CHAPTER 4: CONCLUSION

NOAA's Biogeography Branch, with support from the U.S. National Park Service, has completed benthic habitat mapping and subsequent field validation and accuracy assessment of the nearshore marine environment of St. John, U.S. Virgin Islands. An independent accuracy assessment revealed successful overall map accuracies of over 90% for major structure and cover classes, and over 80% for detailed structure and cover classes. As a result, these digital map products can be used with confidence by scientists and resource managers for a multitude of different applications (Figure 4.1). The scientific and management communities have used previous NOAA benthic habitat maps to structure monitoring programs, support management decisions, and establish and manage marine conservation areas in coral reef ecosystems.

Figure 4.1. A NOAA diver characterizes seagrass habitat during a monitoring mission in St. John.

The final delivery consisted of the benthic habitat maps in several formats and all ancillary data generated in support of map creation. These items are listed in Table 4.1 with a description of the format type and quantity when appropriate.

Table 4.1. Final deliverable items of NOAA's St. John benthic habitat mapping effort. Additional information is given on the item type and a quantitative descriptor.

Item	Format	Quantity
Benthic Habitat Map	GIS	1,940 polygons
Source Imagery	GIS	
Map Atlas	PDF	
Interactive Map Project	On-line	
Ground Validation Dataset	GIS	444 locations
Accuracy Assessment Dataset	GIS	481 locations
Video of Bottom Imaging	Quicktime Movie	807 videos
Final Report	PDF	
FGDC-compliant Metadata for GIS Files	Text	

4.1 MAP SUMMARY STATISTICS

An area of 131.49 km² was considered during the mapping process; of which, 78.05 km² were designated as *Unknown* due to water depth and clarity issues. The remaining 53.44 km² were described by 1,939 polygons corresponding to the structure and biological cover types of the habitat classification scheme outlined in Chapter 1.

Of these 53.44 km², *Unconsolidated Sediment* and *Coral Reef and Hardbottom* each accounted for 26.71 km² of Major Structure type (Table 4.2). Equivalence in area of *Unconsolidated Sediment* and *Coral Reef and Hardbottom* was not an intentional design element; rather, it was an unforeseen coincidence. Together, *Unconsolidated Sediment* and *Coral Reef and Hardbottom* account for 98.98% of Major Structure type; the remaining 0.02% corresponds to *Artificial* structures. The 0.01 km² of *Artificial* type is located in Cruz Bay at the ferry dock and NPS boat dock.

Detailed Structure map summary statistics highlight the composition of Major Structure types (Table 4.2). *Coral Reef and Hardbottom* is subdivided into ten Detailed Structure categories, while *Unconsolidated Sediment* is segmented into three. Note in Table 4.2, that Detailed Structure percentages are derived from total mapped area, not within the corresponding Major Structure classification.

Table 4.2. Area summary of major geomorphological structure classes and the subsets of detailed structure classes.

MAJOR STRUCTURE	AREA (km²)	PERCENT AREA	DETAILED STRUCTURE	AREA (km²)	PERCENT AREA
Coral Reef and Hardbottom	26.71	49.99	Rock Outcrop	1.62	3.03
			Boulder	0.74	1.39
			Aggregate Reef	3.74	6.99
			Individual Patch Reef	0.25	0.47
			Aggregated Patch Reef	1.49	2.79
			Spur and Groove	0.33	0.61
			Pavement	8.74	16.35
			Pavement with Sand Channels	2.68	5.02
			Reef Rubble	2.36	4.41
			Rhodoliths	4.77	8.93
Unconsolidated Sediment	26.71	49.99	Sand	22.98	43.00
			Mud	2.33	4.37
			Sand with Scattered Coral and Rock	1.40	2.62
Other Delineations (Land excluded)	0.01	0.02	Artificial	0.01	0.02
Total	53.44	100		53.44	100

Sand is the most common detailed structure type, accounting for 43% of the total mapped area (Figure 4.2). *Mud* and *Sand with Scattered Coral and Rock* are considerably less common *Unconsolidated Sediment* types, accounting for 4.37% and 2.62% respectively. At 16.35% of total area, *Pavement* is the second most dominant structure type overall and the predominant detailed structure type within *Coral Reef and Hardbottom*. Other common structure types are *Rhodoliths*, which account for 8.93% of total area, and *Aggregate Reef*, which contributes to 6.99% of total area. Although ecologically significant, patch reefs, in the form of *Individual Patch Reefs* and *Aggregated Patch Reefs*, only comprise just over 3% of all the nearshore habitat of St. John.

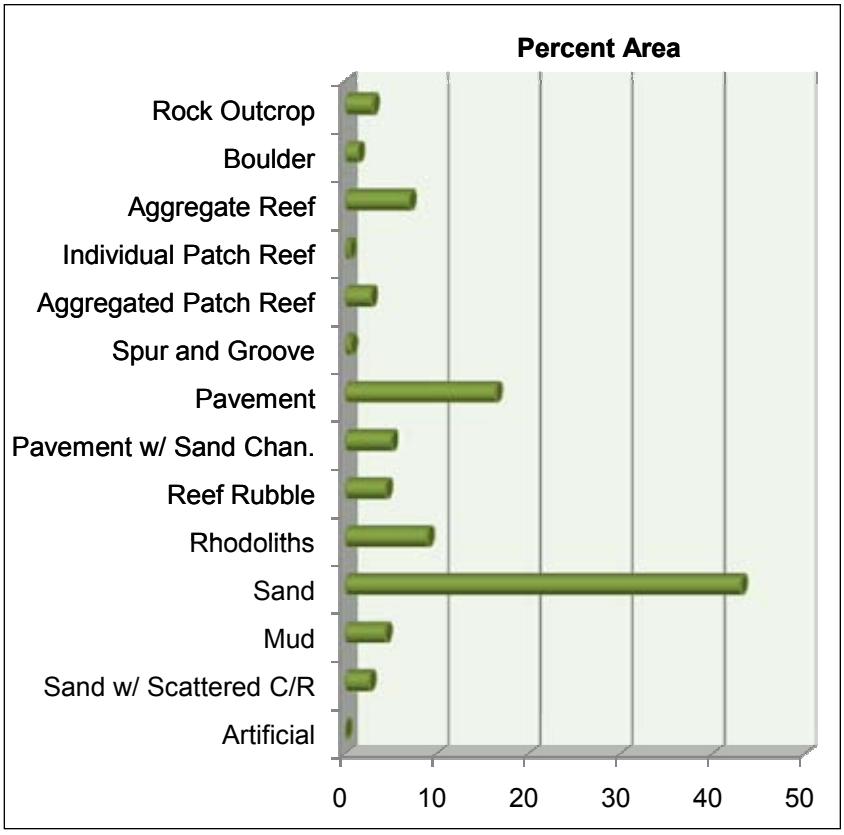

Figure 4.2. Chart illustrating the percent cover of each detailed geomorphological structure type for the entire St. John mapping area. *Sand* being the most common structure type and *Pavement* the most common hardbottom type.

Biological Cover map summary statistics (Figure 4.3) reveal that the overwhelmingly dominant Major Cover is *Algae*, which accounts for 74.28% of the 53.44 km² study area (Table 4.3). About half of the 39.69 km²

of algal dominance is covered by a continuous distribution (*90% - 100%*). This is in large part due to the inclusion of turf algae as a mapped species, since much of St. John's hardbottom is covered by turf in the absence of live coral. At 14.68%, *Seagrass* is the second most common Major Cover type. Areas with *No Cover* account for 8.84% of the total area. *Live Coral* and *Mangrove* are rare Major Covers; the former constitutes 1.51% and the latter 0.66% of the study area. Although live coral colonies exist throughout the St. John seascape, the total area of features dominated by live coral cover was only 0.81 km^2. Coralline Algae was not found to be a Major Cover within the study area.

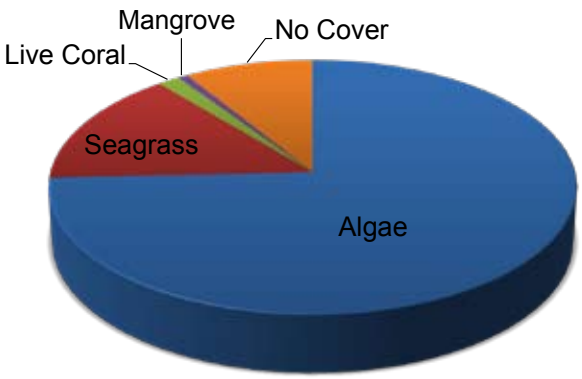

Figure 4.3. Chart depicting the prevalence (~ 75%) of *Algae* as the dominant biological cover type in the mapped area of St. John.

Map summary statistics suggested that almost all of the total mapped area is comprised of less than 50% coral cover (Table 4.4). There are 9.29 km^2 exhibiting a Percent Coral Cover of *10% to <50%*. These areas account for 17.39% of the study area, while 82.59%, or 44.12 km^2, have less than 10% coral cover. Furthermore, Coral Cover does not exceed 50% within any single minimum mapping unit of the study area. For this, it is important to remember the influence of minimum mapping units in the habitat mapping process. It was observed that some areas of St. John are comprised of greater than 50% coral cover, but these areas were not large enough to be mapped with a minimum mapping unit of 1,000 m^2.

Table 4.3. Summary of areas for each biological cover and respective percent cover modifier mapped in St. John.

MAJOR COVER	AREA (km^2)	PERCENT AREA	PERCENT COVER	AREA (km^2)	PERCENT AREA
Algae	39.69	74.28	10% - <50%	7.16	13.40
			50% - <90%	12.07	22.59
			90% - 100%	20.46	38.30
Seagrass	7.85	14.68	10% - <50%	0.48	0.89
			50% - <90%	2.47	4.63
			90% - 100%	4.90	9.17
Live Coral	0.81	1.51	10% - <50%	0.12	0.23
			50% - <90%	0.10	0.19
			90% - 100%	0.58	1.09
Mangrove	0.35	0.66	10% - <50%	0.01	0.01
			50% - <90%	0.01	0.02
			90% - 100%	0.34	0.63
Coralline Algae	0	0	10% - <50%	0	0
			50% - <90%	0	0
			90% - 100%	0	0
No Cover	4.73	8.84	90% - 100%	4.73	8.84
Artificial	0.01	0.02	N/A	0.01	0.02
Total	**53.44**	**100.00**		**53.44**	**100.00**

4.2 COMPARISON TO PREVIOUS NOAA HABITAT MAPS OF ST. JOHN

The 2009 benthic habitat mapping effort described in this report marks the second such effort NOAA has conducted to map the shallow-water coral reef ecosystems of St. John, USVI. The Kendall et al. (2001) digital benthic habitat maps of St. John were a significant improvement over previous paper copy maps (Beets et al. 1986). However, as the complexities of resource management and the capabilities of mapping techniques developed over the past

Table 4.4. Area summary of percent coral cover for St. John habitats.

PERCENT CORAL COVER	AREA (m^2)	AREA (km^2)	PERCENT AREA
0 - <10%	44,131,783	44.13	82.59
10% - <50%	9,293,135	9.29	17.39
50% - <90%	0.00	0.00	0.00
90% - 100%	0.00	0.00	0.00
N/A	10,548	0.01	0.02
Total	**53,435,466**	**53.44**	**100.00**

decade, the management and scientific communities have required benthic habitat maps with greater spatial and thematic detail. In response to these requests, NOAA, in cooperation with the U.S. National Park Service, has completed new fine-scale habitat maps that reflect the most current conditions at the Virgin Islands Coral Reef National Monument, Virgin Islands National Park and the surrounding waters. Components of this new mapping product include an expanded habitat classification scheme (as described in Chapter 1), smaller minimum mapping units, more recent imagery, and improved positional accuracy (Table 4.5).

Table 4.5. Comparison of basic map characteristics between a previous NOAA effort (2001) and the current maps of St. John (2009).

		NOAA MAPPING EFFORT	
		2001	2009
MAP	Source Imagery Date	1999	2007
	Scale of Delineation	1:6,000	1:2,000
	Minimum Mapping Unit (m²)	4,046	1,000
	Positional Accuracy (m)	4.31 (+/- 5.2)	2.15 (+/- 0.7)
FEATURE	Number of Polygons	537	1,939
	Mean Polygon Area (m²)	173,971	53,378
	Sum of Polygon Edges (km)	1,137	2,303
	Mean Polygon Edge (km)	2.12	1.19

NOAA's revised approach to mapping nearshore coral reef ecosystems has provided significant advantages to better represent the natural environment. As displayed in Table 4.5, the 2009 maps were created with finer-scale mapping standards in both scale of delineation and minimum mapping unit. The map interpreter delineated polygon boundaries at a scale of 1:2,000, which is three times as spatially resolute as that of the 1:6,000 of the 2001 mapping effort. In addition, the source imagery of the 2009 habitat maps had a pixel resolution of 0.3 m, as compared to the 2.4 m resolution imagery used by Kendall et al. (2001). These factors resulted in enhanced line accuracy and line detail as more vertices were able to be created along the same amount of line distance with a more detailed view of the seafloor.

A reduction in MMU from approximately 4,000 m² to 1,000 m² in the 2009 mapping effort, had a large impact on the final content of the habitat map product. The smaller minimum mapping unit resulted in over three times as many polygons and about three times as small average polygon area (Table 4.5). Figure 4.4 illustrates the influence of minimum mapping unit on the delineation of patch reefs outside of Reef Bay. Smaller patch reefs that were formerly too small to map individually (< 4,046 m²), under the 2001 standards, are delineated as separate polygons in the 2009 habitat map. Additionally, reduced MMUs allow for more accurate depictions of other patchy environments, as patches were more readily delineated. For instance, large pavement areas formerly mapped as homogeneous hardbottom are now depicted as pavement with smaller sand patches intermixed throughout the broader polygon. The true heterogeneous nature of many marine features was more accurately mapped due to the reduction in minimum mapping unit.

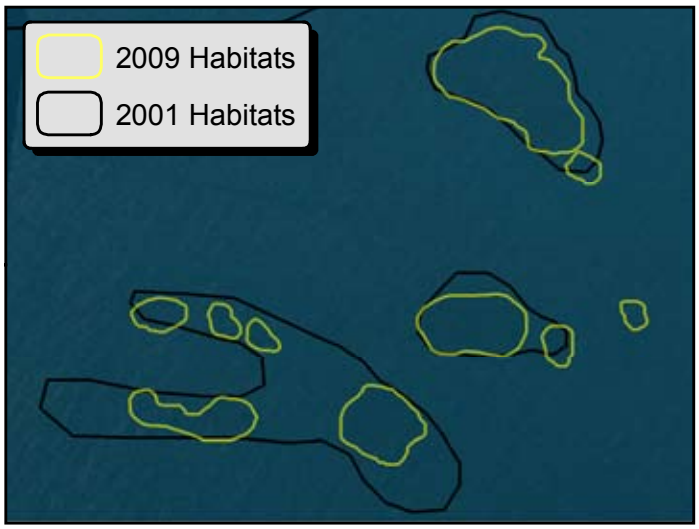

Figure 4.4. Comparison of 2001 and 2009 NOAA habitat boundaries to illustrate the influence of minimum mapping unit on the delineation of patch reefs outside of Reef Bay.

Marine systems are recognized as dynamic, and subject to changes ranging from a single storm event to long-term ecological shifts due to climate change. It was essential for NOAA to use the most current, available source imagery from which to generate the new benthic habitat maps. High resolution orthophotography collected in late 2007 afforded a more recent depiction of the habitats of St. John, as opposed to the 1999 aerials used in Kendall et al. (2001).

It is well documented that St. John has experienced changes in the coral environment, particularly live coral cover, over the past decade (Waddell and Clarke 2008). NOAA's 2009 mapping effort supports this conclusion on softbottom habitats as well. In comparison to Kendall et al. (2001), preliminary spatial comparisons have indicated that seagrass growth has increased dramatically in areas off the coast of St. John. For instance, softbottoms covered by seagrass in Rendezvous Bay have increased from 0.22 km² in 1999 to 0.74 km² in 2007 (Figure

4.5). Growth of 0.52 km² of seagrass in a 1.23 km² embayment, such as Rendevous Bay, over an 8 year period is significant development of submerged aquatic vegetation. The present map results indicate that other bays on the south shore, including Reef Bay, Europa Bay and Little Lameshur Bay, have experienced similar trends in seagrass growth.

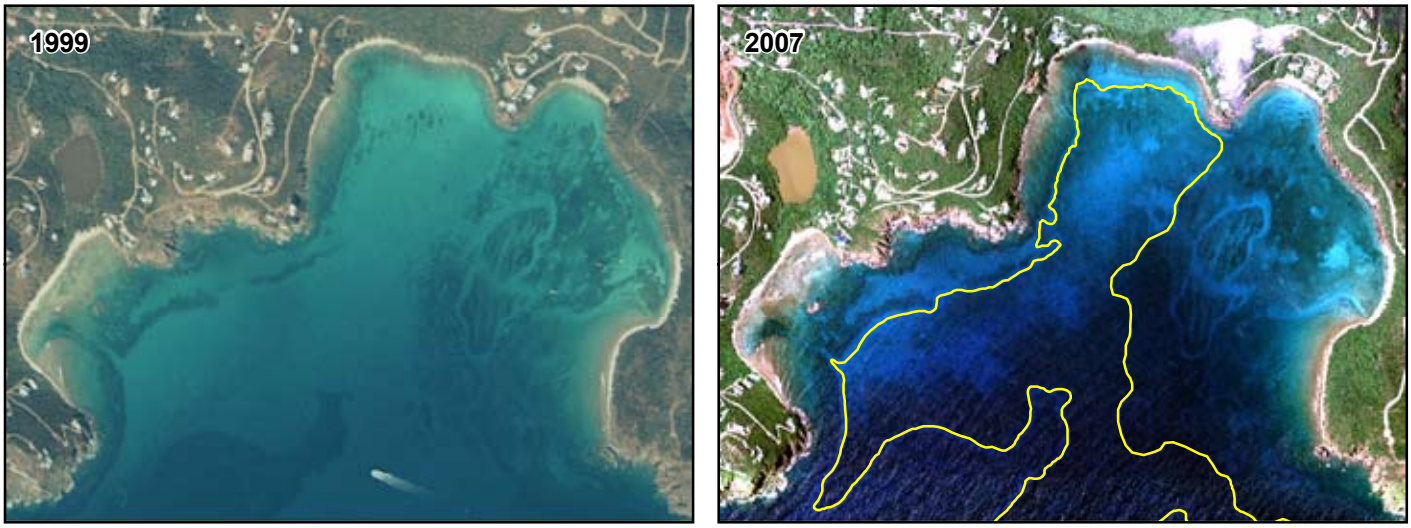

Figure 4.5. Imagery time-series of Rendezvous Bay depicting growth of seagrass beds between 1999 (left) and 2007 (right). The yellow polygon outlines the area of new seagrass growth.

Beyond the changes in mapping technique and standards, NOAA's 2009 effort marked a significant alteration of the benthic habitat classification scheme used to map other coral reef ecosystems. As outlined in *Chapter 1.1 Comparison to Previous NOAA Habitat Classification Schemes*, treatment of the biological cover classification has evolved over the years. In Kendall et al. (2001), biological cover was not explicitly stated for each feature in the map. Instead, the specific biological cover type was only reported for softbottoms colonized by submerged aquatic vegetation. For example, sand bottoms with patchy seagrass were fully reported in the old scheme. However, linear reefs colonized by a mix of turf algae and gorgonians were only classified as *Linear Reef*, with no reference to biological cover. Moreover, the Kendall et al. (2001) scheme made no reference to the amount of live coral cover present on polygon features (Figure 4.6). In contrast, the 2009 effort described the percentage of live coral cover in ranges for every seafloor feature. Other differences exist between the habitat classification scheme used in 2001 and that of 2009; including division of some structure types into more detailed groups. For instance, *Colonized Bedrock* was subdivided into *Rock Outcrop* and *Boulder,* with an associated dominant biological cover. These differences in habitat classification scheme make a direct comparison between NOAA-generated, St. John habitat maps difficult. An analysis comparing both maps is beyond the scope of this report, but should be considered in future efforts.

Overall, the transition to the current version of NOAA's dominance habitat classification scheme from previous iterations was a success. As described in *Chapter 3.5 Conclusions*, the 85.7% accuracy achieved for detailed structure in NOAA's 2009 St. John benthic habitat maps was similar to that of other recent NOAA benthic habitat maps in the Florida Keys (86.2%, Walker and Foster 2009), Palau (90.0%, Battista et al. 2007b), and the Main Hawaiian Islands (90.0%, Battista et al. 2007a). This indicates that the needs of coral reef managers and scientists for a dominance based classification scheme were met, with no loss in thematic map accuracy.

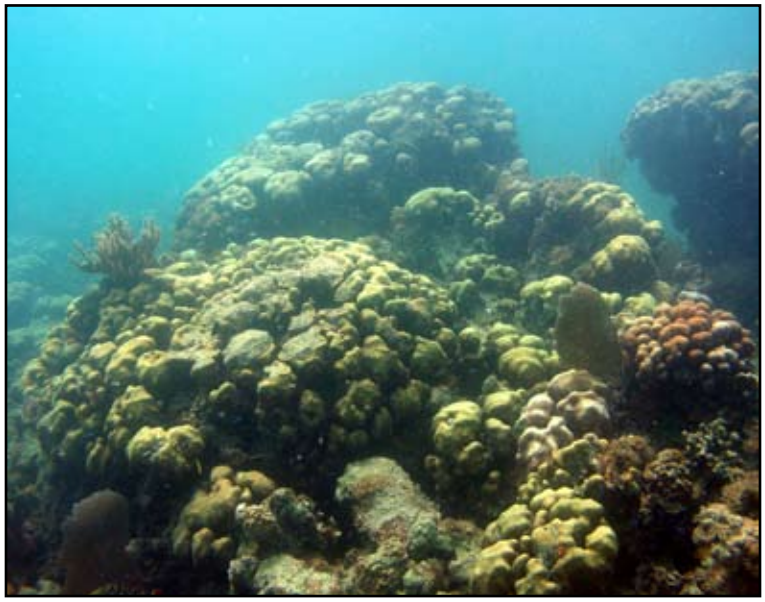

Figure 4.6. A large colony of boulder coral (Montastraea annularis) may have varying percentages of live coral cover.

4.3 PROJECT DELIVERABLES

The NOAA and NPS collaborative effort to map the benthic habitats of St. John resulted in a suite of products. These products were provided directly to NPS project partners by data drive and are available to the public on a NOAA Biogeography Branch website devoted to this mapping effort (http://ccma.nos.noaa.gov/ecosystems/coralreef/benthic_usvi.html). The project deliverables include:

- Benthic habitat maps in GIS format,
- Remotely sensed imagery, including satellite and airborne imagery,
- Underwater video of ground validation and accuracy assessment field sites, including GIS files of their locations,
- Classification manual (contained in this report),
- Description of the specific methods used to create the habitat maps (contained in this report),
- Assessment of the thematic accuracy of the maps (contained in this report),
- FGDC-compliant metadata for all GIS products,
- Map atlas panels in PDF format, and
- An interactive, web-based map that allows users to query and display all spatial datasets and underwater video.

4.4 FUTURE U.S. VIRGIN ISLANDS MAPPING ACTIVITIES

NOAA's Biogeography Branch is undertaking an effort to develop similar habitat maps of the moderate depth area (20 m – 55 m) south of St. John, including the Mid-Shelf Reef. The same habitat classification scheme from the shallow-water maps will be applied to habitat maps derived from acoustic data collected with a multibeam echosounder (MBES). The Biogeography Branch has developed a semi-automated classification technique, combining object and pixel-based approaches to classify acoustic data. The moderate depth mapping area begins at the deepest edge of the shallow-water mapping described in this report (see figure in Introduction). Integration of the shallow-water mapping with the moderate depth mapping will provide NPS and others with one seamless habitat map derived from two different technologies.

Upon completion of the moderate depth mapping effort, the Biogeography Branch, in collaboration with NOAA's Coastal Services Center, will implement a translation of the NOAA dominance habitat classification scheme for coral ecosystems (described in Chapter 1) to the Coastal and Marine Ecological Classification Standard (CMECS) (Madden et al. 2009). CMECS is a national-scale classification scheme that describes an aquatic setting and provides additional detail through five underlying components that describe different aspects of the relevant ecology. Project partners will evaluate the "cross-walking" of these two classification schemes to determine the ability of CMECS to capture the needs of the coral reef management and scientific communities currently described in NOAA's scheme.

Using the knowledge gained from the St. John integrated mapping effort, the Biogeography Branch will conduct a similar approach to St. Croix, U.S. Virgin Islands. The project includes acquisition of acoustic data and production of benthic habitat maps for the Buck Island Reef National Monument (BUIS) and the Salt River Bay National Historical Park and Ecological Reserve (SARI) (Figure 4.7). While NOAA and NPS have collaboratively conducted extensive habitat mapping and biological monitoring inside and outside parts of BUIS and SARI, funding and vessel access has never afforded the opportunity to conduct complete bathymetric and seafloor characterization within all of the marine protected areas (MPA). The Biogeography Branch proposes to conduct small boat operations using acoustic systems which are ideally suited to mapping the remaining shallow areas, to produce integrated shallow to deep water bathymetric and habitat maps within the MPA's.

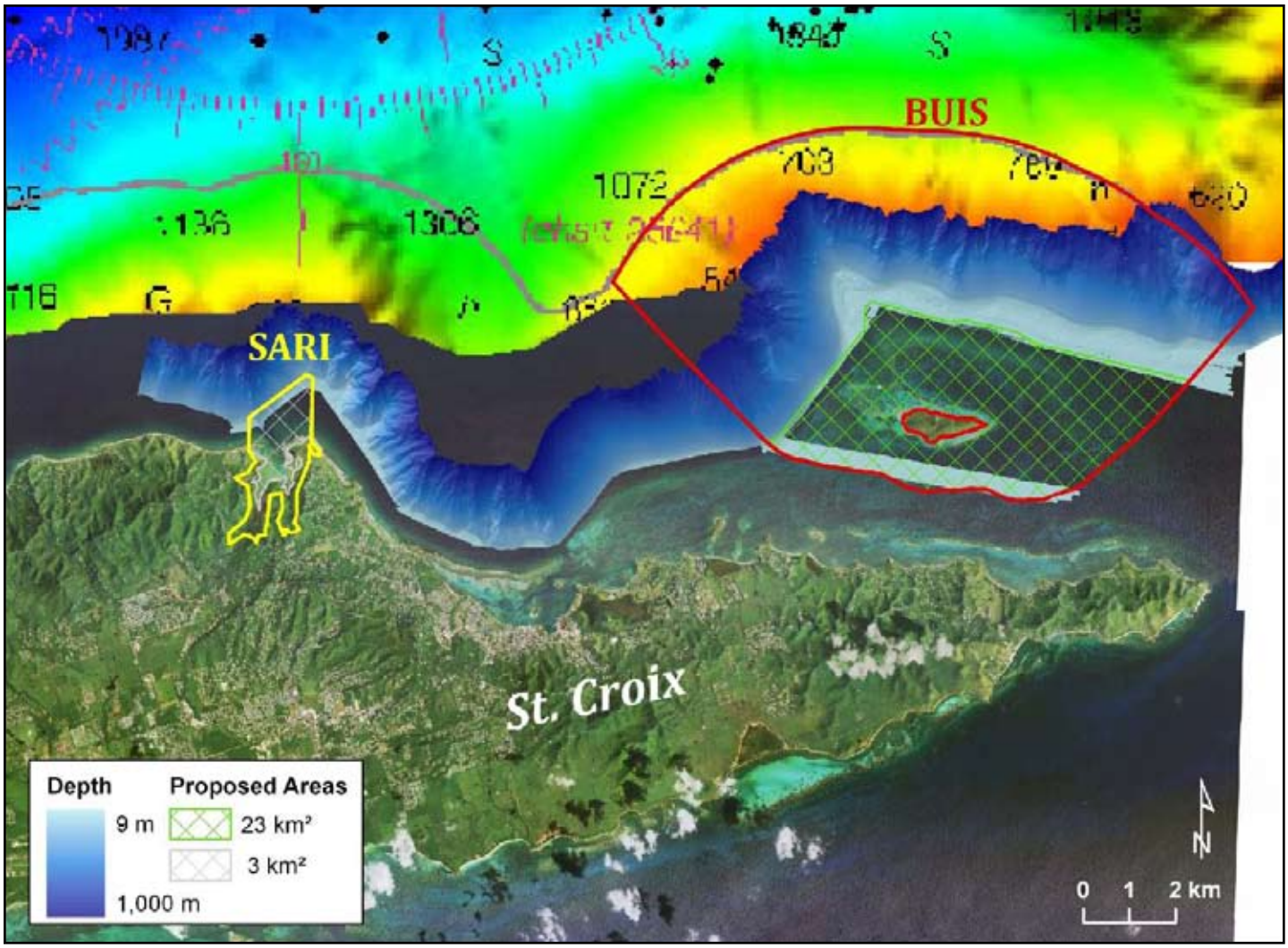

Figure 4.7. Seafloor mapping of Buck Island Reef National Monument and Salt River Bay National Historical Park and Ecological Reserve and adjacent areas of St. Croix, USVI. Previously collected acoustic data is displayed with management boundaries and proposed mapping areas.

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