the shoreline. As can be seen in the table of Figure 2.12, there was considerable differences in the model-predicted biomasses of gorgonians, macroalgae, and colonies of *X. muta*. The southern region had much higher model-predicted biomasses of gorgonians and *X. muta* than the northern region and a much lower model-predicted biomass of macroalgae. The biomass models suggest that the habitats of the outer reef terrace in the south and the ridge complex in the north are not equivalent for the biota examined in this report, whether due to the lower spatial complexity of the ridge complex in the north compared to the outer reef terrace of the south, or some combination of spatial complexity and other environmental variables.



BioMass Model Predictions – Reef

	GORG Cover*Ht	MA Cover*Ht	XESTO # / meter
Reef 1	8.04	-2.34	0.34
Reef 2	6.03	0.78	0.23
Reef 3	6.75	0.95	0.24
Reef 4	3.65	2.10	0.16
Reef 5	7.21	-0.38	0.29
Reef 6	0.85	9.85	0.03
Reef 7	9.77	-2.81	0.37
Reef 8	10.08	-1.65	0.31

Figure 2.11. *Average model-predicted biomasses of gorgonians, macroalgae, and colonies of X. muta for eight selected reefs in the southern portion of Palm Beach County. Outline of reef areas depicted as solid black line in the three close-up maps. The gorgonian biomass contour plot is shown overlaying the LADS bathymetry.*



BioMass Model Predictions – Reef & Colonized HB

	Area (km^2)	GORG Cover*Ht	MA Cover*Ht	XESTO # / meter
North	56.6	0.95	8.90	-0.01
South	9.7	4.46	3.45	0.16

Figure 2.12. *Average model-predicted biomasses of gorgonians, macroalgae, and colonies of X. muta occurring on areas of reef and colonized hardbottom for the southern versus northern portions of Palm Beach County.*

2.4.2 38 kHz E1/E2 Mapping

The value of E1/E2 is calculated as the ratio of the area under the second half of the first echo (E1) to the area under the complete second echo (E2), and generally relates to the spatial complexity and hardness of the sea floor. To better understand how the bottom topography contributed to changes in the ratio of E1/E2, a sub-set of the survey data extending from survey tiles Inner6-Outer6 to Inner10-Outer10 was examined across the depth gradient. The value of E1 increased slightly as the bottom topography transitioned from Sand Flat to Sand over Hardbottom, and increased significantly as the bottom topography transitioned from Sand over Hardbottom to Reef (Figure 2.13a). These trends were not surprising, as the value of E1 is expected to increase with increasing spatial complexity. On the other hand, it was not expected for the value of E2 to decrease in the transition from Sand over Hardbottom to Reef (Figure 2.13b). This is because the value of E2 is generally expected to increase as the hardness of the bottom increases. It is thus apparent that the main topographical factor affecting the value of E2 is spatial complexity. As spatial complexity increases while moving onto the reef, the increased scattering must attenuate the value of E2 more than the increasing hardness amplifies it. This trend of E1 increasing and E2 decreasing when moving onto reef features explains the general observation of reef habitats having much higher values of E1/E2 than hardbottom or sand habitats. It would not seem unreasonable to assume that higher values of E1/E2 within a given reef are indicative of higher spatial complexity. An intensive modeling approach, similar to that employed for the 420 kHz biomass model, would be necessary to confirm this assumption.

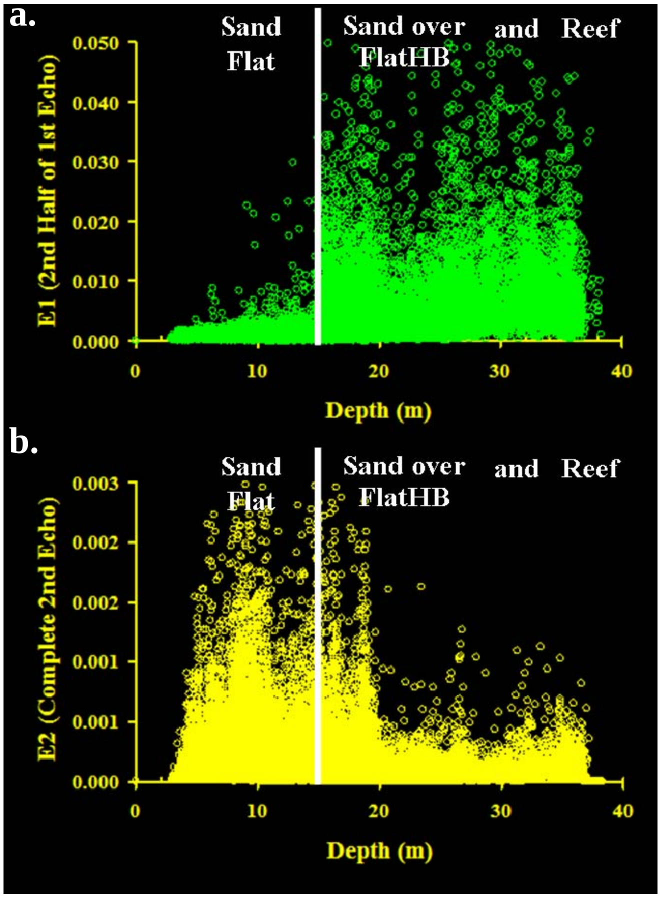


Figure 2.13. *Depth profiles of 38 kHz* ***(a)*** *E1parameter (2nd-half 1st echo) and* ***(b)*** *complete 2nd echo for sub-set of survey area encompassing tiles Inner6-Outer6 to Inner10-Outer10.*

As previously mentioned, it was observed that the value of E1/E2 tended to increase in the transition from Sand Flat to Sand over Hardbottom. This observation was examined further by first re-scaling the range of E1/E2 used in Appendix F to the lower end of E1/E2 values, to accentuate the transition between Sand Flat and Sand over Hardbottom habitats for the same sub-set of survey data extending from tiles Inner6-Outer6 to Inner10-Outer10 (Figure 2.14a). The plot of E1/E2 was then compared to a plot of model-predicted macroalgae biomass for the same area (Figure 2.14b). The demarcation of Sand Flat and Hardbottom observed from ground-truthing of this area corresponds well with the demarcation predicted by the value of E1/E2 (Figure 2.14a). The macroalgae biomass model followed the same line of demarcation, with macroalgae observed to be absent from the Sand Flat habitat and present on the Sand over Hardbottom habitat (Figure 2.14b). Two such disparate frequencies (38 versus 420 kHz) conveying the same information strongly suggests that the 38 kHz E/E2 is capable of distinguishing between the Sand Flat and Sand over Hardbottom habitats.

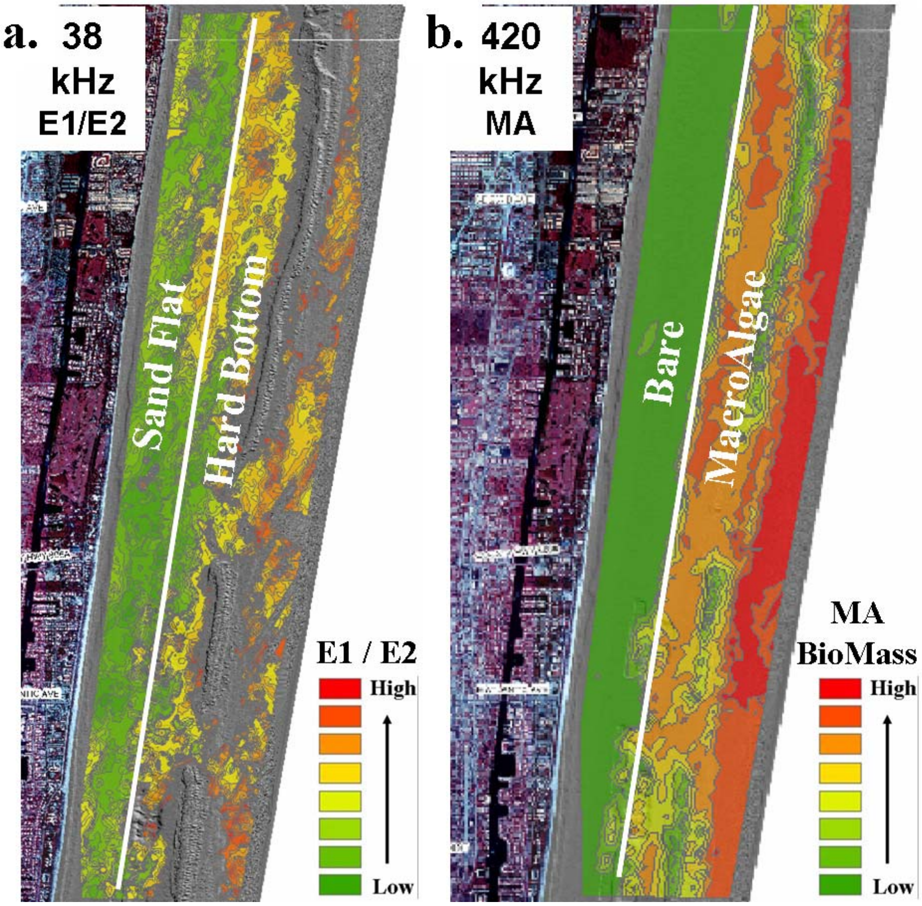


Figure 2.14. ***(a)*** *38 kHz E1/E2 and approximate ground-truthed demarcation of sand and hard-bottom zones, and* ***(b)*** *420 kHz macroalgae biomass model and ground-truthed demarcation of bare and macroalgae-cover for sub-set of survey area encompassing tiles Inner6-Outer6 to Inner10-Outer10.*

2.4.3. 420 kHz Gorgonian Biomass versus 38 kHz E1/E2 Comparison

It could be argued that the 420 kHz gorgonian biomass model is actually detecting the spatial complexity of the substrate, i.e. the preferred habitat, and not the actual presence of gorgonians. The very low number of false-positive detections in the gorgonian confusion matrix (Table 3a, 95.2% user's accuracy for Bare category) argues against such a claim, but it is worthwhile examining it further. In Figure 2.15, the 38 kHz E1/E2 contour plot is displayed next to the 420 kHz gorgonian biomass contour plot. The ground-truthing values of gorgonian Areal Cover* Height are overlayed on both contour plots. As discussed previously, the value of E1/E2 was observed to be much greater on the reef than on hardbottom or sand, seemingly due to the strong E1 parameter caused by the greater spatial complexity of the reef. This trend can be clearly seen in Figure 2.15a. On the other hand, the 420 kHz gorgonian biomass model categorizes the reef feature as bare (albeit slightly less bare than the surrounding hardbottom). Ground-truthing agrees with the gorgonian biomass model in that the area is relatively devoid of gorgonian cover. Taken together, these observations support the idea that the 38 kHz and 420 kHz maps are independent, and that the 420 kHz gorgonian model is not simply detecting spatial complexity.

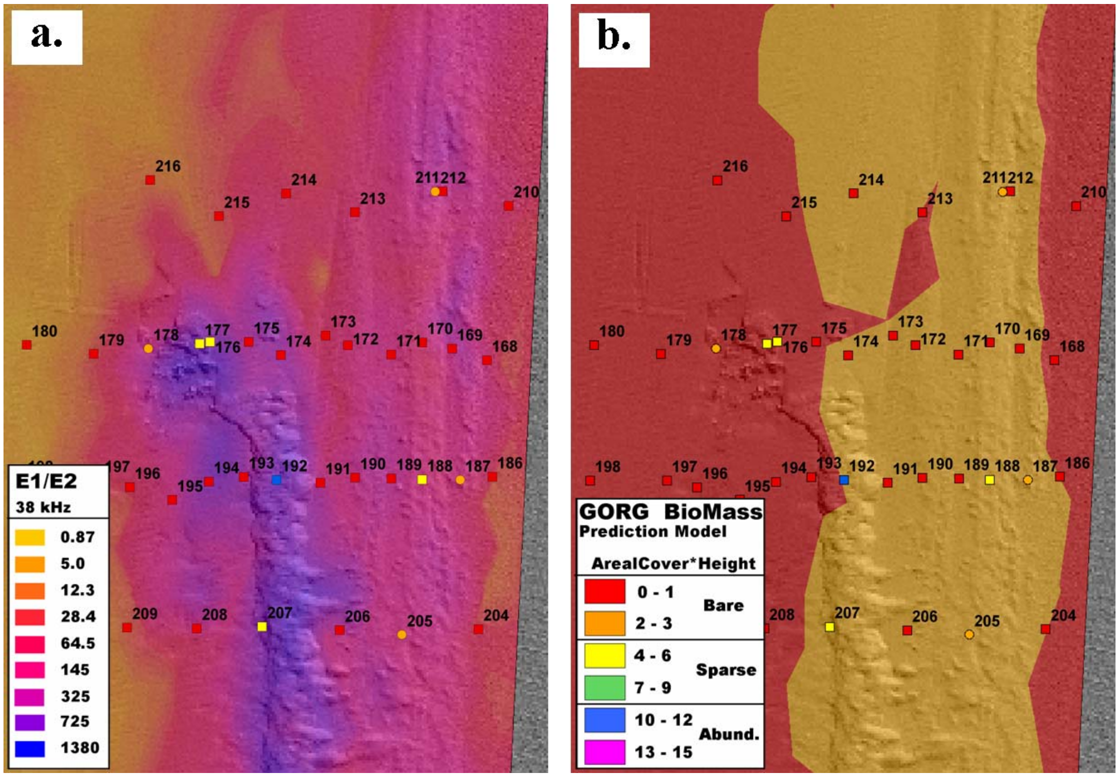


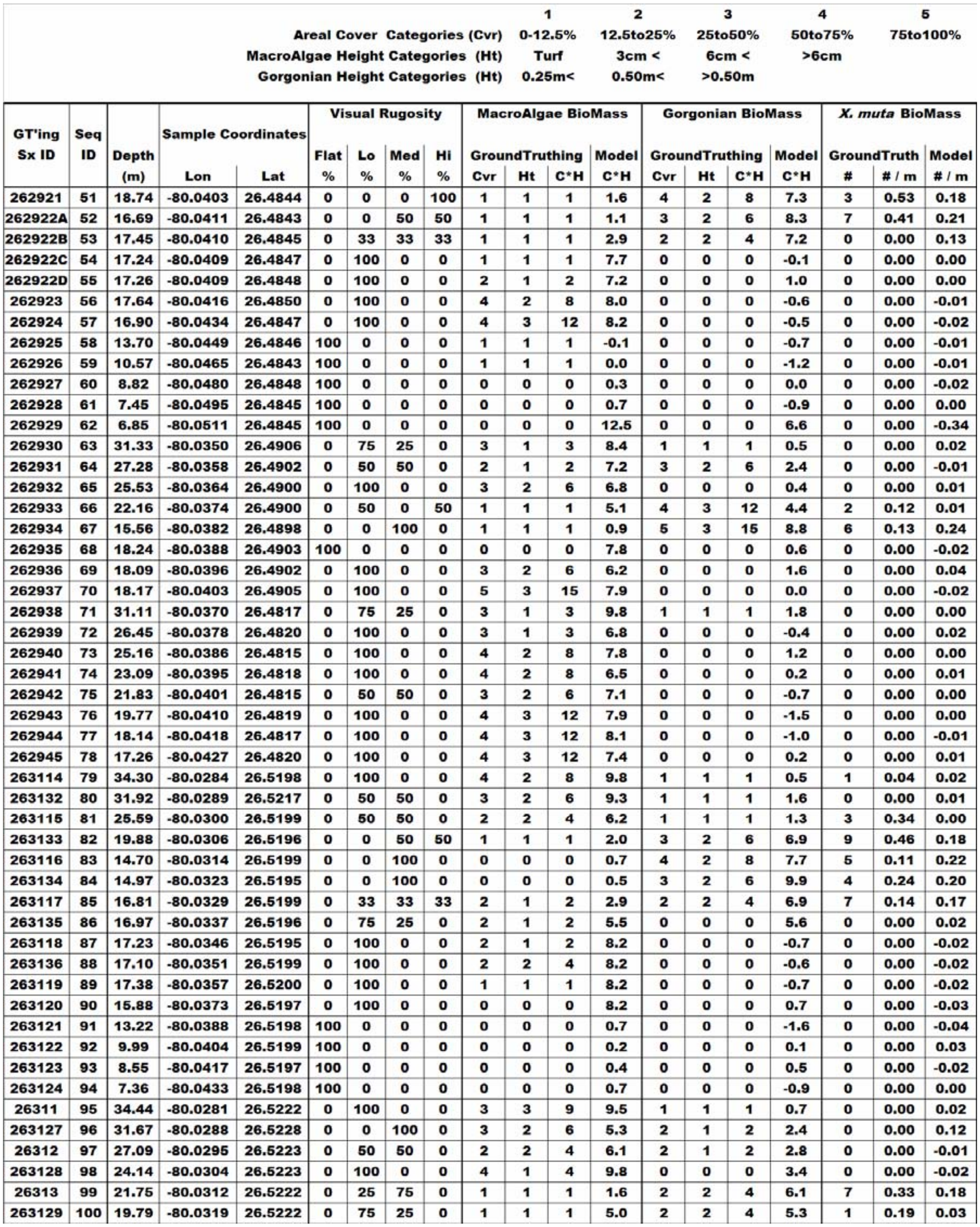
Figure 2.15. ***(a)*** *38 kHz E1/E2 contour plot of ground-truthing corridor GT2639 over LADS bathtmetry; high values of E1/E2 associated with high spatial complexity, and* ***(b)*** *420 kHz model-predicted gorgonian biomass contour plot of same area. Biomass model and ground-truthing both show low gorgonian abundance, despite high spatial complexity revealed by both LADS bathymetry and 38 kHz E1/E2.*

APPENDIX

	1	2	3	4	5
Areal Cover Categories (Cvr)	0-12.5%	12.5to25%	25to50%	50to75%	75to100%
MacroAlgae Height Categories (Ht)	Turf	3cm <	6cm <	>6cm	
Gorgonian Height Categories (Ht)	0.25m<	0.50m<	>0.50m		

GT'ing Sx ID	Seq ID	Depth (m)	Sample Coordinates		Visual Rugosity				MacroAlgae BioMass				Gorgonian BioMass				*X. muta* BioMass		
			Lon	Lat	Flat	Lo	Med	Hi	GroundTruthing			Model	GroundTruthing			Model	GroundTruth		Model
					%	%	%	%	Cvr	Ht	C*H	C*H	Cvr	Ht	C*H	C*H	#	# / m	# / m
26271	1	38.45	-80.0420	26.4473	0	100	0	0	4	2	8	7.9	1	1	1	-1.1	0	0.00	0.04
26272	2	32.66	-80.0429	26.4468	0	90	10	0	3	1	3	10.3	1	2	2	1.5	0	0.00	0.01
26273	3	30.07	-80.0436	26.4473	0	50	50	0	3	1	3	6.2	1	1	1	1.5	1	0.03	0.03
26274	4	26.07	-80.0444	26.4467	0	90	10	0	5	1	5	6.9	1	2	2	2.1	0	0.00	-0.01
26275	5	24.26	-80.0450	26.4469	0	0	100	0	4	3	12	5.8	1	1	1	2.8	5	0.82	-0.02
26276	6	14.63	-80.0466	26.4464	0	0	100	0	1	2	2	0.5	4	3	12	9.0	1	0.28	0.27
26277	7	16.83	-80.0473	26.4469	0	25	75	0	1	2	2	1.8	4	3	12	5.2	1	0.24	0.21
26278	8	16.60	-80.0473	26.4469	0	25	75	0	1	2	2	-0.3	4	3	12	9.4	1	0.25	0.24
26279	9	17.79	-80.0481	26.4474	0	100	0	0	4	2	8	8.1	0	0	0	-0.9	0	0.00	-0.01
262710	10	18.20	-80.0489	26.4467	0	100	0	0	4	2	8	6.0	0	0	0	1.4	0	0.00	0.05
262711	11	15.98	-80.0505	26.4472	0	100	0	0	2	1	2	7.5	0	0	0	-0.4	0	0.00	-0.02
262712	12	11.81	-80.0520	26.4473	100	0	0	0	0	0	0	0.1	0	0	0	-0.7	0	0.00	-0.02
262713	13	13.79	-80.0536	26.4469	100	0	0	0	0	0	0	-0.1	0	0	0	5.1	0	0.00	0.11
262714	14	7.44	-80.0548	26.4471	100	0	0	0	0	0	0	0.8	0	0	0	-0.1	0	0.00	0.00
262715	15	3.82	-80.0564	26.4472	100	0	0	0	0	0	0	10.3	0	0	0	7.8	0	0.00	-0.28
262717	16	38.05	-80.0424	26.4445	0	100	0	0	5	2	10	8.8	1	1	1	-0.8	0	0.00	0.04
262718	17	33.41	-80.0431	26.4446	0	100	0	0	5	2	10	10.1	1	1	1	1.2	0	0.00	0.01
262719	18	31.64	-80.0435	26.4446	0	50	50	0	3	1	3	6.7	1	1	1	1.2	0	0.00	0.01
262720	19	26.36	-80.0446	26.4445	0	50	50	0	2	2	4	6.9	2	1	2	2.9	0	0.00	-0.01
262721	20	25.33	-80.0450	26.4445	0	100	0	0	2	1	2	6.2	0	0	0	-0.2	0	0.00	0.02
262722	21	21.42	-80.0459	26.4445	0	0	100	0	2	1	2	5.4	4	3	12	5.4	1	0.38	0.01
262723	22	16.52	-80.0467	26.4444	0	0	100	0	1	1	1	0.8	4	2	8	5.9	2	0.28	0.23
262724	23	14.64	-80.0474	26.4441	0	0	100	0	1	1	1	0.7	4	3	12	8.3	12	0.57	0.27
262725	24	19.16	-80.0484	26.4443	0	100	0	0	3	1	3	7.3	0	0	0	2.8	0	0.00	-0.03
262726	25	19.08	-80.0489	26.4445	0	100	0	0	3	2	6	8.0	0	0	0	-1.4	0	0.00	-0.01
262727	26	17.91	-80.0503	26.4444	0	100	0	0	5	2	10	8.1	0	0	0	-0.9	0	0.00	-0.01
262728	27	12.11	-80.0519	26.4445	100	0	0	0	0	0	0	0.2	0	0	0	0.0	0	0.00	0.00
262729	28	13.06	-80.0536	26.4446	100	0	0	0	0	0	0	-0.1	0	0	0	-1.8	0	0.00	-0.05
262730	29	7.64	-80.0551	26.4442	100	0	0	0	0	0	0	1.0	0	0	0	1.1	0	0.00	-0.01
262731	30	4.37	-80.0568	26.4443	100	0	0	0	1	1	1	2.8	0	0	0	4.5	0	0.00	-0.07
26291	31	30.80	-80.0358	26.4876	0	100	0	0	3	2	6	8.7	1	1	1	1.5	0	0.00	0.01
26292	32	26.39	-80.0367	26.4873	0	75	25	0	2	1	2	4.7	1	1	1	1.7	0	0.00	0.08
26293	33	25.05	-80.0373	26.4877	0	75	25	0	3	2	6	7.6	0	0	0	0.6	0	0.00	0.01
26294	34	23.46	-80.0377	26.4886	0	25	75	0	2	1	2	4.0	3	1	3	3.4	0	0.00	0.05
26295	35	16.21	-80.0387	26.4880	0	0	100	0	1	1	1	2.1	2	1	2	7.1	4	0.42	0.18
26296	36	18.46	-80.0394	26.4887	0	75	25	0	3	1	3	2.6	0	0	0	4.9	0	0.00	0.12
26297	37	18.11	-80.0401	26.4876	0	100	0	0	5	2	10	6.7	0	0	0	1.4	0	0.00	0.02
26298	38	18.30	-80.0409	26.4874	0	100	0	0	5	3	15	7.8	0	0	0	0.0	0	0.00	-0.01
26299	39	17.54	-80.0425	26.4872	0	100	0	0	4	3	12	8.2	0	0	0	-0.8	0	0.00	-0.02
262910	40	15.70	-80.0435	26.4873	0	100	0	0	3	2	6	8.3	0	0	0	-0.1	0	0.00	-0.03
262911	41	12.04	-80.0451	26.4873	100	0	0	0	0	0	0	0.0	0	0	0	-1.4	0	0.00	-0.05
262912	42	9.85	-80.0465	26.4871	100	0	0	0	0	0	0	0.3	0	0	0	0.5	0	0.00	0.04
262913	43	8.22	-80.0482	26.4876	100	0	0	0	0	0	0	0.4	0	0	0	0.3	0	0.00	-0.02
262914	44	6.71	-80.0496	26.4870	100	0	0	0	0	0	0	0.7	0	0	0	-0.7	0	0.00	0.00
262915	45	5.67	-80.0511	26.4873	100	0	0	0	0	0	0	12.6	0	0	0	7.1	0	0.00	-0.34
262916	46	31.52	-80.0364	26.4844	0	75	25	0	3	2	6	10.4	1	1	1	1.9	1	0.11	0.00
262917	47	27.81	-80.0369	26.4847	0	75	25	0	2	1	2	5.7	4	2	8	2.7	0	0.00	0.03
262918	48	24.84	-80.0379	26.4845	0	100	0	0	2	1	2	6.8	0	0	0	0.0	0	0.00	0.01
262919	49	23.12	-80.0387	26.4845	0	100	0	0	4	3	12	6.5	0	0	0	0.5	0	0.00	0.00
262920	50	21.83	-80.0394	26.4848	0	100	0	0	3	1	3	6.9	0	0	0	-0.2	0	0.00	0.01

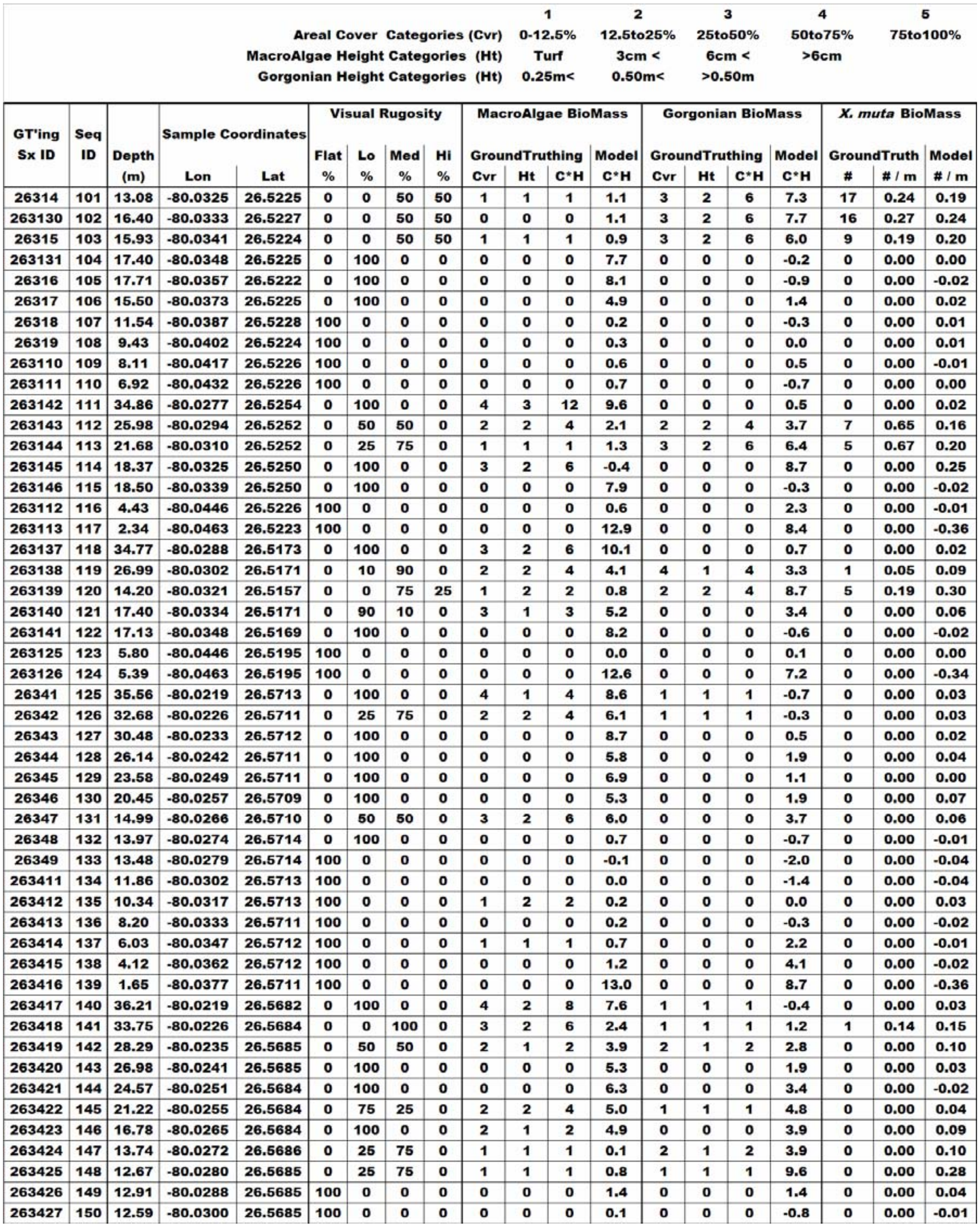
Appendix A1. *Summary of ground-truthing samples*



	1	2	3	4	5
Areal Cover Categories (Cvr)	**0-12.5%**	**12.5to25%**	**25to50%**	**50to75%**	**75to100%**
MacroAlgae Height Categories (Ht)	**Turf**	**3cm <**	**6cm <**	**>6cm**	
Gorgonian Height Categories (Ht)	**0.25m<**	**0.50m<**	**>0.50m**		

GT'ing Sx ID	Seq ID	Depth	Sample Coordinates		Visual Rugosity				MacroAlgae BioMass				Gorgonian BioMass				*X. muta* BioMass		
		(m)	Lon	Lat	Flat %	Lo %	Med %	Hi %	GroundTruthing			Model	GroundTruthing			Model	GroundTruth		Model
									Cvr	Ht	C*H	C*H	Cvr	Ht	C*H	C*H	#	# / m	# / m
262921	51	18.74	-80.0403	26.4844	0	0	0	100	1	1	1	1.6	4	2	8	7.3	3	0.53	0.18
262922A	52	16.69	-80.0411	26.4843	0	0	50	50	1	1	1	1.1	3	2	6	8.3	7	0.41	0.21
262922B	53	17.45	-80.0410	26.4845	0	33	33	33	1	1	1	2.9	2	2	4	7.2	0	0.00	0.13
262922C	54	17.24	-80.0409	26.4847	0	100	0	0	1	1	1	7.7	0	0	0	-0.1	0	0.00	0.00
262922D	55	17.26	-80.0409	26.4848	0	100	0	0	2	1	2	7.2	0	0	0	1.0	0	0.00	0.00
262923	56	17.64	-80.0416	26.4850	0	100	0	0	4	2	8	8.0	0	0	0	-0.6	0	0.00	-0.01
262924	57	16.90	-80.0434	26.4847	0	100	0	0	4	3	12	8.2	0	0	0	-0.5	0	0.00	-0.02
262925	58	13.70	-80.0449	26.4846	100	0	0	0	1	1	1	-0.1	0	0	0	-0.7	0	0.00	-0.01
262926	59	10.57	-80.0465	26.4843	100	0	0	0	1	1	1	0.0	0	0	0	-1.2	0	0.00	-0.01
262927	60	8.82	-80.0480	26.4848	100	0	0	0	0	0	0	0.3	0	0	0	0.0	0	0.00	-0.02
262928	61	7.45	-80.0495	26.4845	100	0	0	0	0	0	0	0.7	0	0	0	-0.9	0	0.00	0.00
262929	62	6.85	-80.0511	26.4845	100	0	0	0	0	0	0	12.5	0	0	0	6.6	0	0.00	-0.34
262930	63	31.33	-80.0350	26.4906	0	75	25	0	3	1	3	8.4	1	1	1	0.5	0	0.00	0.02
262931	64	27.28	-80.0358	26.4902	0	50	50	0	2	1	2	7.2	3	2	6	2.4	0	0.00	-0.01
262932	65	25.53	-80.0364	26.4900	0	100	0	0	3	2	6	6.8	0	0	0	0.4	0	0.00	0.01
262933	66	22.16	-80.0374	26.4900	0	50	0	50	1	1	1	5.1	4	3	12	4.4	2	0.12	0.01
262934	67	15.56	-80.0382	26.4898	0	0	100	0	1	1	1	0.9	5	3	15	8.8	6	0.13	0.24
262935	68	18.24	-80.0388	26.4903	100	0	0	0	0	0	0	7.8	0	0	0	0.6	0	0.00	-0.02
262936	69	18.09	-80.0396	26.4902	0	100	0	0	3	2	6	6.2	0	0	0	1.6	0	0.00	0.04
262937	70	18.17	-80.0403	26.4905	0	100	0	0	5	3	15	7.9	0	0	0	0.0	0	0.00	-0.02
262938	71	31.11	-80.0370	26.4817	0	75	25	0	3	1	3	9.8	1	1	1	1.8	0	0.00	0.00
262939	72	26.45	-80.0378	26.4820	0	100	0	0	3	1	3	6.8	0	0	0	-0.4	0	0.00	0.02
262940	73	25.16	-80.0386	26.4815	0	100	0	0	4	2	8	7.8	0	0	0	1.2	0	0.00	0.00
262941	74	23.09	-80.0395	26.4818	0	100	0	0	4	2	8	6.5	0	0	0	0.2	0	0.00	0.01
262942	75	21.83	-80.0401	26.4815	0	50	50	0	3	2	6	7.1	0	0	0	-0.7	0	0.00	0.00
262943	76	19.77	-80.0410	26.4819	0	100	0	0	4	3	12	7.9	0	0	0	-1.5	0	0.00	0.00
262944	77	18.14	-80.0418	26.4817	0	100	0	0	4	3	12	8.1	0	0	0	-1.0	0	0.00	-0.01
262945	78	17.26	-80.0427	26.4820	0	100	0	0	4	3	12	7.4	0	0	0	0.2	0	0.00	0.01
263114	79	34.30	-80.0284	26.5198	0	100	0	0	4	2	8	9.8	1	1	1	0.5	1	0.04	0.02
263132	80	31.92	-80.0289	26.5217	0	50	50	0	3	2	6	9.3	1	1	1	1.6	0	0.00	0.01
263115	81	25.59	-80.0300	26.5199	0	50	50	0	2	2	4	6.2	1	1	1	1.3	3	0.34	0.00
263133	82	19.88	-80.0306	26.5196	0	0	50	50	1	1	1	2.0	3	2	6	6.9	9	0.46	0.18
263116	83	14.70	-80.0314	26.5199	0	0	100	0	0	0	0	0.7	4	2	8	7.7	5	0.11	0.22
263134	84	14.97	-80.0323	26.5195	0	0	100	0	0	0	0	0.5	3	2	6	9.9	4	0.24	0.20
263117	85	16.81	-80.0329	26.5199	0	33	33	33	2	1	2	2.9	2	2	4	6.9	7	0.14	0.17
263135	86	16.97	-80.0337	26.5196	0	75	25	0	2	1	2	5.5	0	0	0	5.6	0	0.00	0.02
263118	87	17.23	-80.0346	26.5195	0	100	0	0	2	1	2	8.2	0	0	0	-0.7	0	0.00	-0.02
263136	88	17.10	-80.0351	26.5199	0	100	0	0	2	2	4	8.2	0	0	0	-0.6	0	0.00	-0.02
263119	89	17.38	-80.0357	26.5200	0	100	0	0	1	1	1	8.2	0	0	0	-0.7	0	0.00	-0.02
263120	90	15.88	-80.0373	26.5197	0	100	0	0	0	0	0	8.2	0	0	0	0.7	0	0.00	-0.03
263121	91	13.22	-80.0388	26.5198	100	0	0	0	0	0	0	0.7	0	0	0	-1.6	0	0.00	-0.04
263122	92	9.99	-80.0404	26.5199	100	0	0	0	0	0	0	0.2	0	0	0	0.1	0	0.00	0.03
263123	93	8.55	-80.0417	26.5197	100	0	0	0	0	0	0	0.4	0	0	0	0.5	0	0.00	-0.02
263124	94	7.36	-80.0433	26.5198	100	0	0	0	0	0	0	0.7	0	0	0	-0.9	0	0.00	0.00
26311	95	34.44	-80.0281	26.5222	0	100	0	0	3	3	9	9.5	1	1	1	0.7	0	0.00	0.02
263127	96	31.67	-80.0288	26.5228	0	0	100	0	3	2	6	5.3	2	1	2	2.4	0	0.00	0.12
26312	97	27.09	-80.0295	26.5223	0	50	50	0	2	2	4	6.1	2	1	2	2.8	0	0.00	-0.01
263128	98	24.14	-80.0304	26.5223	0	100	0	0	4	1	4	9.8	0	0	0	3.4	0	0.00	-0.02
26313	99	21.75	-80.0312	26.5222	0	25	75	0	1	1	1	1.6	2	2	4	6.1	7	0.33	0.18
263129	100	19.79	-80.0319	26.5222	0	75	25	0	1	1	1	5.0	2	2	4	5.3	1	0.19	0.03

Appendix A2. *Summary of ground-truthing samples*



	1	2	3	4	5
Areal Cover Categories (Cvr)	0-12.5%	12.5to25%	25to50%	50to75%	75to100%
MacroAlgae Height Categories (Ht)	Turf	3cm <	6cm <	>6cm	
Gorgonian Height Categories (Ht)	0.25m<	0.50m<	>0.50m		

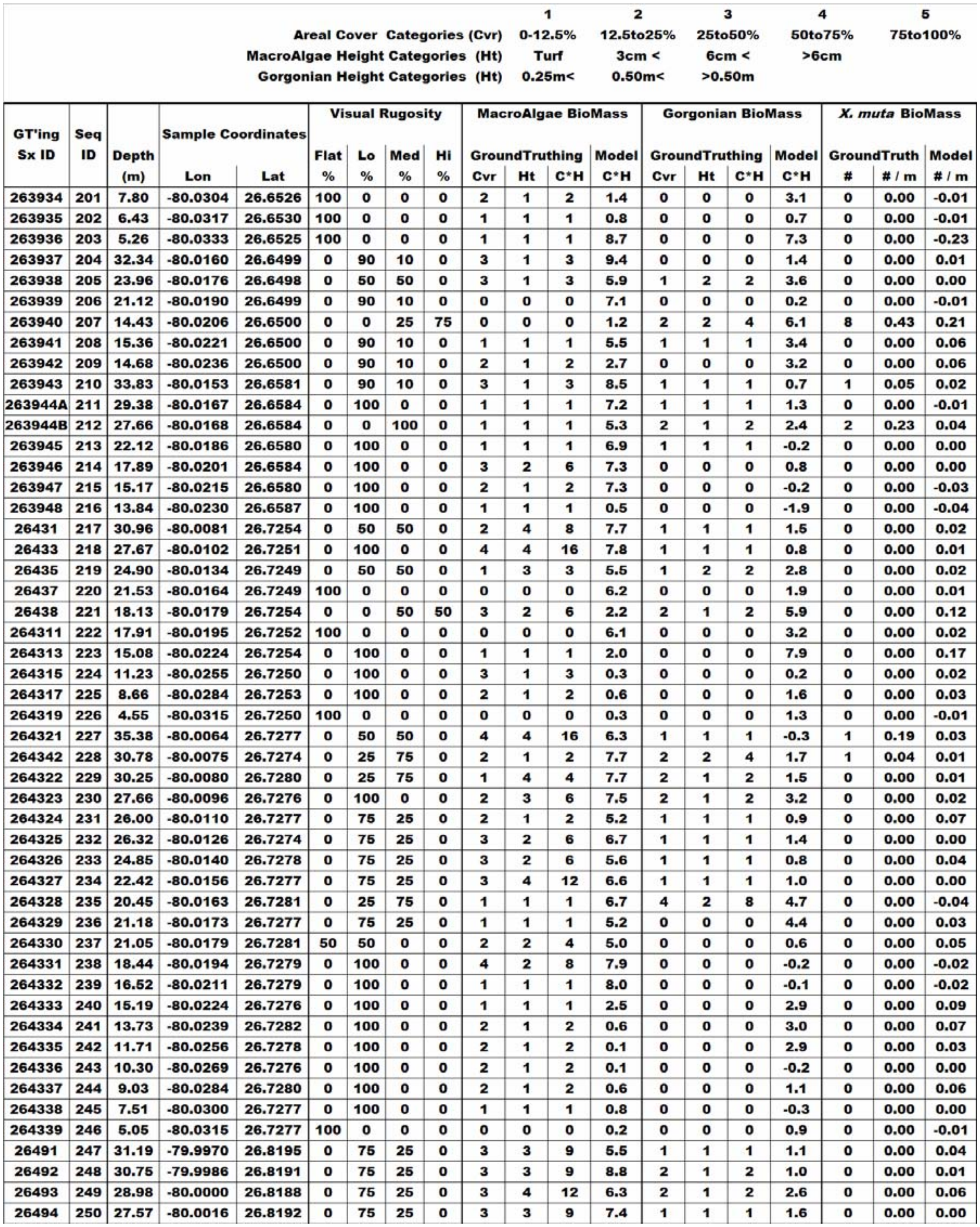
GT'ing Sx ID	Seq ID	Depth (m)	Sample Coordinates		Visual Rugosity				MacroAlgae BioMass				Gorgonian BioMass				*X. muta* BioMass		
					Flat	Lo	Med	Hi	GroundTruthing			Model	GroundTruthing			Model	GroundTruth		Model
			Lon	Lat	%	%	%	%	Cvr	Ht	C*H	C*H	Cvr	Ht	C*H	C*H	#	# / m	# / m
26314	101	13.08	-80.0325	26.5225	0	0	50	50	1	1	1	1.1	3	2	6	7.3	17	0.24	0.19
263130	102	16.40	-80.0333	26.5227	0	0	50	50	0	0	0	1.1	3	2	6	7.7	16	0.27	0.24
26315	103	15.93	-80.0341	26.5224	0	0	50	50	1	1	1	0.9	3	2	6	6.0	9	0.19	0.20
263131	104	17.40	-80.0348	26.5225	0	100	0	0	0	0	0	7.7	0	0	0	-0.2	0	0.00	0.00
26316	105	17.71	-80.0357	26.5222	0	100	0	0	0	0	0	8.1	0	0	0	-0.9	0	0.00	-0.02
26317	106	15.50	-80.0373	26.5225	0	100	0	0	0	0	0	4.9	0	0	0	1.4	0	0.00	0.02
26318	107	11.54	-80.0387	26.5228	100	0	0	0	0	0	0	0.2	0	0	0	-0.3	0	0.00	0.01
26319	108	9.43	-80.0402	26.5224	100	0	0	0	0	0	0	0.3	0	0	0	0.0	0	0.00	0.01
263110	109	8.11	-80.0417	26.5226	100	0	0	0	0	0	0	0.6	0	0	0	0.5	0	0.00	-0.01
263111	110	6.92	-80.0432	26.5226	100	0	0	0	0	0	0	0.7	0	0	0	-0.7	0	0.00	0.00
263142	111	34.86	-80.0277	26.5254	0	100	0	0	4	3	12	9.6	0	0	0	0.5	0	0.00	0.02
263143	112	25.98	-80.0294	26.5252	0	50	50	0	2	2	4	2.1	2	2	4	3.7	7	0.65	0.16
263144	113	21.68	-80.0310	26.5252	0	25	75	0	1	1	1	1.3	3	2	6	6.4	5	0.67	0.20
263145	114	18.37	-80.0325	26.5250	0	100	0	0	3	2	6	-0.4	0	0	0	8.7	0	0.00	0.25
263146	115	18.50	-80.0339	26.5250	0	100	0	0	0	0	0	7.9	0	0	0	-0.3	0	0.00	-0.02
263112	116	4.43	-80.0446	26.5226	100	0	0	0	0	0	0	0.6	0	0	0	2.3	0	0.00	-0.01
263113	117	2.34	-80.0463	26.5223	100	0	0	0	0	0	0	12.9	0	0	0	8.4	0	0.00	-0.36
263137	118	34.77	-80.0288	26.5173	0	100	0	0	3	2	6	10.1	0	0	0	0.7	0	0.00	0.02
263138	119	26.99	-80.0302	26.5171	0	10	90	0	2	2	4	4.1	4	1	4	3.3	1	0.05	0.09
263139	120	14.20	-80.0321	26.5157	0	0	75	25	1	2	2	0.8	2	2	4	8.7	5	0.19	0.30
263140	121	17.40	-80.0334	26.5171	0	90	10	0	3	1	3	5.2	0	0	0	3.4	0	0.00	0.06
263141	122	17.13	-80.0348	26.5169	0	100	0	0	0	0	0	8.2	0	0	0	-0.6	0	0.00	-0.02
263125	123	5.80	-80.0446	26.5195	100	0	0	0	0	0	0	0.0	0	0	0	0.1	0	0.00	0.00
263126	124	5.39	-80.0463	26.5195	100	0	0	0	0	0	0	12.6	0	0	0	7.2	0	0.00	-0.34
26341	125	35.56	-80.0219	26.5713	0	100	0	0	4	1	4	8.6	1	1	1	-0.7	0	0.00	0.03
26342	126	32.68	-80.0226	26.5711	0	25	75	0	2	2	4	6.1	1	1	1	-0.3	0	0.00	0.03
26343	127	30.48	-80.0233	26.5712	0	100	0	0	0	0	0	8.7	0	0	0	0.5	0	0.00	0.02
26344	128	26.14	-80.0242	26.5711	0	100	0	0	0	0	0	5.8	0	0	0	1.9	0	0.00	0.04
26345	129	23.58	-80.0249	26.5711	0	100	0	0	0	0	0	6.9	0	0	0	1.1	0	0.00	0.00
26346	130	20.45	-80.0257	26.5709	0	100	0	0	0	0	0	5.3	0	0	0	1.9	0	0.00	0.07
26347	131	14.99	-80.0266	26.5710	0	50	50	0	3	2	6	6.0	0	0	0	3.7	0	0.00	0.06
26348	132	13.97	-80.0274	26.5714	0	100	0	0	0	0	0	0.7	0	0	0	-0.7	0	0.00	-0.01
26349	133	13.48	-80.0279	26.5714	100	0	0	0	0	0	0	-0.1	0	0	0	-2.0	0	0.00	-0.04
263411	134	11.86	-80.0302	26.5713	100	0	0	0	0	0	0	0.0	0	0	0	-1.4	0	0.00	-0.04
263412	135	10.34	-80.0317	26.5713	100	0	0	0	1	2	2	0.2	0	0	0	0.0	0	0.00	0.03
263413	136	8.20	-80.0333	26.5711	100	0	0	0	0	0	0	0.2	0	0	0	-0.3	0	0.00	-0.02
263414	137	6.03	-80.0347	26.5712	100	0	0	0	1	1	1	0.7	0	0	0	2.2	0	0.00	-0.01
263415	138	4.12	-80.0362	26.5712	100	0	0	0	0	0	0	1.2	0	0	0	4.1	0	0.00	-0.02
263416	139	1.65	-80.0377	26.5711	100	0	0	0	0	0	0	13.0	0	0	0	8.7	0	0.00	-0.36
263417	140	36.21	-80.0219	26.5682	0	100	0	0	4	2	8	7.6	1	1	1	-0.4	0	0.00	0.03
263418	141	33.75	-80.0226	26.5684	0	0	100	0	3	2	6	2.4	1	1	1	1.2	1	0.14	0.15
263419	142	28.29	-80.0235	26.5685	0	50	50	0	2	1	2	3.9	2	1	2	2.8	0	0.00	0.10
263420	143	26.98	-80.0241	26.5685	0	100	0	0	0	0	0	5.3	0	0	0	1.9	0	0.00	0.03
263421	144	24.57	-80.0251	26.5684	0	100	0	0	0	0	0	6.3	0	0	0	3.4	0	0.00	-0.02
263422	145	21.22	-80.0255	26.5684	0	75	25	0	2	2	4	5.0	1	1	1	4.8	0	0.00	0.04
263423	146	16.78	-80.0265	26.5684	0	100	0	0	2	1	2	4.9	0	0	0	3.9	0	0.00	0.09
263424	147	13.74	-80.0272	26.5686	0	25	75	0	1	1	1	0.1	2	1	2	3.9	0	0.00	0.10
263425	148	12.67	-80.0280	26.5685	0	25	75	0	1	1	1	0.8	1	1	1	9.6	0	0.00	0.28
263426	149	12.91	-80.0288	26.5685	100	0	0	0	0	0	0	1.4	0	0	0	1.4	0	0.00	0.04
263427	150	12.59	-80.0300	26.5685	100	0	0	0	0	0	0	0.1	0	0	0	-0.8	0	0.00	-0.01

Appendix A3. *Summary of ground-truthing samples*

	1	2	3	4	5
Areal Cover Categories (Cvr)	0-12.5%	12.5to25%	25to50%	50to75%	75to100%
MacroAlgae Height Categories (Ht)	Turf	3cm <	6cm <	>6cm	
Gorgonian Height Categories (Ht)	0.25m<	0.50m<	>0.50m		

GT'ing Sx ID	Seq ID	Depth (m)	Sample Coordinates		Visual Rugosity				MacroAlgae BioMass				Gorgonian BioMass				*X. muta* BioMass		
			Lon	Lat	Flat %	Lo %	Med %	Hi %	GroundTruthing Cvr	Ht	C*H	Model C*H	GroundTruthing Cvr	Ht	C*H	Model C*H	GroundTruth #	# / m	Model # / m
263428	151	10.96	-80.0316	26.5685	100	0	0	0	0	0	0	0.9	0	0	0	3.7	0	0.00	0.16
263429	152	8.54	-80.0330	26.5684	100	0	0	0	0	0	0	0.8	0	0	0	1.7	0	0.00	0.04
263430	153	6.55	-80.0346	26.5685	100	0	0	0	0	0	0	0.9	0	0	0	1.1	0	0.00	-0.01
263431	154	3.73	-80.0361	26.5685	100	0	0	0	0	0	0	7.6	0	0	0	7.9	0	0.00	-0.20
263432	155	1.59	-80.0378	26.5686	100	0	0	0	0	0	0	13.0	0	0	0	8.7	0	0.00	-0.36
263433	156	36.03	-80.0215	26.5741	0	100	0	0	4	2	8	5.8	0	0	0	-1.3	0	0.00	0.01
263434	157	31.23	-80.0230	26.5740	0	100	0	0	2	1	2	5.1	0	0	0	1.0	0	0.00	0.09
263435	158	23.85	-80.0246	26.5739	0	75	25	0	1	2	2	3.9	0	0	0	4.4	0	0.00	0.08
263436	159	17.29	-80.0260	26.5740	0	100	0	0	2	1	2	0.3	0	0	0	7.8	0	0.00	0.30
263437	160	13.05	-80.0276	26.5739	100	0	0	0	0	0	0	0.1	0	0	0	-0.6	0	0.00	0.00
263438	161	11.94	-80.0290	26.5740	100	0	0	0	0	0	0	0.0	0	0	0	-1.5	0	0.00	-0.04
263439	162	35.61	-80.0223	26.5660	0	100	0	0	4	2	8	7.8	1	1	1	-0.8	1	0.16	0.04
263440	163	27.74	-80.0241	26.5655	0	0	50	50	1	2	2	6.5	1	1	1	1.8	1	0.16	0.00
263441	164	23.43	-80.0255	26.5658	0	100	0	0	0	0	0	6.8	0	0	0	-0.5	0	0.00	0.01
263442	165	17.60	-80.0269	26.5659	0	100	0	0	1	1	1	6.7	0	0	0	2.7	0	0.00	-0.06
263443	166	13.83	-80.0284	26.5658	0	100	0	0	0	0	0	0.7	0	0	0	0.4	0	0.00	0.01
263444	167	12.51	-80.0300	26.5658	100	0	0	0	0	0	0	0.1	0	0	0	-0.5	0	0.00	0.00
26391	168	32.81	-80.0158	26.6551	0	75	25	0	5	1	5	9.2	1	1	1	1.2	1	0.05	0.01
26392	169	29.76	-80.0165	26.6554	0	33	33	34	2	2	4	5.1	1	1	1	2.0	2	0.15	0.07
26393	170	25.95	-80.0171	26.6555	0	100	0	0	1	1	1	3.0	1	1	1	4.6	0	0.00	0.13
26394	171	23.49	-80.0178	26.6553	0	100	0	0	1	1	1	7.0	1	1	1	2.5	0	0.00	-0.01
26395	172	21.42	-80.0188	26.6554	0	100	0	0	1	1	1	5.9	1	1	1	3.0	0	0.00	0.02
26396	173	21.36	-80.0192	26.6556	0	100	0	0	3	1	3	6.8	0	0	0	2.4	0	0.00	-0.02
26397	174	18.33	-80.0202	26.6553	0	75	25	0	3	2	6	8.1	0	0	0	-1.1	0	0.00	-0.01
26398	175	16.09	-80.0209	26.6555	0	100	0	0	4	2	8	3.4	1	1	1	1.9	0	0.00	0.03
26399	176	14.82	-80.0217	26.6555	0	75	25	0	1	1	1	1.2	3	2	6	6.1	0	0.00	0.22
263910	177	13.47	-80.0219	26.6555	0	0	50	50	1	1	1	1.3	3	2	6	6.4	1	0.03	0.20
263911	178	15.58	-80.0230	26.6554	0	100	0	0	3	1	3	8.3	1	2	2	0.0	0	0.00	-0.03
263912	179	13.67	-80.0242	26.6553	0	100	0	0	1	1	1	0.3	0	0	0	-1.2	0	0.00	-0.03
263913	180	12.57	-80.0257	26.6555	0	100	0	0	1	1	1	-0.1	0	0	0	-1.7	0	0.00	-0.04
263914	181	11.05	-80.0272	26.6551	100	0	0	0	1	1	1	0.1	0	0	0	-1.1	0	0.00	-0.05
263915	182	9.18	-80.0289	26.6555	100	0	0	0	1	1	1	0.5	0	0	0	1.0	0	0.00	0.03
263916	183	8.08	-80.0302	26.6557	100	0	0	0	1	1	1	0.7	0	0	0	0.5	0	0.00	-0.01
263917	184	6.83	-80.0318	26.6552	100	0	0	0	1	2	2	0.8	0	0	0	-0.4	0	0.00	0.00
263918	185	3.88	-80.0332	26.6556	100	0	0	0	1	2	2	6.5	0	0	0	7.8	0	0.00	-0.17
263919	186	33.02	-80.0157	26.6529	0	100	0	0	3	1	3	9.8	1	1	1	1.3	0	0.00	0.01
263920	187	29.96	-80.0164	26.6528	0	100	0	0	2	1	2	0.8	1	2	2	3.0	0	0.00	0.20
263921	188	25.81	-80.0172	26.6528	0	10	90	0	1	1	1	3.4	3	2	6	3.7	2	0.08	0.11
263922	189	23.90	-80.0178	26.6529	0	100	0	0	1	1	1	5.5	0	0	0	2.8	0	0.00	0.03
263923	190	21.53	-80.0186	26.6529	0	90	10	0	1	2	2	3.6	0	0	0	5.7	0	0.00	0.09
263924	191	20.79	-80.0194	26.6528	0	100	0	0	3	1	3	3.4	0	0	0	6.4	0	0.00	0.09
263925	192	13.53	-80.0203	26.6529	0	0	100	0	1	1	1	0.8	4	3	12	8.3	2	0.06	0.24
263926	193	15.23	-80.0210	26.6529	0	90	10	0	0	0	0	1.6	0	0	0	7.8	0	0.00	0.17
263927	194	14.55	-80.0218	26.6528	0	100	0	0	0	0	0	0.0	0	0	0	1.5	0	0.00	0.06
263928	195	14.51	-80.0226	26.6525	0	100	0	0	2	1	2	0.6	0	0	0	7.2	0	0.00	0.26
263929	196	15.09	-80.0235	26.6527	0	100	0	0	3	1	3	0.9	0	0	0	6.0	0	0.00	0.14
263930	197	14.34	-80.0241	26.6529	0	100	0	0	1	1	1	0.7	0	0	0	-0.8	0	0.00	-0.01
263931	198	12.48	-80.0258	26.6529	0	100	0	0	1	1	1	0.1	0	0	0	0.2	0	0.00	0.01
263932	199	11.03	-80.0271	26.6528	100	0	0	0	1	1	1	0.3	0	0	0	0.1	0	0.00	0.00
263933	200	9.23	-80.0288	26.6529	100	0	0	0	2	1	2	0.4	0	0	0	0.5	0	0.00	0.01

Appendix A4. *Summary of ground-truthing samples*



	1	2	3	4	5
Areal Cover Categories (Cvr)	0-12.5%	12.5to25%	25to50%	50to75%	75to100%
MacroAlgae Height Categories (Ht)	Turf	3cm <	6cm <	>6cm	
Gorgonian Height Categories (Ht)	0.25m<	0.50m<	>0.50m		

GT'ing Sx ID	Seq ID	Depth (m)	Sample Coordinates		Visual Rugosity				MacroAlgae BioMass				Gorgonian BioMass				*X. muta* BioMass		
					Flat	Lo	Med	Hi	GroundTruthing			Model	GroundTruthing			Model	GroundTruth		Model
			Lon	Lat	%	%	%	%	Cvr	Ht	C*H	C*H	Cvr	Ht	C*H	C*H	#	# / m	# / m
263934	201	7.80	-80.0304	26.6526	100	0	0	0	2	1	2	1.4	0	0	0	3.1	0	0.00	-0.01
263935	202	6.43	-80.0317	26.6530	100	0	0	0	1	1	1	0.8	0	0	0	0.7	0	0.00	-0.01
263936	203	5.26	-80.0333	26.6525	100	0	0	0	1	1	1	8.7	0	0	0	7.3	0	0.00	-0.23
263937	204	32.34	-80.0160	26.6499	0	90	10	0	3	1	3	9.4	0	0	0	1.4	0	0.00	0.01
263938	205	23.96	-80.0176	26.6498	0	50	50	0	3	1	3	5.9	1	2	2	3.6	0	0.00	0.00
263939	206	21.12	-80.0190	26.6499	0	90	10	0	0	0	0	7.1	0	0	0	0.2	0	0.00	-0.01
263940	207	14.43	-80.0206	26.6500	0	0	25	75	0	0	0	1.2	2	2	4	6.1	8	0.43	0.21
263941	208	15.36	-80.0221	26.6500	0	90	10	0	1	1	1	5.5	1	1	1	3.4	0	0.00	0.06
263942	209	14.68	-80.0236	26.6500	0	90	10	0	2	1	2	2.7	0	0	0	3.2	0	0.00	0.06
263943	210	33.83	-80.0153	26.6581	0	90	10	0	3	1	3	8.5	1	1	1	0.7	1	0.05	0.02
263944A	211	29.38	-80.0167	26.6584	0	100	0	0	1	1	1	7.2	1	1	1	1.3	0	0.00	-0.01
263944B	212	27.66	-80.0168	26.6584	0	0	100	0	1	1	1	5.3	2	1	2	2.4	2	0.23	0.04
263945	213	22.12	-80.0186	26.6580	0	100	0	0	1	1	1	6.9	1	1	1	-0.2	0	0.00	0.00
263946	214	17.89	-80.0201	26.6584	0	100	0	0	3	2	6	7.3	0	0	0	0.8	0	0.00	0.00
263947	215	15.17	-80.0215	26.6580	0	100	0	0	2	1	2	7.3	0	0	0	-0.2	0	0.00	-0.03
263948	216	13.84	-80.0230	26.6587	0	100	0	0	1	1	1	0.5	0	0	0	-1.9	0	0.00	-0.04
26431	217	30.96	-80.0081	26.7254	0	50	50	0	2	4	8	7.7	1	1	1	1.5	0	0.00	0.02
26433	218	27.67	-80.0102	26.7251	0	100	0	0	4	4	16	7.8	1	1	1	0.8	0	0.00	0.01
26435	219	24.90	-80.0134	26.7249	0	50	50	0	1	3	3	5.5	1	2	2	2.8	0	0.00	0.02
26437	220	21.53	-80.0164	26.7249	100	0	0	0	0	0	0	6.2	0	0	0	1.9	0	0.00	0.01
26438	221	18.13	-80.0179	26.7254	0	0	50	50	3	2	6	2.2	2	1	2	5.9	0	0.00	0.12
264311	222	17.91	-80.0195	26.7252	100	0	0	0	0	0	0	6.1	0	0	0	3.2	0	0.00	0.02
264313	223	15.08	-80.0224	26.7254	0	100	0	0	1	1	1	2.0	0	0	0	7.9	0	0.00	0.17
264315	224	11.23	-80.0255	26.7250	0	100	0	0	3	1	3	0.3	0	0	0	0.2	0	0.00	0.02
264317	225	8.66	-80.0284	26.7253	0	100	0	0	2	1	2	0.6	0	0	0	1.6	0	0.00	0.03
264319	226	4.55	-80.0315	26.7250	100	0	0	0	0	0	0	0.3	0	0	0	1.3	0	0.00	-0.01
264321	227	35.38	-80.0064	26.7277	0	50	50	0	4	4	16	6.3	1	1	1	-0.3	1	0.19	0.03
264342	228	30.78	-80.0075	26.7274	0	25	75	0	2	1	2	7.7	2	2	4	1.7	1	0.04	0.01
264322	229	30.25	-80.0080	26.7280	0	25	75	0	1	4	4	7.7	2	1	2	1.5	0	0.00	0.01
264323	230	27.66	-80.0096	26.7276	0	100	0	0	2	3	6	7.5	2	1	2	3.2	0	0.00	0.02
264324	231	26.00	-80.0110	26.7277	0	75	25	0	2	1	2	5.2	1	1	1	0.9	0	0.00	0.07
264325	232	26.32	-80.0126	26.7274	0	75	25	0	3	2	6	6.7	1	1	1	1.4	0	0.00	0.00
264326	233	24.85	-80.0140	26.7278	0	75	25	0	3	2	6	5.6	1	1	1	0.8	0	0.00	0.04
264327	234	22.42	-80.0156	26.7277	0	75	25	0	3	4	12	6.6	1	1	1	1.0	0	0.00	0.00
264328	235	20.45	-80.0163	26.7281	0	25	75	0	1	1	1	6.7	4	2	8	4.7	0	0.00	-0.04
264329	236	21.18	-80.0173	26.7277	0	75	25	0	1	1	1	5.2	0	0	0	4.4	0	0.00	0.03
264330	237	21.05	-80.0179	26.7281	50	50	0	0	2	2	4	5.0	0	0	0	0.6	0	0.00	0.05
264331	238	18.44	-80.0194	26.7279	0	100	0	0	4	2	8	7.9	0	0	0	-0.2	0	0.00	-0.02
264332	239	16.52	-80.0211	26.7279	0	100	0	0	1	1	1	8.0	0	0	0	-0.1	0	0.00	-0.02
264333	240	15.19	-80.0224	26.7276	0	100	0	0	1	1	1	2.5	0	0	0	2.9	0	0.00	0.09
264334	241	13.73	-80.0239	26.7282	0	100	0	0	2	1	2	0.6	0	0	0	3.0	0	0.00	0.07
264335	242	11.71	-80.0256	26.7278	0	100	0	0	2	1	2	0.1	0	0	0	2.9	0	0.00	0.03
264336	243	10.30	-80.0269	26.7276	0	100	0	0	2	1	2	0.1	0	0	0	-0.2	0	0.00	0.00
264337	244	9.03	-80.0284	26.7280	0	100	0	0	2	1	2	0.6	0	0	0	1.1	0	0.00	0.06
264338	245	7.51	-80.0300	26.7277	0	100	0	0	1	1	1	0.8	0	0	0	-0.3	0	0.00	0.00
264339	246	5.05	-80.0315	26.7277	100	0	0	0	0	0	0	0.2	0	0	0	0.9	0	0.00	-0.01
26491	247	31.19	-79.9970	26.8195	0	75	25	0	3	3	9	5.5	1	1	1	1.1	0	0.00	0.04
26492	248	30.75	-79.9986	26.8191	0	75	25	0	3	3	9	8.8	2	1	2	1.0	0	0.00	0.01
26493	249	28.98	-80.0000	26.8188	0	75	25	0	3	4	12	6.3	2	1	2	2.6	0	0.00	0.06
26494	250	27.57	-80.0016	26.8192	0	75	25	0	3	3	9	7.4	1	1	1	1.6	0	0.00	0.00

Appendix A5. *Summary of ground-truthing samples*

	1	2	3	4	5
Areal Cover Categories (Cvr)	0-12.5%	12.5to25%	25to50%	50to75%	75to100%
MacroAlgae Height Categories (Ht)	Turf	3cm <	6cm <	>6cm	
Gorgonian Height Categories (Ht)	0.25m<	0.50m<	>0.50m		

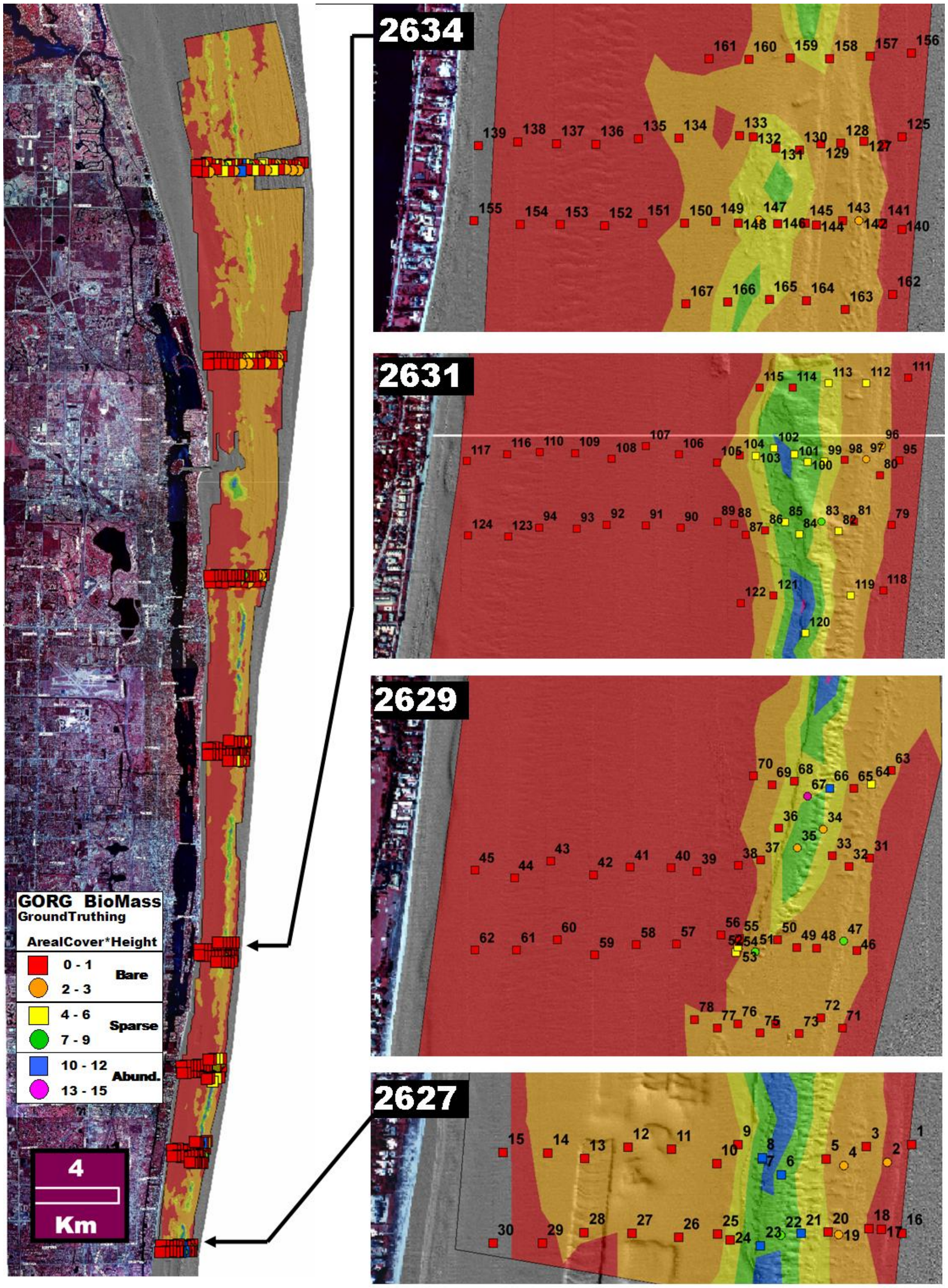
GT'ing Sx ID	Seq ID	Depth (m)	Sample Coordinates		Visual Rugosity				MacroAlgae BioMass				Gorgonian BioMass				*X. muta* BioMass		
									GroundTruthing			Model	GroundTruthing			Model	GroundTruth		Model
			Lon	Lat	Flat %	Lo %	Med %	Hi %	Cvr	Ht	C*H	C*H	Cvr	Ht	C*H	C*H	#	# / m	# / m
26495	251	29.87	-80.0030	26.8196	0	0	50	50	4	2	8	7.8	1	1	1	0.7	0	0.00	0.00
26496	252	30.61	-80.0046	26.8190	0	75	25	0	4	3	12	9.4	1	1	1	1.2	0	0.00	0.01
26497	253	25.83	-80.0063	26.8192	0	75	25	0	3	2	6	5.3	0	0	0	2.3	0	0.00	0.02
26498	254	24.95	-80.0076	26.8191	0	0	100	0	3	3	9	6.4	1	1	1	1.0	0	0.00	0.00
26499	255	21.96	-80.0092	26.8191	0	75	25	0	2	4	8	6.7	2	1	2	0.6	0	0.00	0.00
264910	256	23.45	-80.0105	26.8190	0	75	25	0	2	4	8	6.4	1	1	1	1.1	0	0.00	0.00
264911	257	23.08	-80.0120	26.8190	0	75	25	0	2	4	8	6.5	2	2	4	2.5	0	0.00	-0.01
264912	258	21.78	-80.0132	26.8189	0	75	25	0	2	4	8	6.6	2	2	4	2.6	0	0.00	-0.02
264913	259	23.59	-80.0148	26.8188	0	50	50	0	2	3	6	5.0	2	1	2	4.5	0	0.00	0.04
264914	260	23.52	-80.0164	26.8191	0	75	25	0	2	3	6	6.4	2	1	2	1.2	0	0.00	0.00
264915	261	23.54	-80.0178	26.8192	0	100	0	0	0	0	0	6.8	0	0	0	0.9	0	0.00	0.00
264916	262	22.16	-80.0193	26.8191	0	100	0	0	0	0	0	4.8	0	0	0	2.8	0	0.00	0.07
264917	263	20.85	-80.0208	26.8189	0	100	0	0	0	0	0	7.1	0	0	0	0.7	0	0.00	-0.01
264918	264	18.60	-80.0223	26.8191	0	100	0	0	1	1	1	4.9	0	0	0	2.5	0	0.00	0.09
264919	265	16.35	-80.0238	26.8190	0	100	0	0	0	0	0	5.3	0	0	0	3.0	0	0.00	0.06
264920	266	13.19	-80.0254	26.8193	100	0	0	0	0	0	0	-0.1	0	0	0	-1.9	0	0.00	-0.04
264921	267	10.16	-80.0268	26.8191	100	0	0	0	0	0	0	0.1	0	0	0	-0.6	0	0.00	-0.01
264922	268	8.52	-80.0283	26.8189	100	0	0	0	0	0	0	0.3	0	0	0	0.0	0	0.00	-0.01
264923	269	8.26	-80.0297	26.8194	100	0	0	0	0	0	0	0.6	0	0	0	0.4	0	0.00	0.03
264924	270	7.94	-80.0313	26.8192	100	0	0	0	0	0	0	0.5	0	0	0	-0.9	0	0.00	0.00
264926	271	31.80	-79.9987	26.8165	0	100	0	0	4	4	16	9.9	2	1	2	1.4	0	0.00	0.01
264928	272	27.15	-80.0018	26.8166	0	100	0	0	3	4	12	7.3	1	1	1	0.8	0	0.00	0.01
264930	273	30.80	-80.0048	26.8167	0	75	25	0	4	3	12	10.2	2	1	2	2.1	0	0.00	0.00
264932	274	25.86	-80.0077	26.8165	0	100	0	0	2	2	4	6.2	0	0	0	2.2	0	0.00	-0.01
264934	275	22.51	-80.0106	26.8165	0	100	0	0	2	3	6	6.7	0	0	0	0.0	0	0.00	0.01
264936	276	22.66	-80.0129	26.8165	0	75	25	0	3	3	9	5.2	3	1	3	3.9	0	0.00	0.03
264938	277	23.37	-80.0159	26.8166	0	50	50	0	2	1	2	4.5	2	1	2	4.0	0	0.00	0.06
264940	278	21.96	-80.0193	26.8162	0	100	0	0	0	0	0	6.7	0	0	0	0.8	0	0.00	0.00
264942	279	18.47	-80.0221	26.8166	0	100	0	0	0	0	0	5.1	0	0	0	2.9	0	0.00	0.07
264944	280	13.07	-80.0252	26.8165	100	0	0	0	0	0	0	-0.1	0	0	0	-1.8	0	0.00	-0.05
264946	281	8.37	-80.0282	26.8165	100	0	0	0	0	0	0	0.8	0	0	0	1.1	0	0.00	0.03
264948	282	6.99	-80.0314	26.8165	0	100	0	0	3	1	3	0.9	0	0	0	0.5	0	0.00	-0.01
26541	283	39.53	-79.9866	26.9007	0	75	25	0	4	3	12	7.5	1	1	1	-1.6	0	0.00	0.05
26542	284	31.09	-79.9883	26.9002	0	50	50	0	4	3	12	8.3	1	1	1	0.9	0	0.00	0.01
26543	285	31.04	-79.9897	26.8997	0	75	25	0	5	3	15	8.3	2	1	2	2.2	0	0.00	0.04
26544	286	31.93	-79.9913	26.8996	0	75	25	0	5	3	15	9.7	1	1	1	1.4	0	0.00	0.01
26545	287	30.84	-79.9928	26.8995	0	50	50	0	5	3	15	6.1	1	1	1	1.4	0	0.00	0.01
26546	288	29.58	-79.9943	26.8998	0	33	33	33	4	2	8	7.1	1	1	1	1.5	0	0.00	0.01
26547	289	28.89	-79.9958	26.8999	0	33	33	33	3	2	6	5.1	2	1	2	2.4	0	0.00	0.03
26548	290	28.62	-79.9974	26.8998	0	75	25	0	4	3	12	8.8	1	1	1	1.5	0	0.00	0.00
26549	291	27.92	-79.9988	26.8999	0	33	33	33	3	3	9	5.1	2	1	2	2.5	1	0.03	0.04
265410	292	26.80	-80.0004	26.9001	0	75	25	0	4	4	16	8.7	2	1	2	2.0	0	0.00	0.00
265411	293	25.60	-80.0019	26.9001	0	50	50	0	3	3	9	6.3	1	1	1	2.2	0	0.00	-0.01
265412	294	23.66	-80.0035	26.9002	0	100	0	0	5	4	20	6.9	1	1	1	0.7	1	0.06	0.00
265413	295	24.23	-80.0050	26.9003	0	75	25	0	3	3	9	6.9	3	2	6	1.5	0	0.00	0.00
265414	296	23.76	-80.0065	26.8998	0	50	50	0	2	2	4	6.4	2	2	4	2.4	0	0.00	-0.01
265415	297	23.64	-80.0079	26.8995	0	25	75	0	2	4	8	6.4	1	2	2	0.0	0	0.00	0.01
265416	298	23.10	-80.0096	26.8997	0	25	75	0	3	3	9	6.6	1	1	1	1.9	0	0.00	-0.01
265417	299	22.25	-80.0112	26.8999	0	50	50	0	3	4	12	6.5	1	2	2	2.2	0	0.00	-0.01
265418	300	22.43	-80.0125	26.8999	0	25	75	0	2	2	4	4.9	3	3	9	4.4	0	0.00	0.03

Appendix A6. *Summary of ground-truthing samples*

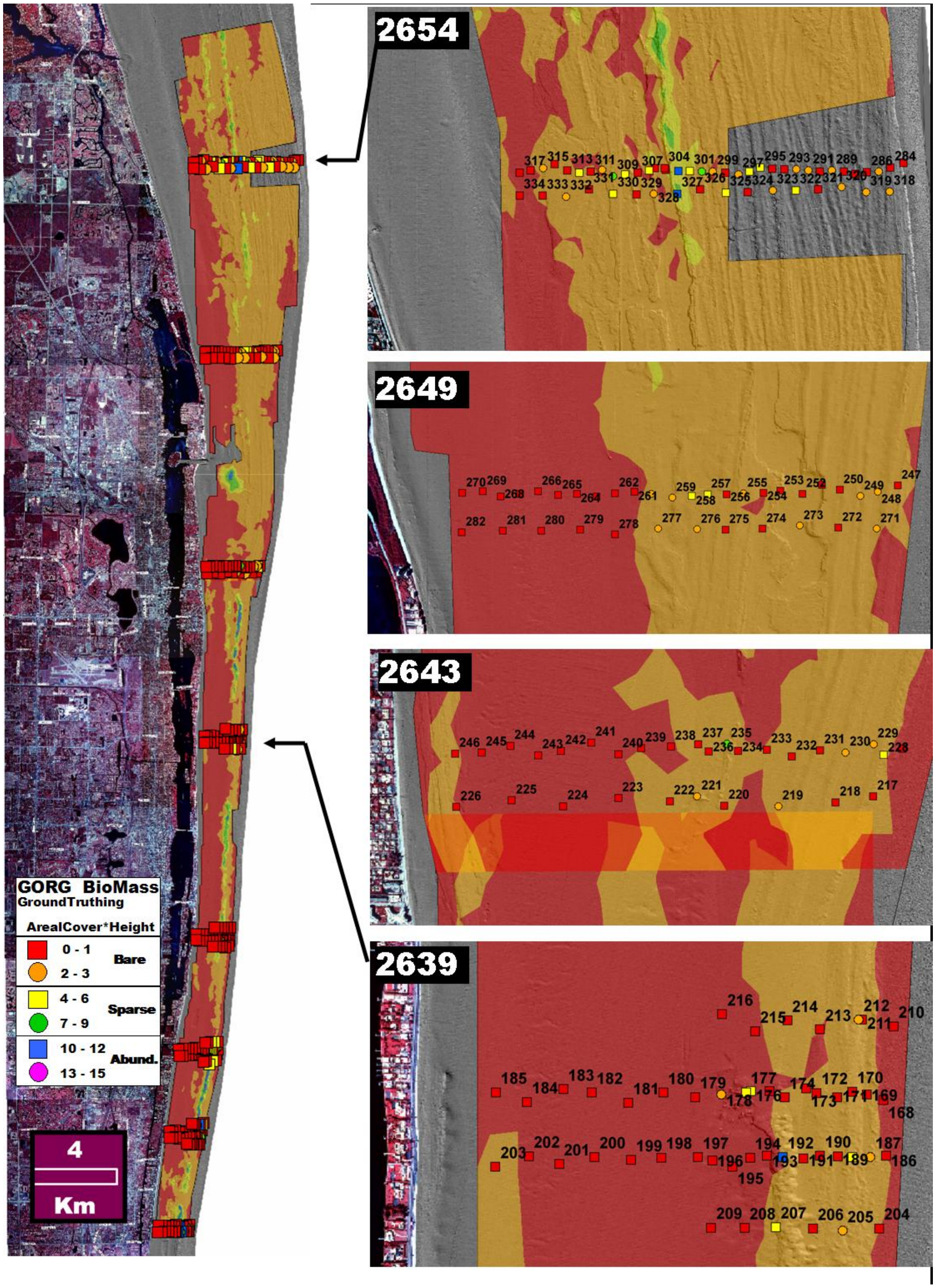
	1	2	3	4	5
Areal Cover Categories (Cvr)	0-12.5%	12.5to25%	25to50%	50to75%	75to100%
MacroAlgae Height Categories (Ht)	Turf	3cm <	6cm <	>6cm	
Gorgonian Height Categories (Ht)	0.25m<	0.50m<	>0.50m		

GT'ing Sx ID	Seq ID	Depth (m)	Sample Coordinates		Visual Rugosity				MacroAlgae BioMass				Gorgonian BioMass				*X. muta* BioMass		
					Flat	Lo	Med	Hi	GroundTruthing			Model	GroundTruthing			Model	GroundTruth		Model
			Lon	Lat	%	%	%	%	Cvr	Ht	C*H	C*H	Cvr	Ht	C*H	C*H	#	# / m	# / m
265419	301	22.55	-80.0141	26.9000	0	33	33	33	2	2	4	5.3	2	2	4	5.0	0	0.00	0.02
265420	302	20.42	-80.0156	26.9000	0	0	100	0	1	1	1	1.6	4	3	12	7.2	0	0.00	0.16
265421	303	23.82	-80.0172	26.9001	0	100	0	0	1	2	2	6.6	0	0	0	-0.2	0	0.00	0.01
265421A	304	23.71	-80.0174	26.9003	0	75	25	0	2	3	6	6.5	0	0	0	2.2	0	0.00	-0.01
265422	305	23.53	-80.0186	26.9003	0	75	25	0	4	3	12	6.4	0	0	0	0.1	0	0.00	0.01
265423	306	23.59	-80.0193	26.9001	0	75	25	0	3	2	6	6.5	3	2	6	3.3	0	0.00	-0.02
265424	307	23.14	-80.0208	26.8998	0	75	25	0	2	2	4	6.5	0	0	0	0.5	0	0.00	0.01
265425	308	22.03	-80.0225	26.8996	0	75	25	0	2	2	4	6.9	3	2	6	2.9	0	0.00	-0.02
265426	309	20.90	-80.0240	26.8994	0	50	50	0	2	2	4	5.9	3	3	9	5.0	0	0.00	0.00
265427	310	22.62	-80.0254	26.9002	0	25	75	0	2	3	6	0.2	2	1	2	5.8	0	0.00	0.30
265428	311	22.94	-80.0269	26.9000	0	75	25	0	2	3	6	5.8	0	0	0	2.2	0	0.00	0.02
265429	312	21.61	-80.0283	26.8998	0	25	75	0	2	2	4	6.8	2	2	4	2.1	0	0.00	-0.02
265430	313	21.34	-80.0299	26.9001	0	100	0	0	2	2	4	6.8	0	0	0	1.0	0	0.00	-0.01
265431	314	21.31	-80.0315	26.9009	0	25	75	0	3	2	6	7.3	1	1	1	0.3	0	0.00	-0.01
265432	315	21.99	-80.0330	26.9004	0	0	100	0	3	3	9	5.5	1	2	2	4.3	0	0.00	0.02
265433	316	22.08	-80.0346	26.9002	0	100	0	0	0	0	0	6.7	0	0	0	0.3	0	0.00	0.00
265434	317	21.64	-80.0360	26.8999	0	100	0	0	0	0	0	6.9	0	0	0	0.9	0	0.00	-0.01
265436	318	30.81	-79.9884	26.8974	0	75	25	0	5	4	20	9.6	2	1	2	1.7	0	0.00	0.00
265438	319	29.55	-79.9914	26.8973	0	75	25	0	4	3	12	8.2	2	1	2	2.3	0	0.00	0.00
265440	320	29.51	-79.9946	26.8979	0	100	0	0	4	4	16	9.4	2	1	2	1.9	0	0.00	0.00
265442	321	27.33	-79.9976	26.8977	0	100	0	0	5	4	20	6.3	1	1	1	1.9	0	0.00	0.02
265444	322	25.42	-80.0005	26.8976	0	100	0	0	4	3	12	7.5	2	2	4	1.4	0	0.00	0.00
265446	323	24.31	-80.0035	26.8976	0	0	100	0	4	3	12	6.3	2	1	2	2.2	0	0.00	-0.01
265448	324	24.64	-80.0067	26.8975	0	50	50	0	3	2	6	6.5	1	1	1	2.7	1	0.04	0.00
265450	325	22.60	-80.0095	26.8974	0	50	50	0	2	2	4	6.5	2	2	4	2.7	0	0.00	-0.02
265452	326	23.18	-80.0128	26.8978	0	100	0	0	1	2	2	6.6	0	0	0	0.9	0	0.00	0.00
265454	327	19.91	-80.0157	26.8973	0	0	100	0	2	2	4	3.6	4	3	12	6.7	0	0.00	0.08
265456	328	21.80	-80.0188	26.8974	0	50	50	0	3	3	9	5.7	3	1	3	3.5	0	0.00	0.02
265458	329	22.28	-80.0210	26.8973	0	100	0	0	3	3	9	5.9	1	1	1	3.2	0	0.00	0.01
265460	330	21.71	-80.0240	26.8974	0	75	25	0	3	2	6	6.6	2	2	4	2.8	0	0.00	-0.02
265462	331	23.02	-80.0271	26.8979	0	75	25	0	2	2	4	5.6	0	0	0	2.8	0	0.00	0.02
265464	332	21.41	-80.0301	26.8971	0	100	0	0	3	2	6	5.2	1	2	2	2.1	0	0.00	0.05
265466	333	22.44	-80.0331	26.8972	0	75	25	0	2	2	4	3.8	1	1	1	5.0	0	0.00	0.08
265468	334	21.67	-80.0361	26.8973	0	100	0	0	2	1	2	6.6	0	0	0	0.8	0	0.00	0.00

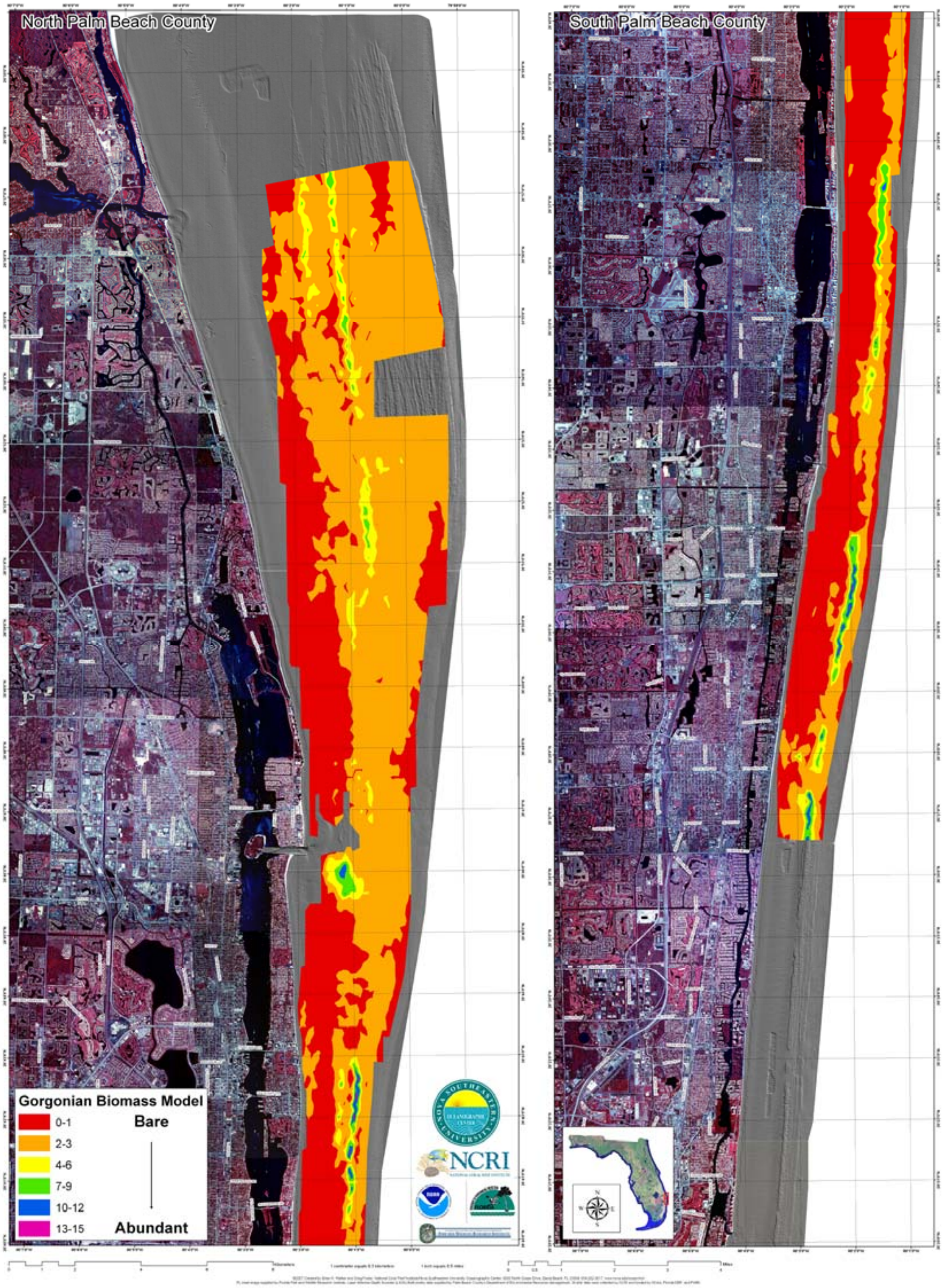
Appendix A7. *Summary of ground-truthing samples*



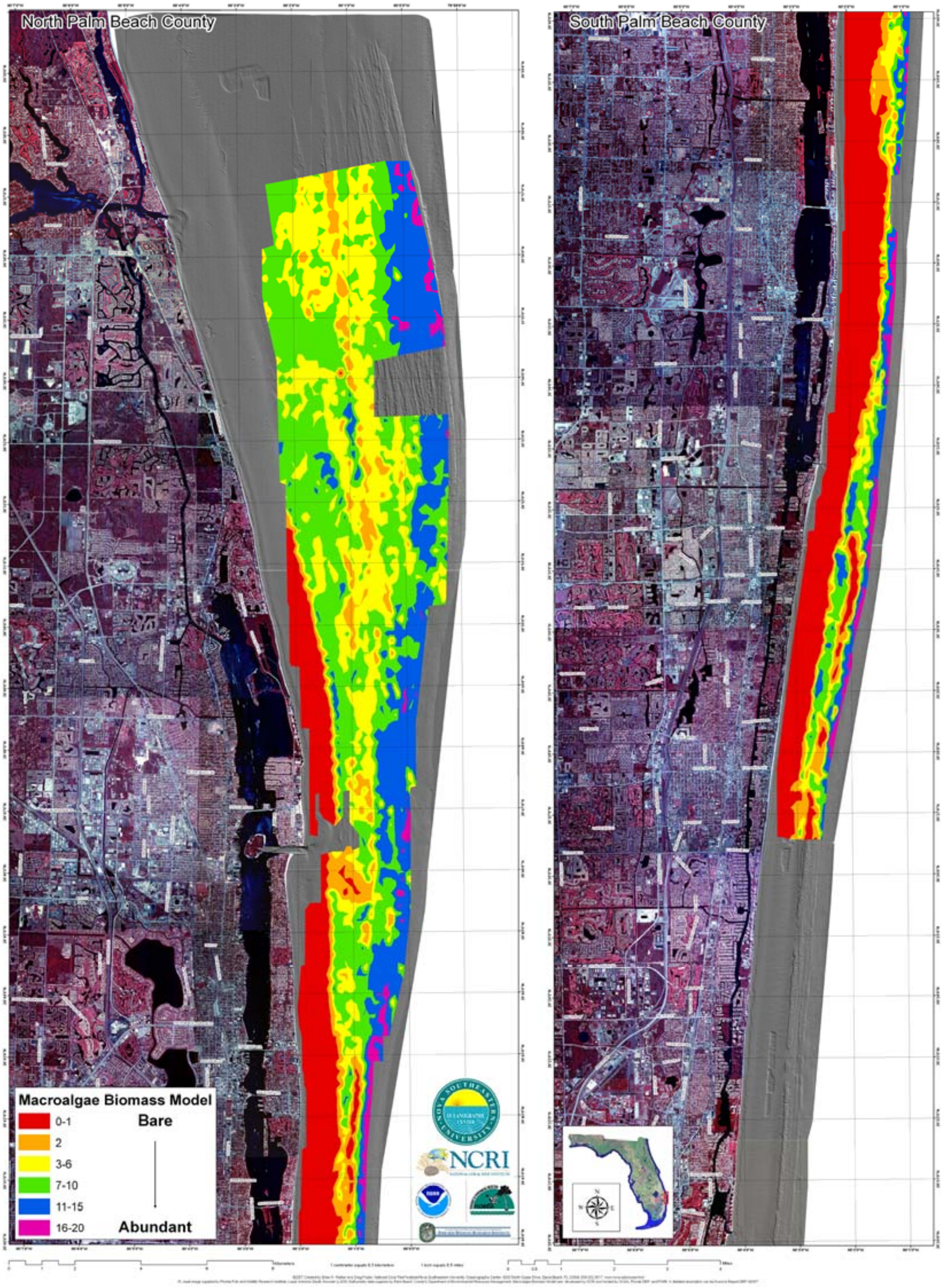
Appendix B1. *Location of ground-truthing points in southern portion of Palm Beach County. Gorgonian model-predicted biomass contour plot shown overlaying LADS bathymetry. Gorgonian ground-truthing depicted. Numbers refer to column 'Seq ID' in Appendix A.*



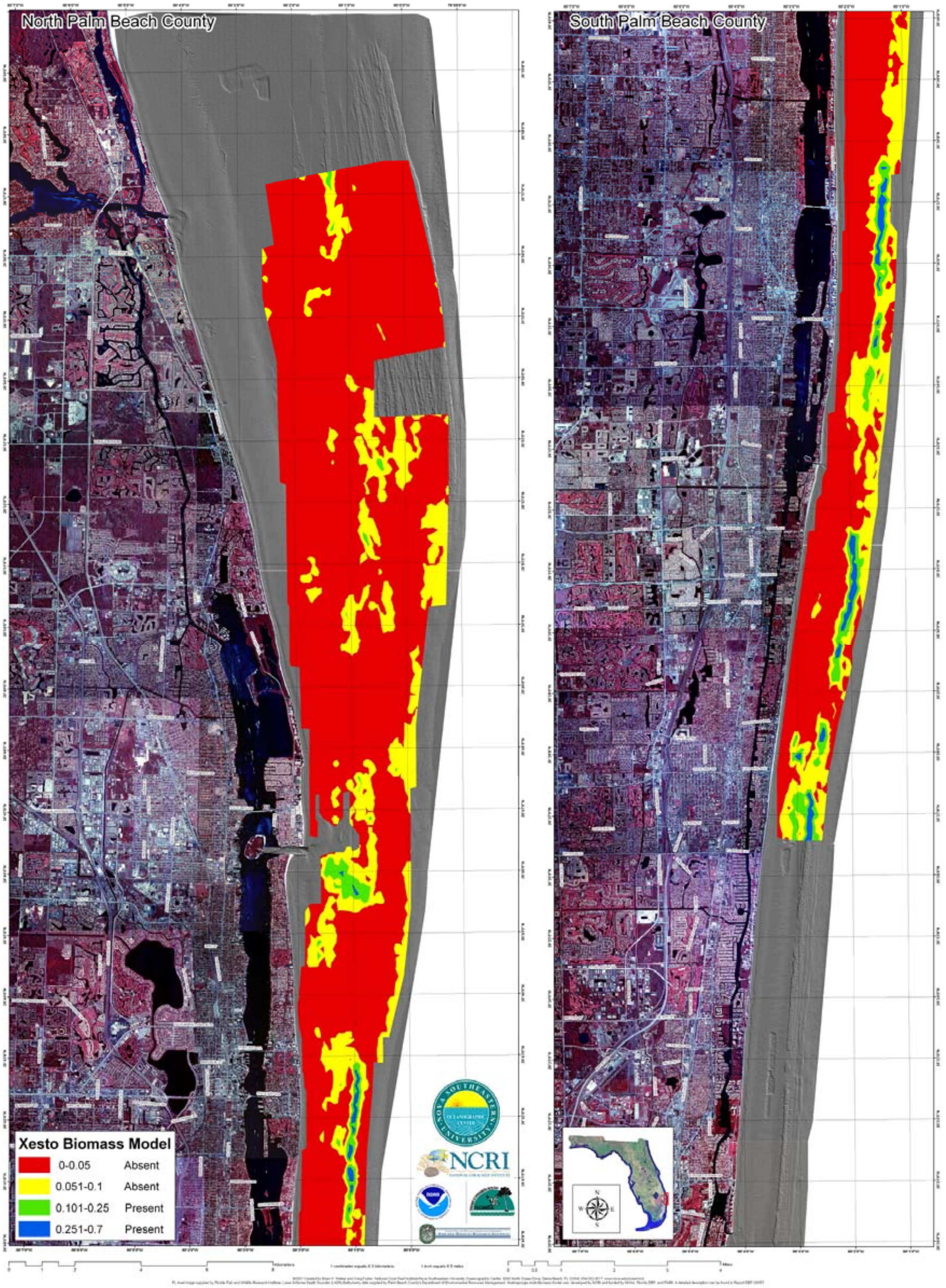
Appendix B2. Location of ground-truthing points in southern portion of Palm Beach County. Gorgonian model-predicted biomass contour plot shown overlaying LADS bathymetry. Gorgonian ground-truthing depicted. Numbers refer to column 'Seq ID' in Appendix G.



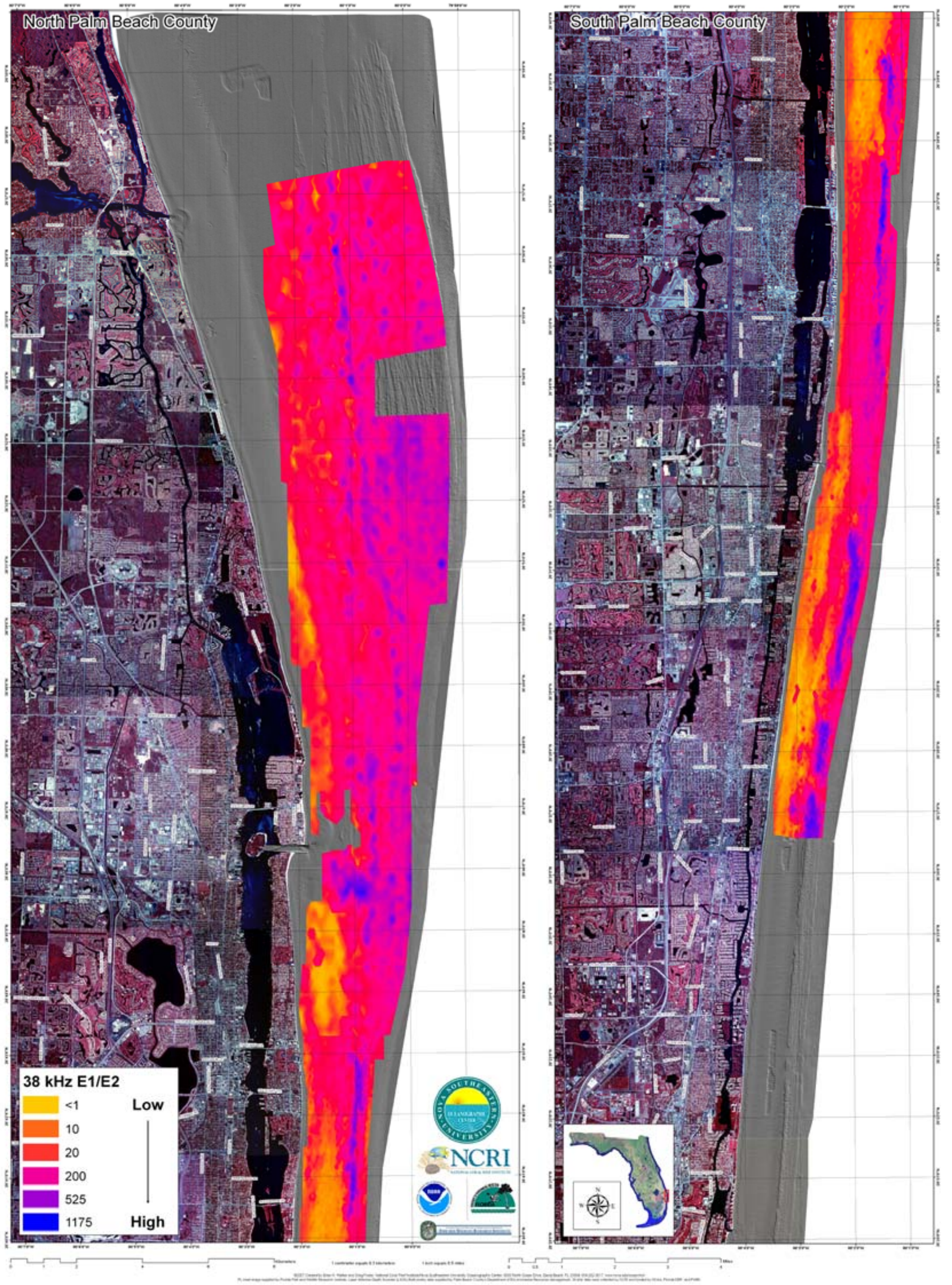
Appendix C. *Kriged contour plots of 420 kHz gorgonian model-predicted biomass for northern (left) and southern (right) Palm Beach County.*



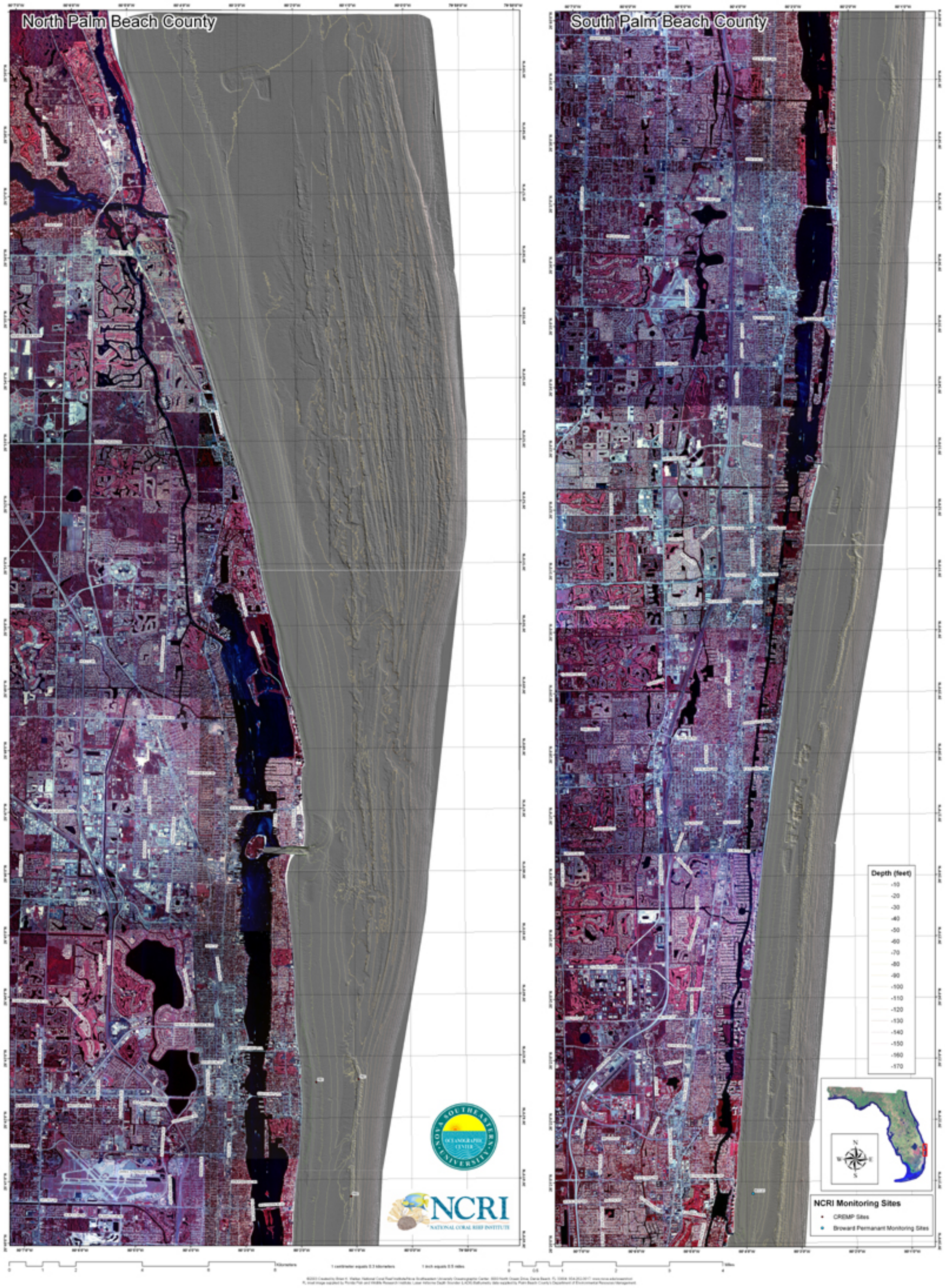
Appendix D. *Kriged contour plots of 420 kHz macroalgae model-predicted biomass for northern (left) and southern (right) Palm Beach County.*



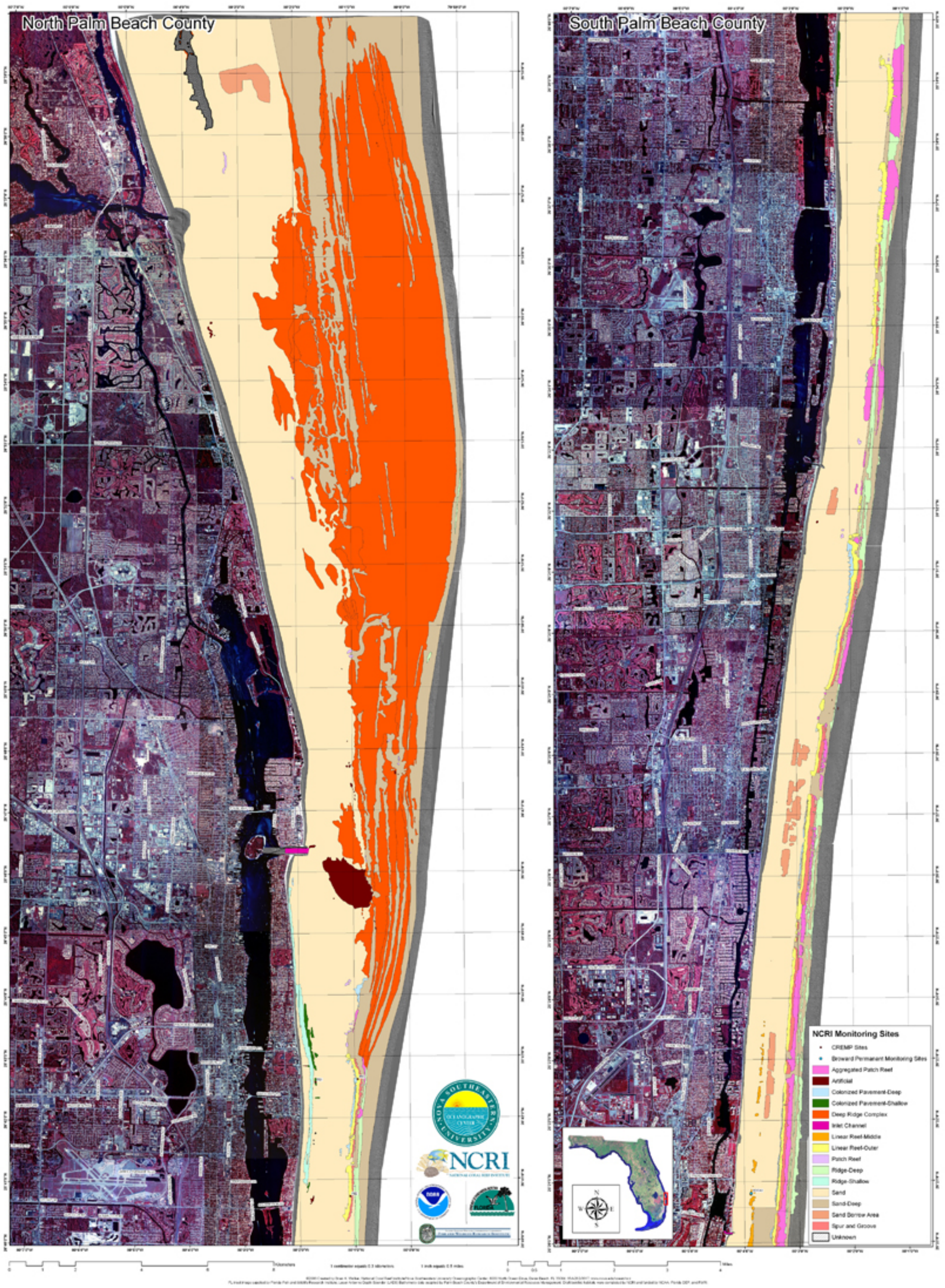
Appendix E. *Kriged contour plots of 420 kHz Xestospongia muta model-predicted biomass for northern (left) and southern (right) Palm Beach County.*



Appendix F. *Kriged contour plots of 38 kHz E1/E2 values for northern (left) and southern (right) Palm Beach County.*



***Appendix G**. Map of the bathymetric base-layer used in the Phase I mapping and to plan the surveys in Phase II. The grey surface is the hillshaded seafloor from 0 to ~40m depth*



Appendix H. *Benthic habitat map of Palm Beach County after Phase I. The colors correspond to habitats discerned from the bathymetric layer and confirmed with video groundtruthing.*

Appendix I. GIS Deliverables:

PalmBeachHabitatMapping2007.mxd
PalmBeachHabitat_draft.dbf
PalmBeachHabitat_draft.lyr
PalmBeachHabitat_draft.prj
PalmBeachHabitat_draft.sbn
PalmBeachHabitat_draft.sbx
PalmBeachHabitat_draft.shp
PalmBeachHabitat_draft.shp.xml
PalmBeachHabitat_draft.shx
Phase1AccuracyAssessment.dbf
Phase1AccuracyAssessment.lyr
Phase1AccuracyAssessment.prj
Phase1AccuracyAssessment.sbn
Phase1AccuracyAssessment.sbx
Phase1AccuracyAssessment.shp
Phase1AccuracyAssessment.shx
Phase1Groundtruthing.dbf
Phase1Groundtruthing.lyr
Phase1Groundtruthing.prj
Phase1Groundtruthing.sbn
Phase1Groundtruthing.sbx
Phase1Groundtruthing.shp
Phase1Groundtruthing.shx
Phase2GorgN6classKrig.dbf
Phase2GorgN6classKrig.lyr
Phase2GorgN6classKrig.prj
Phase2GorgN6classKrig.sbn
Phase2GorgN6classKrig.sbx
Phase2GorgN6classKrig.shp
Phase2GorgN6classKrig.shp.xml
Phase2GorgN6classKrig.shx
Phase2GorgS6classKrig.dbf
Phase2GorgS6classKrig.lyr
Phase2GorgS6classKrig.prj
Phase2GorgS6classKrig.sbn
Phase2GorgS6classKrig.sbx
Phase2GorgS6classKrig.shp
Phase2GorgS6classKrig.shp.xml
Phase2GorgS6classKrig.shx
Phase2groundtruthing.dbf
Phase2groundtruthing.prj
Phase2groundtruthing.sbn
Phase2groundtruthing.sbx
Phase2groundtruthing.shp
Phase2groundtruthing.shx
Phase2groundtruthingGorgDisplay.lyr
Phase2groundtruthingMADisplay.lyr
Phase2groundtruthingXestoDisplay.lyr
Phase2MacroAlgaeN6classKrig.dbf
Phase2MacroAlgaeN6classKrig.lyr
Phase2MacroAlgaeN6classKrig.prj
Phase2MacroAlgaeN6classKrig.sbn
Phase2MacroAlgaeN6classKrig.sbx
Phase2MacroAlgaeN6classKrig.shp
Phase2MacroAlgaeN6classKrig.shp.xml
Phase2MacroAlgaeN6classKrig.shx
Phase2MacroAlgaeS6classKrig.dbf
Phase2MacroAlgaeS6classKrig.lyr
Phase2MacroAlgaeS6classKrig.prj
Phase2MacroAlgaeS6classKrig.sbn
Phase2MacroAlgaeS6classKrig.sbx
Phase2MacroAlgaeS6classKrig.shp
Phase2MacroAlgaeS6classKrig.shp.xml
Phase2MacroAlgaeS6classKrig.shx
Phase2XestoSpongeN6classKrig.dbf
Phase2XestoSpongeN6classKrig.lyr
Phase2XestoSpongeN6classKrig.prj
Phase2XestoSpongeN6classKrig.sbn
Phase2XestoSpongeN6classKrig.sbx
Phase2XestoSpongeN6classKrig.shp
Phase2XestoSpongeN6classKrig.shp.xml
Phase2XestoSpongeN6classKrig.shx
Phase2XestoSpongeS6classKrig.dbf
Phase2XestoSpongeS6classKrig.lyr
Phase2XestoSpongeS6classKrig.prj
Phase2XestoSpongeS6classKrig.sbn
Phase2XestoSpongeS6classKrig.sbx
Phase2XestoSpongeS6classKrig.shp
Phase2XestoSpongeS6classKrig.shp.xml
Phase2XestoSpongeS6classKrig.shx
Phase2_38kHz_KrigNorth.dbf
Phase2_38kHz_KrigNorth.lyr
Phase2_38kHz_KrigNorth.prj
Phase2_38kHz_KrigNorth.sbn
Phase2_38kHz_KrigNorth.sbx
Phase2_38kHz_KrigNorth.shp
Phase2_38kHz_KrigNorth.shp.xml
Phase2_38kHz_KrigNorth.shx
Phase2_38kHz_KrigSouth.dbf
Phase2_38kHz_KrigSouth.lyr
Phase2_38kHz_KrigSouth.prj
Phase2_38kHz_KrigSouth.sbn
Phase2_38kHz_KrigSouth.sbx
Phase2_38kHz_KrigSouth.shp
Phase2_38kHz_KrigSouth.shp.xml
Phase2_38kHz_KrigSouth.shx
Phase2_I1-O22_420kHzSurveyPoints.dbf
Phase2_I1-O22_420kHzSurveyPoints.prj
Phase2_I1-O22_420kHzSurveyPoints.sbn
Phase2_I1-O22_420kHzSurveyPoints.sbx
Phase2_I1-O22_420kHzSurveyPoints.shp
Phase2_I1-O22_420kHzSurveyPoints.shx
Phase2_I6-O22_38kHzSurveyPoints.dbf
Phase2_I6-O22_38kHzSurveyPoints.prj
Phase2_I6-O22_38kHzSurveyPoints.sbn
Phase2_I6-O22_38kHzSurveyPoints.sbx
Phase2_I6-O22_38kHzSurveyPoints.shp
Phase2_I6-O22_38kHzSurveyPoints.shx
Phase2_IR1-OR14_38kHzSurveyPoint.dbf
Phase2_IR1-OR14_38kHzSurveyPoint.prj
Phase2_IR1-OR14_38kHzSurveyPoint.sbn
Phase2_IR1-OR14_38kHzSurveyPoint.sbx
Phase2_IR1-OR14_38kHzSurveyPoint.shp
Phase2_IR1-OR14_38kHzSurveyPoint.shx
Phase2_IR1-OR14_420kHzSurveyPoints.dbf
Phase2_IR1-OR14_420kHzSurveyPoints.prj
Phase2_IR1-OR14_420kHzSurveyPoints.sbn
Phase2_IR1-OR14_420kHzSurveyPoints.sbx
Phase2_IR1-OR14_420kHzSurveyPoints.shp
Phase2_IR1-OR14_420kHzSurveyPoints.shx

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