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 moderate-depth marine environment south of St. John, U.S. Virgin Islands. An independent accuracy assessment revealed overall map accuracies to be over 95% for major structure and cover classes, and over 88% and 74% for detailed structure and cover classes, respectively. As a result, these digital map products can be used with confidence by scientists and resource managers for a multitude of different applications. 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. 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 for NOAA's moderate-depth benthic habitat map of St. John. Additional information is provided describing the item, its format and quantity.

ITEM	FORMAT	QUANTITY
Benthic Habitat Map	GIS	1,283 polygons
Acoustic Imagery	GIS	11 images
Interactive Map Project	Online	-
Ground Validation Dataset	GIS	117 locations & 13 transects
Accuracy Assessment Datatset	GIS	299 locations
Video of Seafloor	.mov or .wmv	432 videos
Final Report	PDF	1
FGDC-compliant Metadata for GIS Files	Text	17 files

4.1 MAP SUMMARY STATISTICS

In total, 90.2 km² of the seafloor was mapped in and around the VICRNM. Of this 90.2 km², 43.2 km² fell inside and 47.0 km² fell outside the VICRNM boundaries. Several patterns emerged when examining the summary map statistics for the total mapped area, as well as the mapped area inside and outside the park boundaries. These patterns are discussed in more detail below.

Total Mapped Area

In looking at major structure, *Coral Reef and Hardbottom* constituted the majority of the total mapped area (91.8%), while *Unconsolidated Sediment* only comprised a small fraction of this area (Table 4.2; Figure 4.1). *Coral Reef and Hardbottom* constituted the majority of the mapped area because the *Rhodoliths* habitat type dominated the entire moderate-depth region south of St. John. If the *Rhodoliths* category is excluded, the *Coral Reef and Hardbottom* category only accounted for 14.9% of the total mapped area. After *Rhodoliths*, *Sand* was

Table 4.2. Summary statistics describing the total amount (and percent) of mapped area by major and detailed geomorphological structure types. These numbers are further divided into the amount of mapped area inside and outside the VICRNM.

	GEOMORPHOLOGICAL STRUCTURE	TOTAL AREA (km²) INSIDE VICRNM	TOTAL AREA (km²) OUTSIDE VICRNM	TOTAL AREA (km²) MAPPED	% OF TOTAL MAPPED AREA
Major Structure	Coral Reef and Hardbottom	39.4	43.4	82.8	91.8
	Unconsolidated Sediment	3.83	3.59	7.4	8.23
Detailed Structure	Aggregate Reef	0.24	2.31	2.6	2.83
	Aggregated Patch Reefs	2.13	1.22	3.4	3.72
	Individual Patch Reef	0.21	0.13	0.3	0.39
	Pavement	3.07	2.02	5.1	5.64
	Pavement with Sand Channels	0.11	0.37	0.5	0.53
	Rhodoliths	32.8	36.6	69.4	76.9
	Rhodoliths with Scattered Coral and Rock	0.87	0.79	1.7	1.84
	Sand	3.74	3.57	7.3	8.11
	Sand with Scattered Coral and Rock	0.09	0.02	0.1	0.12
	Total Area (km²) Mapped	**43.2**	**47.0**	**90.2**	**100**

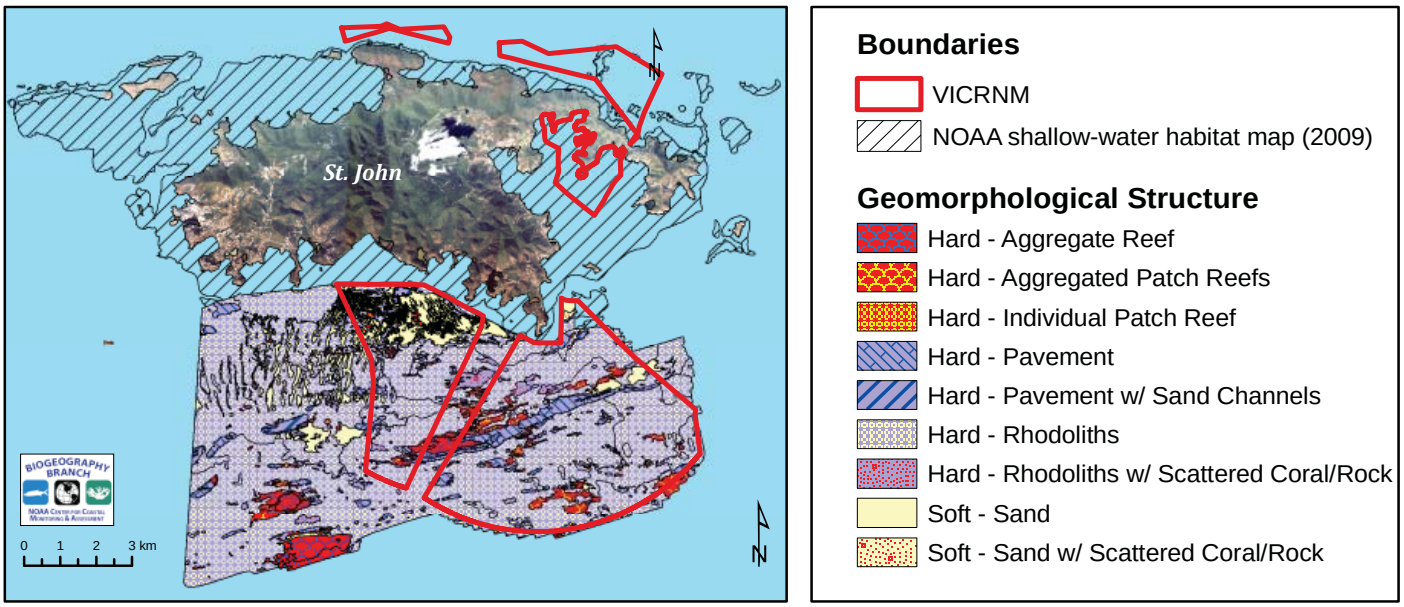

Figure 4.1. This figure depicts the major and detailed geomorphological structure of the moderate-depth area that was mapped using acoustic imagery south of St. John. The black hatched polygon denotes the area mapped using optical imagery. The red polygons show the boundaries of the VICRNM.

the second most dominant detailed structure type, followed respectively by: *(3) Pavement, (4) Aggregated Patch Reefs, (5) Aggregate Reef, (6) Rhodoliths with Scattered Coral and Rock, (7) Pavement with Sand Channels, (8) Individual Patch Reef, and (9) Sand with Scattered Coral and Rock*. Although ecologically significant, *Individual Patch Reefs* and *Aggregated Patch Reefs* comprised just over 4% of the moderate-depth habitat that was mapped south of St. John.

In looking at major biological cover, *Algae* colonized the majority of the total mapped area (92.8%) (Table 4.3; Figure 4.2). *Algae* dominated this moderate-depth region because this category included any combination of numerous types of red, green, or brown algae that were turf, fleshy, filamentous or crustose coralline species. After *Algae*, *No Cover* was the second most dominant major cover type, followed respectively by *Seagrass* and *Live Coral*. When the percent cover modifier is added to the calculations, *Algae 90% - 100%* colonized the majority of the total mapped area (54.8%), followed respectively by *Algae 50% - <90%, No Cover 90% - 100%, Algae 10% - <50%, Live Coral 50% - <90%* and *Seagrass 50% - <90%* and *90% - 100%*. The area colo-

Table 4.3. Summary statistics describing the total amount (and percent) of mapped area by major and detailed biological cover type as well as by amount of live coral cover. These numbers are further divided into the amount of mapped area inside and outside the VICRNM.

	BIOLOGICAL COVER	TOTAL MAPPED AREA (km²) INSIDE VICRNM	TOTAL MAPPED AREA (km²) OUTSIDE VICRNM	TOTAL MAPPED AREA (km²)	% OF TOTAL MAPPED AREA
Major Cover	Algae	39.9	43.8	83.7	92.8
	Live Coral	0.00	0.25	0.25	0.28
	No Cover	3.36	2.93	6.28	6.97
	Seagrass	0.02	0.02	0.04	0.04
Detailed Cover	Algae 10% - <50%	2.03	2.29	4.32	4.79
	Algae 50% - <90%	11.7	18.2	29.9	33.2
	Algae 90% - 100%	26.1	23.3	49.4	54.8
	Live Coral 50% - <90%	0.00	0.25	0.25	0.28
	No Cover 90% - 100%	3.36	2.93	6.28	6.97
	Seagrass 50% - <90%	0.02	0.01	0.02	0.02
	Seagrass 90% - 100%	0.00	0.02	0.02	0.02
Live Coral Cover	0% - <10%	42.9	45.4	88.3	97.9
	10% - <50%	0.39	1.33	1.72	1.91
	50% - <90%	0.00	0.25	0.25	0.28
	Total Area (km²) Mapped	**43.2**	**47.0**	**90.2**	**100**

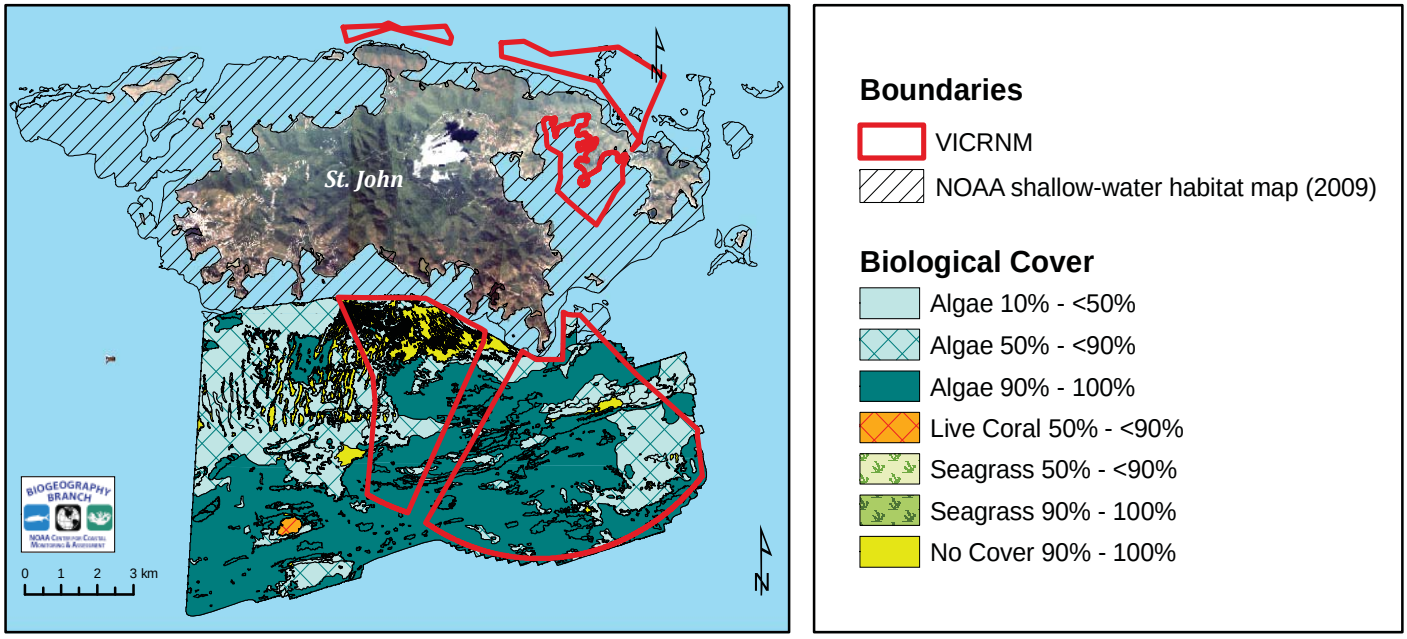

Figure 4.2. This figure depicts the major and detailed biological cover of the moderate-depth area that was mapped using acoustic imagery south of St. John. The black hatched polygon denotes the area mapped using optical imagery. The red polygons show the boundaries of the VICRNM.

nized by *Live Coral 50% - <90%* is the only polygon of its kind within the mapped area. This polygon is located in the southwestern part of the mapped area between 26 and 37 m in depth (Figure 4.3). Except for this one polygon, the majority of the mapped area (97.9%) was colonized by *0% - <10%* live scleractinian and/or soft corals. Only 2 km^2 (or 2.2%) of the mapped area was colonized by coral covers greater than or equal to 10%.

Total Mapped Area Outside VICRNM Boundaries

In looking at major structure, *Coral Reef and Hardbottom* also constituted the majority of the mapped area inside the VICRNM boundaries (92.4%), while *Unconsolidated Sediment* only comprised a small fraction (7.6%). *Coral Reef and Hardbottom* again constituted the majority of the mapped area inside the VICRNM boundaries because *Rhodoliths* were the dominant habitat type outside the park boundaries. If the *Rhodoliths* category is excluded, *Coral Reef and Hardbottom* only accounts for 14.6% of the mapped area outside the VICRNM boundaries. After *Rhodoliths*, *Sand* was the second most dominant detailed structure type (just as it was for the total mapped

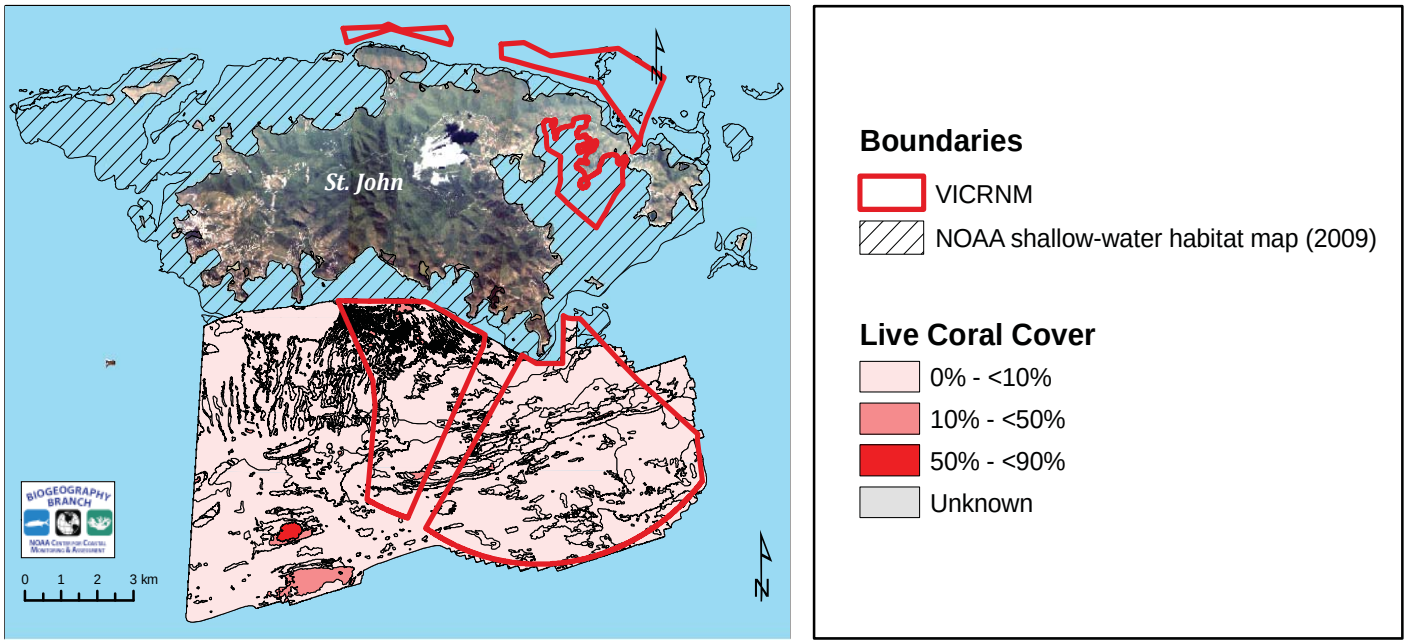

Figure 4.3. This figure depicts the amount of live coral cover present in the moderate-depth area that was mapped using acoustic imagery south of St. John. The black hatched polygon denotes the area mapped using optical imagery. The red polygons show the boundaries of the VICRNM.

area) followed respectively by: *(3) Aggregate Reef, (4) Pavement, (5) Aggregated Patch Reefs, (6) Rhodoliths with Scattered Coral and Rock, (7) Pavement with Sand Channels, (8) Individual Patch Reef, and (9) Sand with Scattered Coral and Rock*. Although ecologically significant, *Individual Patch Reefs* and *Aggregated Patch Reefs* again only comprised approximately 3% of the moderate-depth habitat mapped outside the VICRNM boundaries.

In looking at major biological cover, *Algae* colonized the majority of the mapped area outside the VICRNM boundaries (93.2%). Again, *Algae* dominated the mapped area outside the VICRNM boundaries because this category included any combination of numerous types of turf, fleshy, filamentous or crustose coralline algal species. After *Algae*, *No Cover* was the second most dominant major cover type, followed respectively by *Live Coral* and *Seagrass*. When the percent cover modifier is added to the calculations, *Algae 90% - 100%* colonized the majority of the mapped area outside the park boundaries (49.5%), followed respectively by *Algae 50% - <90%, No Cover 90% - 100%, Algae 10% - <50%, Live Coral 50% - <90%, Seagrass 90% - 100%* and *Seagrass 50% - <90%*. The area colonized by *Live Coral 50% - <90%* is the only polygon of its kind within the mapped area outside the VICRNM boundaries (and within the mapped area as a whole). Except for this one polygon, the majority (96.6%) of the mapped area outside the VICRNM boundaries was colonized by *0% - <10%* live corals. Only 1.6 km^2 (or 3.4%) of the mapped area outside the VICRNM was colonized by coral covers greater than or equal to 10%.

Total Mapped Area Inside VICRNM Boundaries

In looking at major structure, *Coral Reef and Hardbottom* also constituted the majority of the mapped area inside the VICRNM boundaries (91.1%), while *Unconsolidated Sediment* only comprised a small fraction (8.9%), because rhodoliths dominated the seafloor inside the park boundaries. If the *Rhodoliths* category is excluded, the *Coral Reef and Hardbottom* category only accounted for 15.3% of the mapped area within the VICRNM boundaries. After *Rhodoliths*, *Sand* was the second most dominant detailed structure type (just as it was for the total mapped area). This detailed structure type was followed respectively by: *(3) Pavement, (4) Aggregated Patch Reefs, (5) Rhodoliths with Scattered Coral and Rock, (6) Aggregate Reef, (7) Individual Patch Reef, (8) Pavement with Sand Channels, and (9) Sand with Scattered Coral and Rock*. Although ecologically significant, *Individual Patch Reefs* and *Aggregated Patch Reefs* again only comprised 5.4% of the moderate-depth habitat mapped inside the VICRNM boundaries.

In looking at major biological cover, *Algae* colonized the majority of the mapped area inside the VICRNM boundaries (92.2%). Again, *Algae* dominated the area inside the VICRNM boundaries because this category included any combination of numerous types of turf, fleshy, filamentous or crustose coralline algal species. After *Algae*, *No Cover* was the second most dominant major cover type, followed respectively by *Seagrass* and *Live Coral*. When the percent cover modifier is added to the calculations, *Algae 90% - 100%* colonized the majority of the mapped area inside the park boundaries (60.4%), followed respectively by *Algae 50% - <90%, No Cover 90% - 100%, Algae 10% - <50%,* and *Seagrass 50% - <90%*. No polygons within the VICRNM boundaries were dominated by live coral. The majority (99.1%) of the mapped area inside the VICRNM boundaries was colonized by *0% - <10%* live scleractinian and/or soft corals. Only 0.4 km^2 (or 0.9%) of the mapped area inside the VICRNM was colonized by coral covers greater than or equal to 10%.

Comparing Total Mapped Areas Inside and Outside VICRNM Boundaries

The mapped areas inside and outside the VICRNM followed the same general trends for major and detailed structure types. In particular, the seafloor both outside and inside the park boundaries was dominated by *Coral Reef and Hardbottom* habitat because *Rhodoliths* were ubiquitous on the shelf south of St. John. When *Rhodoliths* were removed from the calculation, roughly 15% of both areas were covered by *Coral Reef and Hardbottom*. In terms of detailed structure, both areas had the same diversity of structure types represented, although the quantity of these structure types differed slightly. In particular, the mapped area outside the VICRNM boundaries had approximately: (1) 4.3% more *Aggregate Reef*, (2) 2.0% more *Rhodoliths*, and (3) 0.5% more *Pavement with Sand Channels* than did the mapped area inside the VICRNM boundaries. The mapped area inside the VICRNM boundaries, on the other hand, had approximately: (1) 2.8% more *Pavement*, (2) 2.3% more *Aggregated Patch Reefs*, (3) 1.1% more *Sand*, (4) 0.3% more *Rhodoliths with Scattered Coral and Rock*, (5) 0.2% more *Individual Patch Reef*, and (6) 0.2% more *Sand with Scattered Coral and Rock* than did the mapped area outside the VICRNM boundaries.

The mapped areas inside and outside the VICRNM followed the same general trends for major and detailed biological cover types. In general, *Algae* colonized the majority of the mapped area both inside and outside the VICRNM boundary, with *No Cover* being the second most common cover category. Both areas were also dominated by continuous, high density algae (*Algae 90% - 100%*), followed respectively by *Algae 50% - <90%, No Cover 90% - 100%,* and *Algae 10% - <50%*. The mapped area outside the park boundary did, however, have 11.7% more *Algae 50% - <90%* and 10.9% less *Algae 90% - 100%* than the mapped area inside the VICRNM boundary.

In terms of coral cover, the majority (>96%) of both areas were colonized by *0% - <10%* live scleractinian and/or soft corals. It is important to note, however, that the mapped area outside the VICRNM had one 0.25 km^2 polygon dominated by live coral (i.e., *Live Coral 50% - <90%*), whereas the mapped area inside the VICRNM did not. In addition to this one polygon, the mapped area outside the park was found to have 1.9% more *Live Coral 10% - <50%* habitat than the mapped area inside the VICRNM. This difference suggests that there is slightly more live coral outside (than inside) the current VICRNM boundaries south of St. John.

4.2 INTEGRATION WITH SHALLOW-WATER NOAA HABITAT MAPS OF ST. JOHN

In 2009, NOAA's Biogeography Branch has successfully mapped the majority of the shallow-water (< 30 m) benthic habitats and a significant portion of the moderate-depth (30 – 60 m) benthic habitats around St. John in the U.S. Virgin Islands. The moderate-depth benthic habitat map begins at the optical limit of the shallow-water map, and continues to the edge of the acoustic imagery. Integration of the shallow-water and moderate-depth maps will provide NPS with one seamless benthic habitat map, extending from the shoreline of St. John southward to the 55 m isobath.

The integration of these two maps is possible, given that the same general habitat classification schemes and MMUs were applied to both habitat maps. That being said, the differences between these two maps must be thoroughly understood, in order to recognize the limitations associated with using such an integrated map. Most notably, the important differences between the two maps include: (1) slightly different definitions of *Pavement*, (2) different definitions of *Algae*, and (3) different methods used to quantify percent biological cover. These classification differences and their potential ramifications are discussed in more detail in the following paragraph.

Pavement, first of all, is defined as an area of "flat, low-relief solid carbonate rock with little or no fine-scale rugosity" in the shallow-water scheme. In the moderate-depth scheme, *Pavement* is defined as an area of "flat, low-relief or sloping solid carbonate rock with little or no fine-scale rugosity." Thus, in the shallow-water scheme, *Pavement* does not have relief, whereas in the moderate-depth classification scheme, *Pavement* may be sloping. These differing degrees of slope may influence the physical oceanography of an area, which in turn may affect the zonation and distribution patterns of corals (Geister, 1977; Sheppard, 1982; Done, 1983).

Algae, secondly, is defined as an area dominated by "any combination of numerous species of red, green, or brown algae that may be turf, fleshy or filamentous species" in the shallow-water scheme. In the moderate-depth scheme, *Algae* is defined as an area of "any combination of numerous species of red, green, or brown algae that may be turf, fleshy, filamentous or crustose coralline species." Thus, in the shallow-water scheme, the *Algae* class does not include crustose coralline species, whereas in the moderate-depth classification scheme, the *Algae* class does include these algal types. As a result, the *Algae* and *Coralline Algae* classes should be merged together in the shallow-water habitat map, if it is to be integrated with the moderate-depth habitat map.

Lastly, in the shallow-water scheme, the percent biological cover modifier represents a measure of the level of patchiness of the biological cover at the scale of the ≥ 1,000 m^2 habitat feature. It does not represent the density of biological cover observed by divers in the water. The moderate-depth classification scheme, on the other hand, quantified percent biological cover by accounting for both the density of biological cover at the scale of the 4 m^2 pixel and the patchiness of biological cover at the scale of the ≥ 1,000 m^2 habitat feature. This methodological difference caused some polygons in the shallow-water map to have higher percent covers than spatially coincident polygons in the moderate-depth map. Thus, the percent biological cover modifiers are not directly comparable in both maps, and should be viewed independently.

4.3 THE NEXT GENERATION OF MAPPING

The majority of shallow-water coral reef habitats have been successfully characterized at high thematic resolutions (≤ 32 classes) by conducting heads-up digitizing and interpretation of high resolution (≤ 4 x 4 m) imagery (Kendall et al., 2001; Battista et al., 2007[a]; Battista et al., 2007[b]). These resulting maps, however, are time-intensive to produce, limited by the size of the minimum mapping unit, and ultimately subjective and irreproducible because they depend on the accuracy and interpretation of the person that is digitizing.

Other studies have also successfully mapped marine habitats using pixel-based semi-automated classification techniques (Maeder et al., 2002; Mishra et al., 2006; Purkis et al., 2006). While these methods are more objective and reproducible than heads-up digitizing, they are not synoptic and easily scalable to coral reef areas of different sizes. Changing environmental conditions also inhibit these methods from producing maps with thematic accuracies and resolutions high enough to meet the needs of most marine resource managers.

In order to address these difficulties and increase the repeatability and efficiency with which maps are produced, the Biogeography Branch has been experimenting with alternative techniques to automate the process of delineating and attributing features on the seafloor. This moderate-depth map represents the Biogeography Branch's first attempt to create a benthic habitat map from acoustic imagery using this new semi-automated methodology. Results from this moderate-depth mapping effort suggest that this new mapping approach is 7x more time efficient (and just as thematically accurate) as heads-up habitat delineation and attribution (Table 4.4). Additionally, less than 40% of the polygons created using the semi-automated method were manually edited (Tables 2.7 and 2.8 (pg. 36)), suggesting that the majority of the moderate-depth map produced using this method is completely reproducible.

Table 4.4. Estimated time required to map St. John's shallow-water habitats using the heads-up digitizing and attribution method, and St. John's moderate-depth habitats using the semi-automated delineation and classification technique. These numbers were used to estimate of the number of square kilometers that were mapped per hour using each technique.

Mapping Method	Area Mapped (km^2)	Estimated Time (hours)*	Estimated Area Mapped (km^2) per Hour
Manual Heads-up Digitizing and Attribution	53.4	571	0.09
Semi-automated Delineation and Attribution	90.2	120	0.75
Total Difference	-36.8	451	-0.66

*This number only includes the time needed to delineate and attribute habitat features in the imagery. It does not included the time required for image processing, field work, data processing, expert reviews as well as report and product generation.

These initial results indicate that this new semi-automated approach has the potential to increase the repeatability and efficiency with which maps are produced. The ability to quickly, accurately and objectively create benthic habitat maps would transform the process of mapping from a static, resource inventory tool to a dynamic, resource monitoring tool. By doing so, resource managers would be able to more frequently assess the changing distribution (and ultimately, health) of the coral reef systems that they manage. Improving our understanding of these ecosystems is the key to identifying and mitigating the heterogeneous threats that face these important and precious resources.

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