CHAPTER 1: BENTHIC HABITAT CLASSIFICATION SCHEME

A habitat classification scheme allows scientists to systematically group habitat types based on common ecological characteristics. The initial task in any mapping effort is to create such a scheme by clearly identifying and defining discrete habitat classes. This scheme is subsequently used to guide the delineation and attribution of polygons throughout the mapping process. It is, consequently, critical for map users to have an understanding of the classification system, its structure and its definitions. This understanding allows users to decide on the appropriate uses and limitations of the map.

The St. John moderate-depth habitat classification scheme defines benthic communities on the basis of four primary coral reef ecosystem attributes: 1) broad geographic zone, 2) geomorphological structure, 3) dominant biological cover, and 4) amount of live coral cover. Habitat features are described by varying levels of detail (i.e. at the major and minor levels), so that users can refine the information depicted by the habitat map to best suit their research and management needs. Every polygon in the benthic habitat map was assigned a geomorphological structure, biological cover type and live coral cover percentage within a geographic zone. For example, many areas along the Mid Shelf Reef (MSR), which is located on the *Bank/Shelf*, are comprised of *Aggregate Reef* that is colonized by continuous, high density *Algae 90% - 100%* and low density live coral *0% - <10%*.

1.1. COMPARISON TO 2009 NOAA SHALLOW-WATER HABITAT CLASSIFICATION SCHEME

Many important factors were considered in the development of the St. John moderate-depth habitat classification scheme. These factors specifically included: (1) existing shallow-water classification schemes for coastal ecosystems, (2) quantitative *in situ* habitat data, (3) minimum mapping unit (MMU), (4) and limitations of the acoustic imagery (particularly, the intensity imagery).

In order to simplify this process, the St. John moderate-depth habitat classification scheme was based on the recently updated classification scheme developed by NOAA to map shallow-water (< 30 m) benthic habitats around St. John (Zitello et al., 2009). Specifically, the geographic zones, major and detailed geomorphological structure types, biological cover types and live coral cover classes used in the moderate-depth scheme were based on the same groupings developed for the shallow-water scheme. Also, a consistent MMU (i.e., 1,000 m^2) was used in both the shallow-water and moderate-depth classification schemes. However despite the similarities, there were also some differences between the two schemes because not all of the habitats found in shallow-waters are present at deeper depths. Specifically, these differences included: (1) changing the definitions of *Pavement* and *Algae* slightly to broaden their meanings, (2) removing 11 geographic zones, 7 geomorphological structure and 2 biological cover types because they were not present in the mod-

Table 1.1. This table depicts the changes made to the 2009 NOAA shallow-water classification scheme, in order to tailor it to the habitats seen at deeper depths (> 30 m) on the shelf south of St. John. Classes with a line through them were not present at moderate depths. The class with a star was added to the moderate-depth classification scheme. Italicized classes had their definitions changed slightly from those used in the shallow-water scheme.

GEOGRAPHIC ZONE	GEOMORPHOLOGICAL STRUCTURE	BIOLOGICAL COVER
~~Land~~	Coral Reef and Hard Bottom (Hard)	Major Cover
~~Salt Pond~~	~~Rock Outcrop~~	*Algae*
~~Shoreline Intertidal~~	~~Boulder~~	Live Coral
~~Lagoon~~	Aggregate Reef	~~Coralline Algae~~
~~Reef Flat~~	Individual Patch Reef	~~Mangrove~~
~~Back Reef~~	Aggregated Patch Reefs	Seagrass
~~Reef Crest~~	~~Spur and Groove~~	No Cover
~~Fore Reef~~	*Pavement*	Unknown
Bank/Shelf	Pavement with Sand Channels	Percent Major Cover
~~Escarpment~~	~~Reef Rubble~~	*10% - <50%*
~~Channel~~	Rhodoliths	*50% - <90%*
~~Dredged~~	Rhodoliths with Scattered Coral & Rock*	*90% - 100%*
Unknown	Unknown	Unknown
	Unconsolidated Sediment (Soft)	Percent Coral Cover
	Sand	0% - <10%
	~~Mud~~	10% - <50%
	Sand with Scattered Coral and Rock	50% - <90%
	Unknown	90% - 100%
	Other Delineations	Unknown
	~~Land~~	
	~~Artificial~~	
	~~Unknown~~	

erate-depth area, and (3) adding 1 new geomorphological structure type to accommodate a new habitat seen at these deeper depths (Table 1.1).

The other difference between the St. John shallow-water and moderate-depth classification schemes is how the two systems quantified percent biological cover. Specifically, in the shallow-water scheme, percent biological cover represents a measure 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. For example, a seagrass bed maybe described as covering 90% - 100% of a given polygon, but may have sparse shoot densities when observed by divers. 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. For example, a habitat feature defined as having 10% - <50% biological cover may have continuous algal cover at low densities, or it may have small, patchy areas of moderately dense algal cover scattered within large areas with no biological cover. Percent biological cover differs between the two schemes due to inherent differences in the technological approaches. Further research is being conducted to reconcile this difference in the future.

1.2. GEOGRAPHIC ZONES

One geographic zone (i.e., *Bank/Shelf*) was identified in the moderate-depth area, corresponding to typical insular shelf and coral reef geomorphology. Figure 1.1 illustrates zone types across typical cross-sections when the reef feature is fringing the shore. Zone only refers to the location of a benthic habitat feature and does not address the habitat feature's substrate or biological cover types. For example, the *Bank/Shelf* zone may include patch reefs and pavement; however, these are considered structural elements that may or may not occur within the *Bank/Shelf* zone and therefore, are not used to define it (Kendall et al., 2001). A brief description of the *Bank/Shelf* zone is provided in the proceeding text.

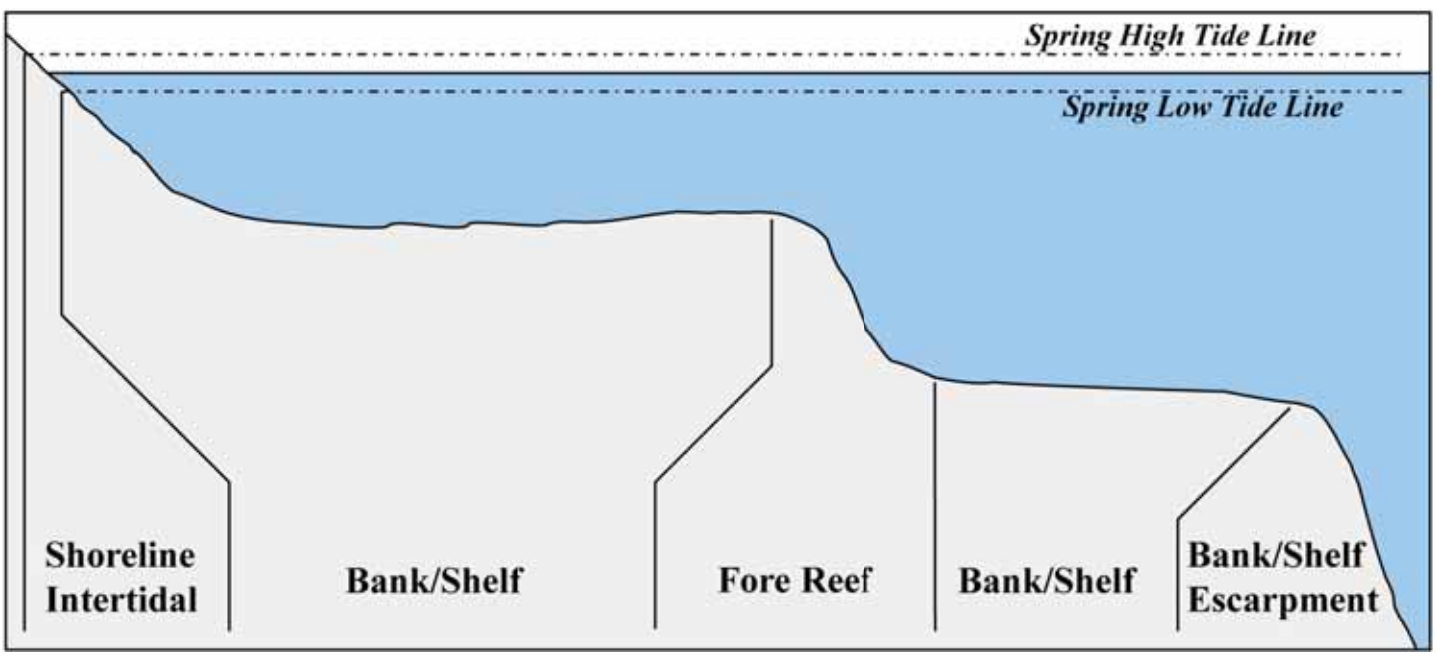

Figure 1.1. Cross-section of zone types where no emergent reef crest is present.

Bank/Shelf

Deeper water area (usually >30 m) extending offshore from the seaward edge of the *Fore Reef* or shoreline to the beginning of the bank/shelf escarpment where the insular shelf drops off into deep, oceanic water.

Unknown

Zone indistinguishable due to random or systematic noise in the bathymetry and/or backscatter, or other interference with an acoustic signature of the seafloor.

1.3. GEOMORPHOLOGICAL STRUCTURE TYPES

Thirteen distinct and non-overlapping geomorphological structure types were mapped using a combination of semi-automated classification and visual interpretation of acoustic imagery. Geomorphological structure refers to a habitat feature's dominate physical composition and does not address its location (e.g., on the *Bank/Shelf*). The structure types are defined in a collapsible hierarchy ranging from three major classes (*Coral Reef and Hard-*

bottom, *Unconsolidated Sediment*, and *Unknown*), to ten detailed classes (*Individual Patch Reef*, *Aggregated Patch Reefs*, *Aggregate Reef*, *Pavement*, *Pavement with Sand Channels*, *Rhodoliths*, *Rhodoliths with Scattered Coral and Rock*, *Sand*, *Sand with Scattered Coral and Rock* and *Unknown*). Habitat features with areas smaller than the map's minimum mapping unit or MMU (1,000 m^2) were not considered. For example, sand halos surrounding individual patch reefs were often too small to be mapped independently.

Coral Reef and Hardbottom

Areas on the seafloor with solid substrates including bedrock, boulders and/or the deposition of calcium carbonate by reef or nodule building organisms. Substrates typically have no sediment cover, but a thin veneer of sediment may be present at times. Detailed structure classes include *Individual Patch Reef*, *Aggregated Patch Reefs*, *Aggregate Reef*, *Pavement*, *Pavement with Sand Channels*, *Rhodoliths* and *Rhodoliths with Scattered Coral and Rock*.

Aggregate Reef

Continuous, high-relief coral formation of variable shapes lacking sand channels. Includes linear coral formations that are oriented parallel to the shelf edge (Figure 1.2).

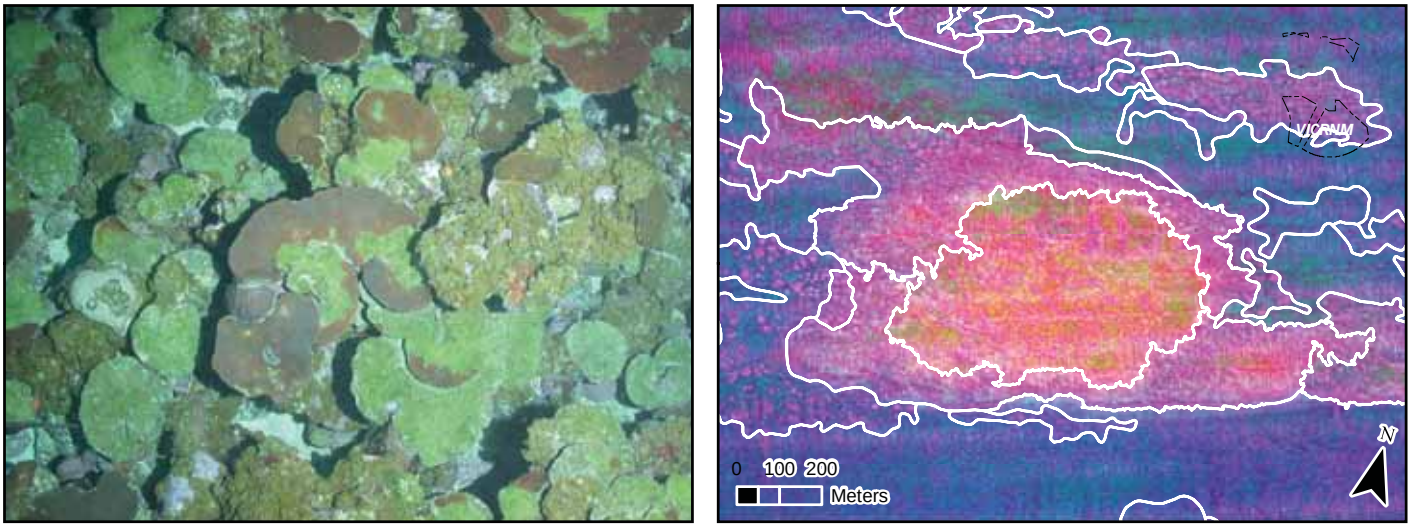

Figure 1.2. Underwater photograph (left) depicting the detailed structure type: *Aggregate Reef*. Red polygons outline the features in the acoustic imagery (right).

Individual Patch Reef

Individual Patch Reefs are coral formations with a circular or oblong shapes, and vertical reliefs of one meter or more in relation to the surrounding seafloor. They are isolated from other coral reef formations by bare sand, seagrass, rhodoliths or other habitats, and have no organized structural axis relative to the contours of the insular shelf edge. *Individual Patch Reefs* are larger than or equal to the map's MMU (Figure 1.3).

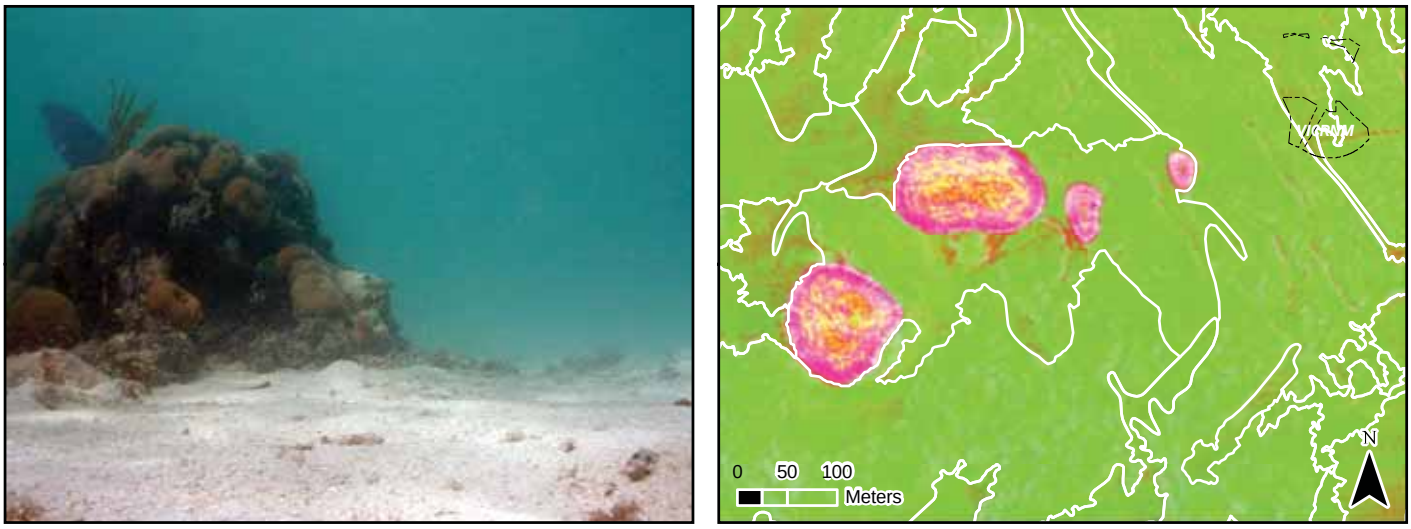

Figure 1.3. Underwater photograph (left) depicting the detailed structure type: *Individual Patch Reef*. Red polygons outline the features in the acoustic imagery (right).

Aggregated Patch Reefs

Aggregated Patch Reefs have the same defining characteristics as an *Individual Patch Reef*. This class, however, refers to clustered patch reefs that cover ≥ 10% of an entire polygon's area, but are too small (less than the MMU) or are too close together to map individually. Where aggregated patch reefs share sand halos, the halo is included in the polygon (Figure 1.4). If the density of small or aggregated coral heads is < 10% of the entire polygon, then the structure type is described as either *Rhodoliths with Scattered Coral and Rock* or *Sand with Scattered Coral and Rock*.

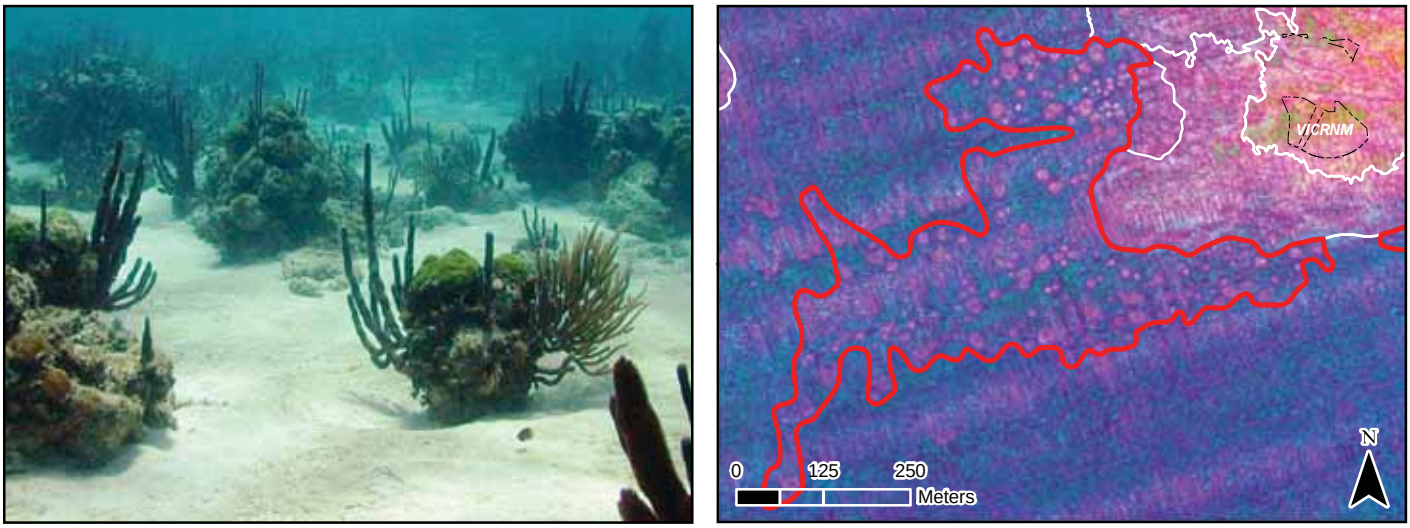

Figure 1.4. Underwater photograph (left) depicting the detailed structure type: *Aggregated Patch Reefs*. Red polygons outline the features in the acoustic imagery (right).

Pavement

Flat, low-relief or sloping solid carbonate rock with little or no fine-scale rugosity that is covered with algae, hard coral, gorgonians, zooanthids or other sessile vertebrates that are dense enough to partially obscure the underlying surface. On less colonized *Pavement* features, rock may be covered by a thin sand veneer (Figure 1.5).

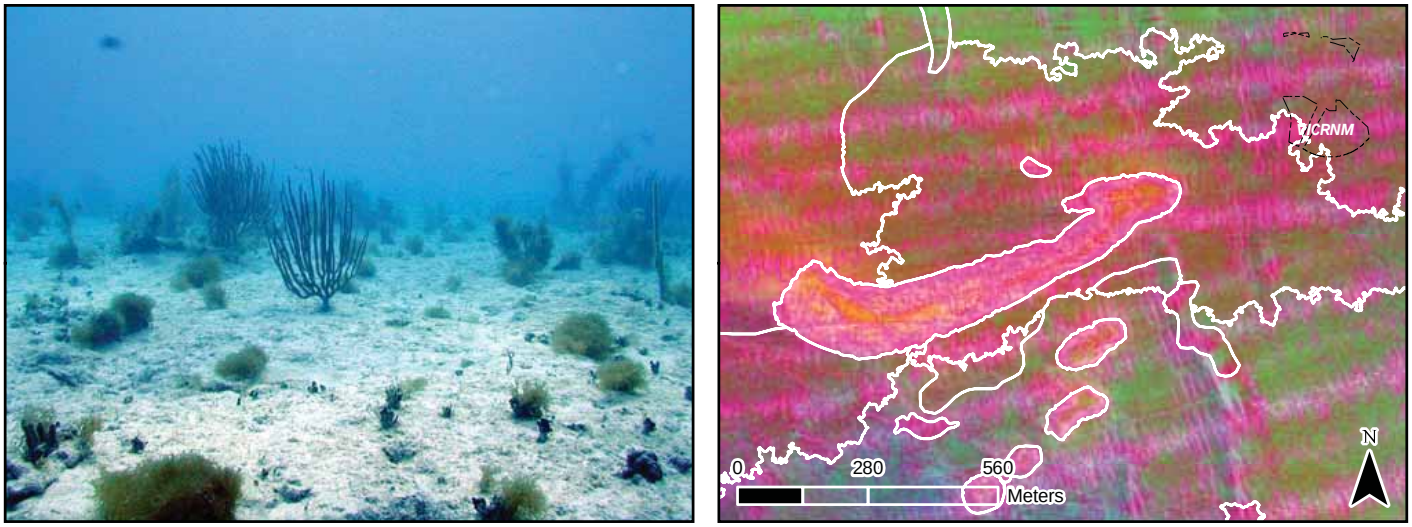

Figure 1.5. Underwater photograph (left) depicting the detailed structure type: *Pavement*. Red polygons outline the features in the acoustic imagery (right).

Pavement with Sand Channels

Pavement with Sand Channels have the same defining characteristics as *Pavement*, in addition to having periodic sand/surge channels oriented perpendicular to the *Bank/Shelf Escarpment*. The sand/surge channels of this feature have low vertical relief and are typically erosional in origin. This habitat type occurs in areas exposed to moderate wave surge, such as the *Bank/Shelf* zone (Figure 1.6).

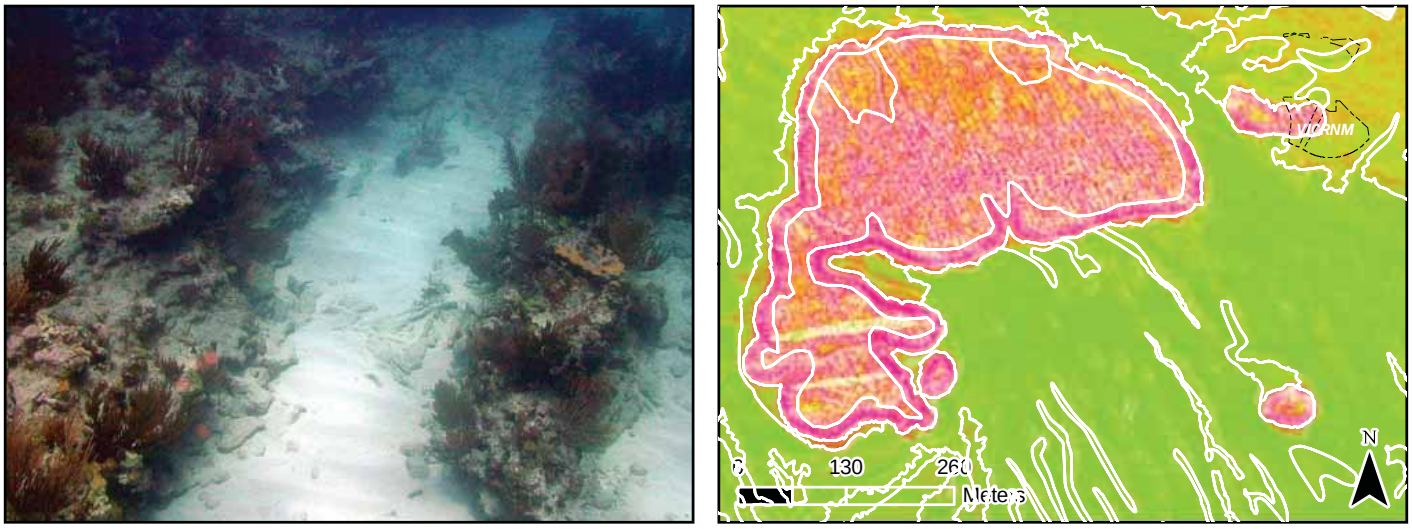

Figure 1.6. Underwater photograph (left) depicting the detailed structure type: *Pavement with Sand Channels*. Red polygons outline the features in the acoustic imagery (right).

Rhodoliths

Areas on the seafloor that are covered by ≥ 10% rhodoliths. Rhodoliths are cylindrical, discoidal, or irregular shaped calcareous nodules averaging approximately 6 cm in diameter (Foster 2001). These unattached nodules are colonized by successive layers of coralline red algae, and are commonly found in offshore topographic depressions (Figure 1.7). Since Rhodoliths are unattached to the seafloor and mobile, their distributions can change quantifiably from year to year.

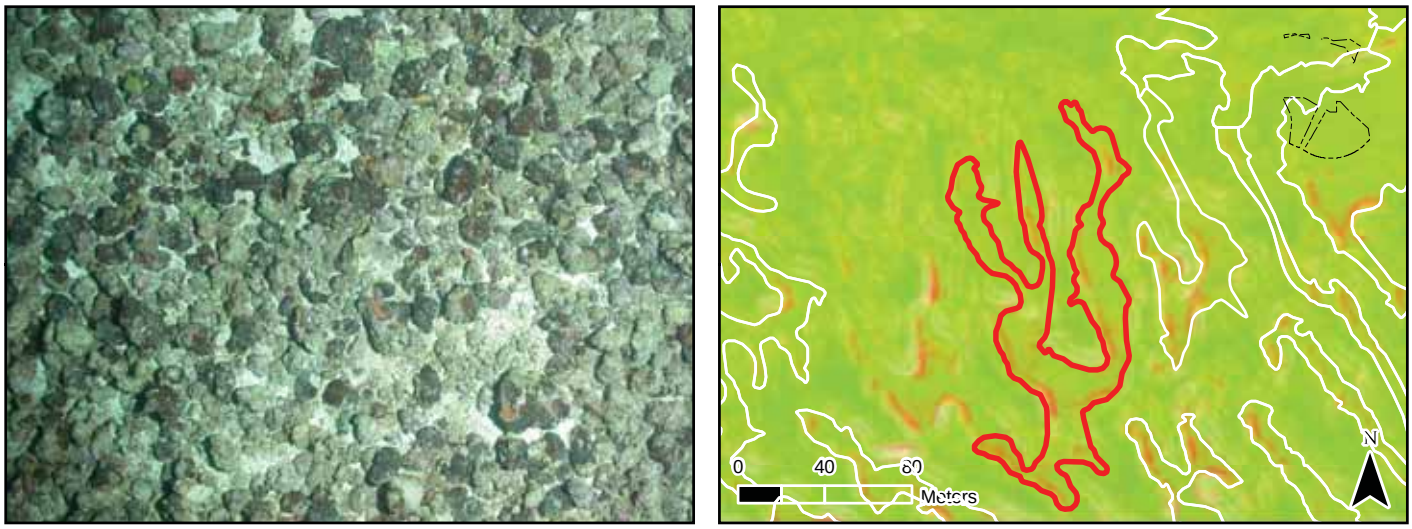

Figure 1.7. Underwater photograph (left) depicting the detailed structure type: *Rhodoliths*. Red polygons outline the features in the acoustic imagery (right).

Rhodoliths with Scattered Coral and Rock

Areas on the seafloor where ≥ 10% of the entire polygon is covered by rhodoliths, and < 10% of the entire polygon is covered by scattered rocks or isolated coral heads that are too small to be delineated individually (Figure 1.8). If the density of the rocks and/or coral heads is ≥ 10% of the entire polygon's area, then the structure type is described as *Aggregated Patch Reefs*.

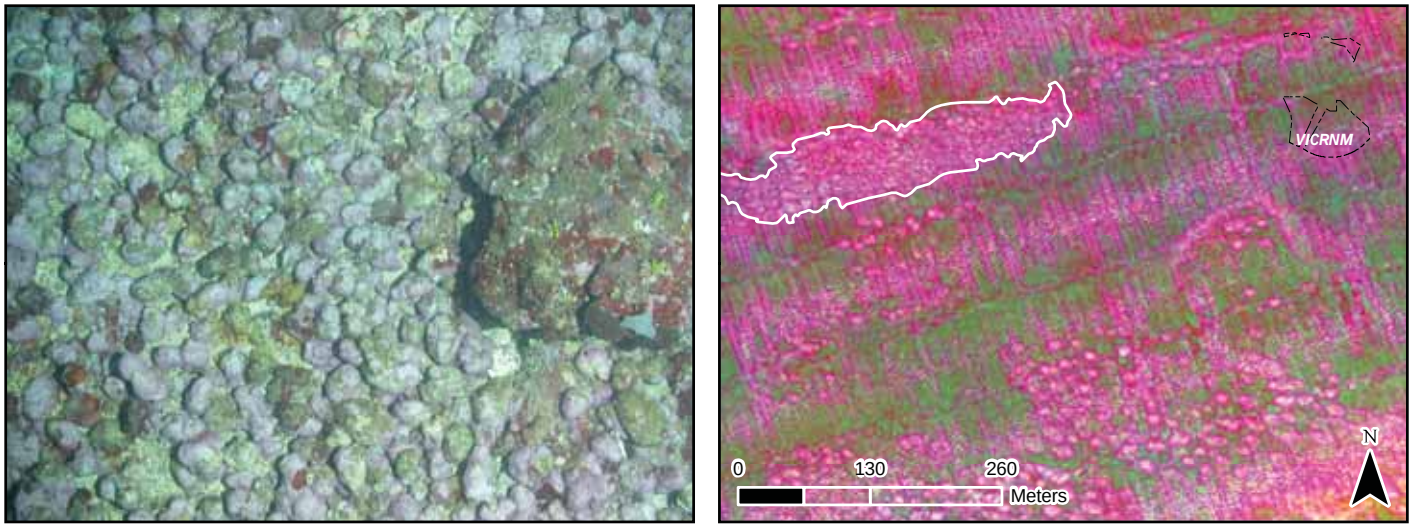

Figure 1.8. Underwater photograph (left) depicting the detailed structure type: *Rhodoliths with Scattered Coral and Rock*. Red polygons outline the features in the acoustic imagery (right).

Unconsolidated Sediment

Areas on the seafloor consisting of small particles (< 256 mm) with less than 10% cover of rhodoliths or large stable substrate. Detailed structure classes include: *Sand* and *Sand with Scattered Coral and Rock*.

Sand

Areas on the seafloor covered by coarse sediments (Figure 1.9). Particle sizes for these coarse sediments range from 0.0625 – 256 mm, including pebbles and cobbles (Wentworth 1922). This structure type is typically found in areas exposed to currents or moderate wave energy.

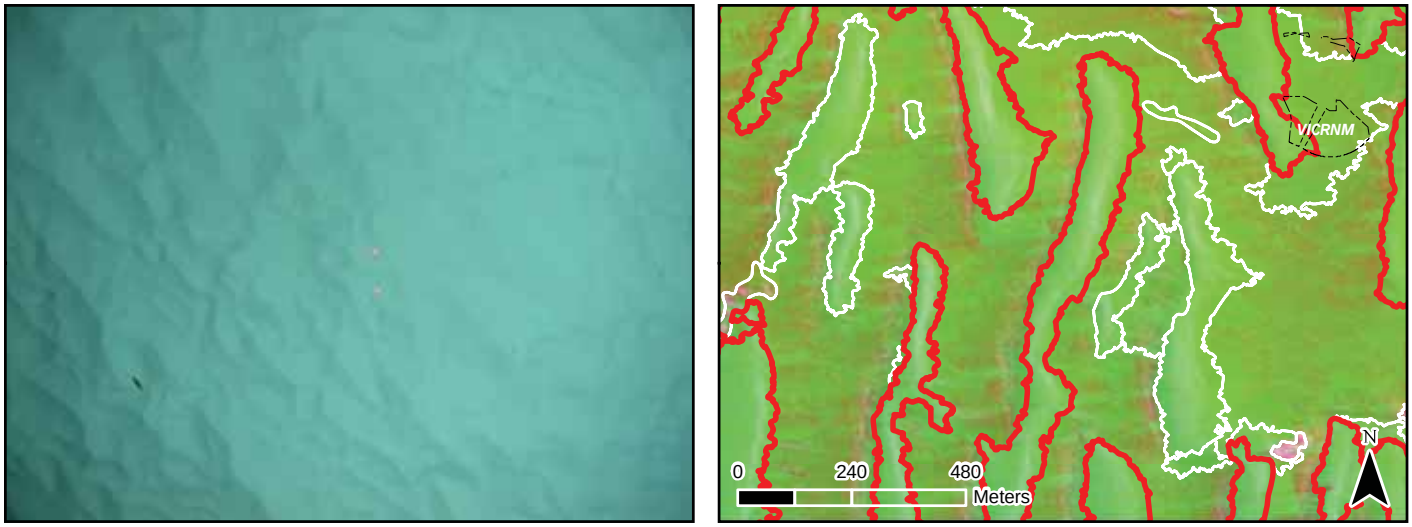

Figure 1.9. Underwater photograph (left) depicting the detailed structure type: *Sand*. Red polygons outline the features in the acoustic imagery (right).

Sand with Scattered Coral and Rock

Areas on the seafloor covered by sand, and < 10% of the entire polygon is covered by scattered rocks or isolated coral heads that are too small to be delineated individually (Figure 1.10). If the density of small coral heads is ≥ 10% of the entire polygon, then the structure type is described as *Aggregated Patch Reefs*. If rhodoliths cover ≥ 10% of the entire polygon, and < 10% of the entire polygon is covered by scattered rocks and isolated coral heads, then the structure type is described as *Rhodoliths with Scattered Coral and Rock*.

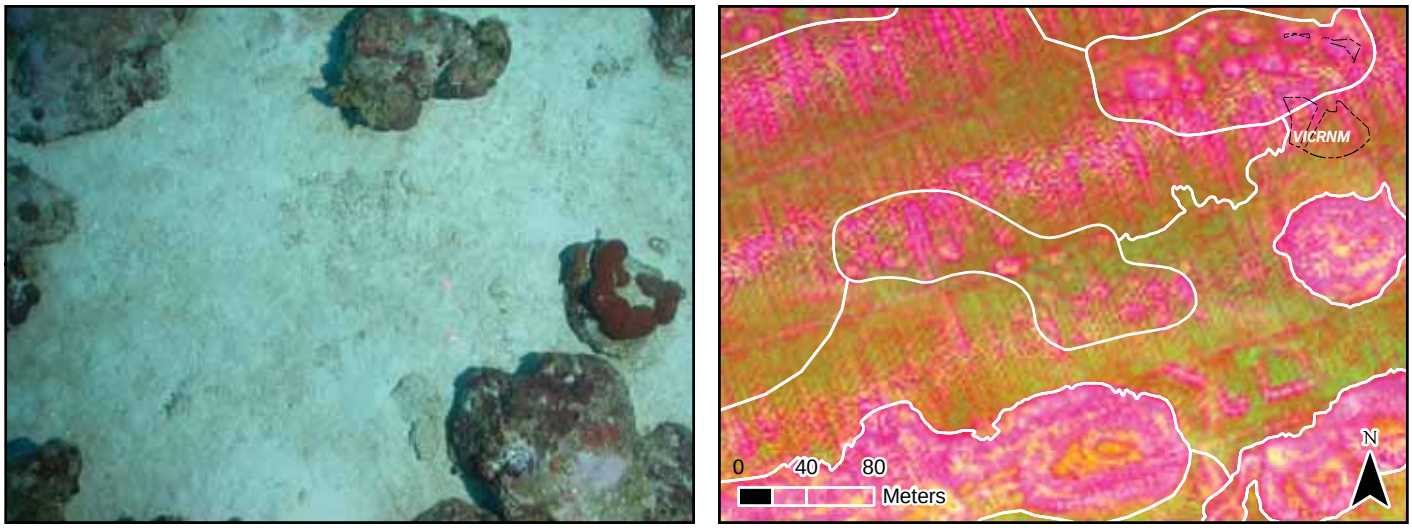

Figure 1.10. Underwater photograph (left) depicting the detailed structure type: *Sand with Scattered Coral and Rock*. A red polygon outlines the feature in the acoustic imagery (right).

Unknown

Major structure indistinguishable due to random or systematic noise in the bathymetry and/or backscatter, or other interference with an acoustic signature of the seafloor (Figure 1.11).

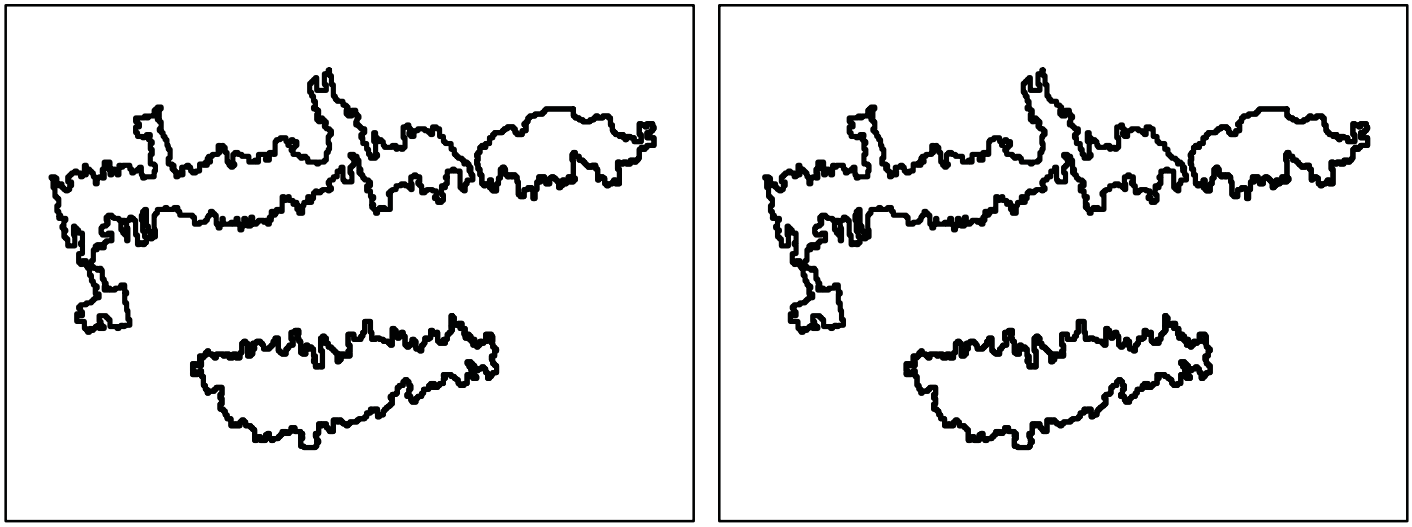

Figure 1.11. These red polygons are highlighting artifacts or noise in the acoustic imagery. This noise is depicted both in the intensity imagery (left) and the PCA imagery (right). This type of noise is akin to turbidity, wave action and/or sunglint in optical imagery, making it difficult for the cartographer to determine the habitat type underneath.

1.4 BIOLOGICAL COVER CLASSES

Five distinct and non-overlapping biological cover classes were mapped using a combination of semi-automated classification and visual interpretation of acoustic imagery. Cover classes refer to the dominant biological component colonizing the surface of the habitat feature, and does not address its location (e.g., on the *Bank/Shelf*). Habitats features that covered areas smaller than the MMU (1,000 m^2) were not mapped independently. Biological cover types were grouped into five major classes (i.e., *Algae, Seagrass, Live Coral, No Cover* and *Unknown*), and were combined with a modifier describing the density and distribution of the dominant cover type within the habitat feature (i.e., *10%-<50%, 50%-<90%*, and *90%-100%*). It is important to emphasize that the percent biological cover modifier represents a combined measure of density at the scale of the 4 m^2 pixel and of patchiness at the scale of the ≥ 1,000 m^2 habitat feature. For example, a habitat feature defined as having 10%-50% biological cover may have continuous algal cover at low densities, or it may be covered by small, patchy areas of moderately dense algae scattered within large areas with no biological cover. Figures 1.12, 1.14 and 1.15 are helpful for understanding how density within a pixel and patchiness within a habitat feature affected the assignment of percent cover.

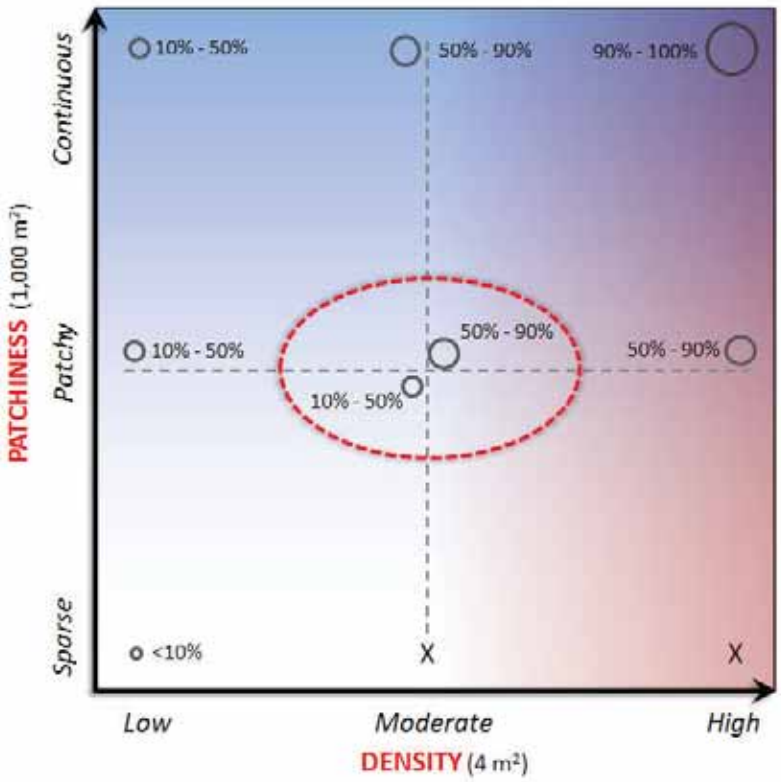

Figure 1.12. Graph denoting how the biological cover modifier represents a confounded measure of density at the scale of the 4 m^2 pixel and of patchiness at the scale of the ≥ 1,000 m^2 habitat feature. The dashed red circle in the middle denotes how the size of the patches of biological cover can influence whether a polygon is moved down into the 10% - 50% or up into the 50% – 90% category.

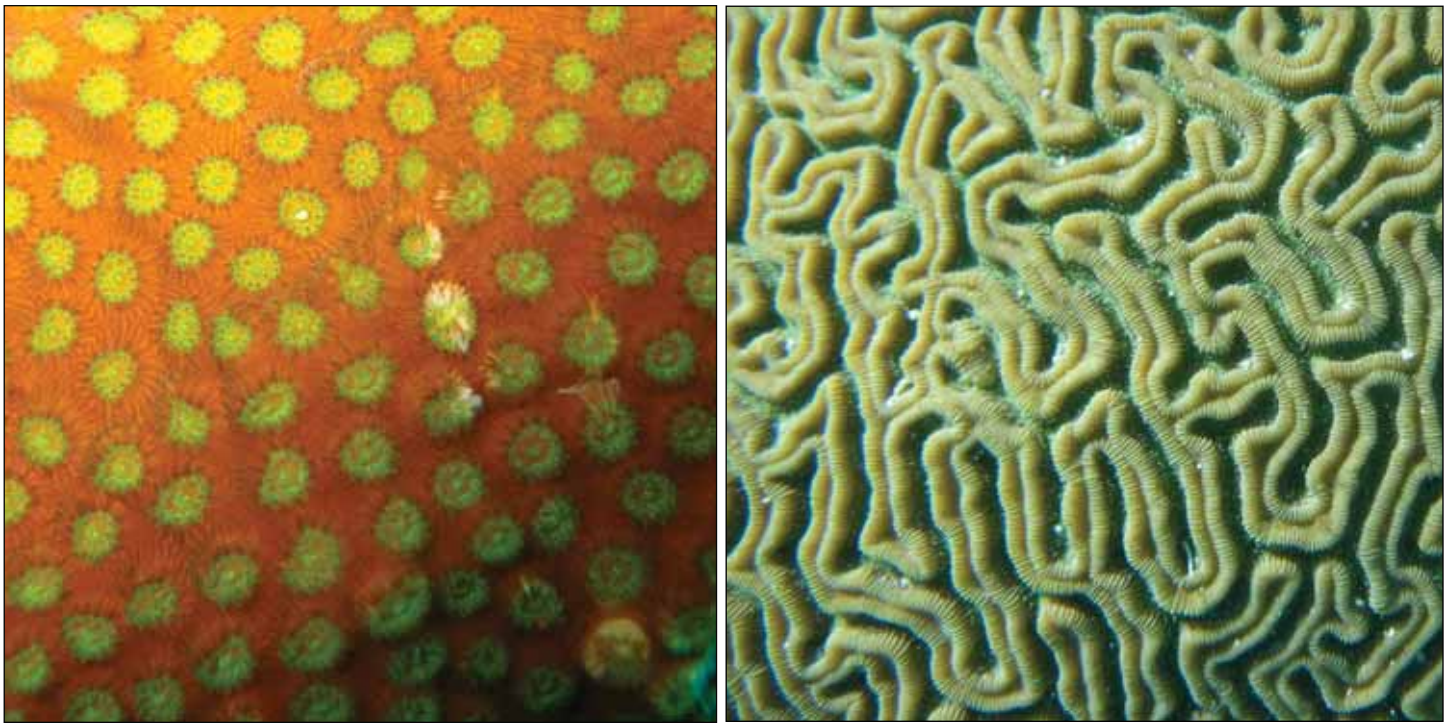

Figure 1.13. Underwater photographs of Lesser Starlet Coral (*Siderastrea radians*) (left) and Groved Brain Coral (*Diploria labyrinthiformis*) (right).

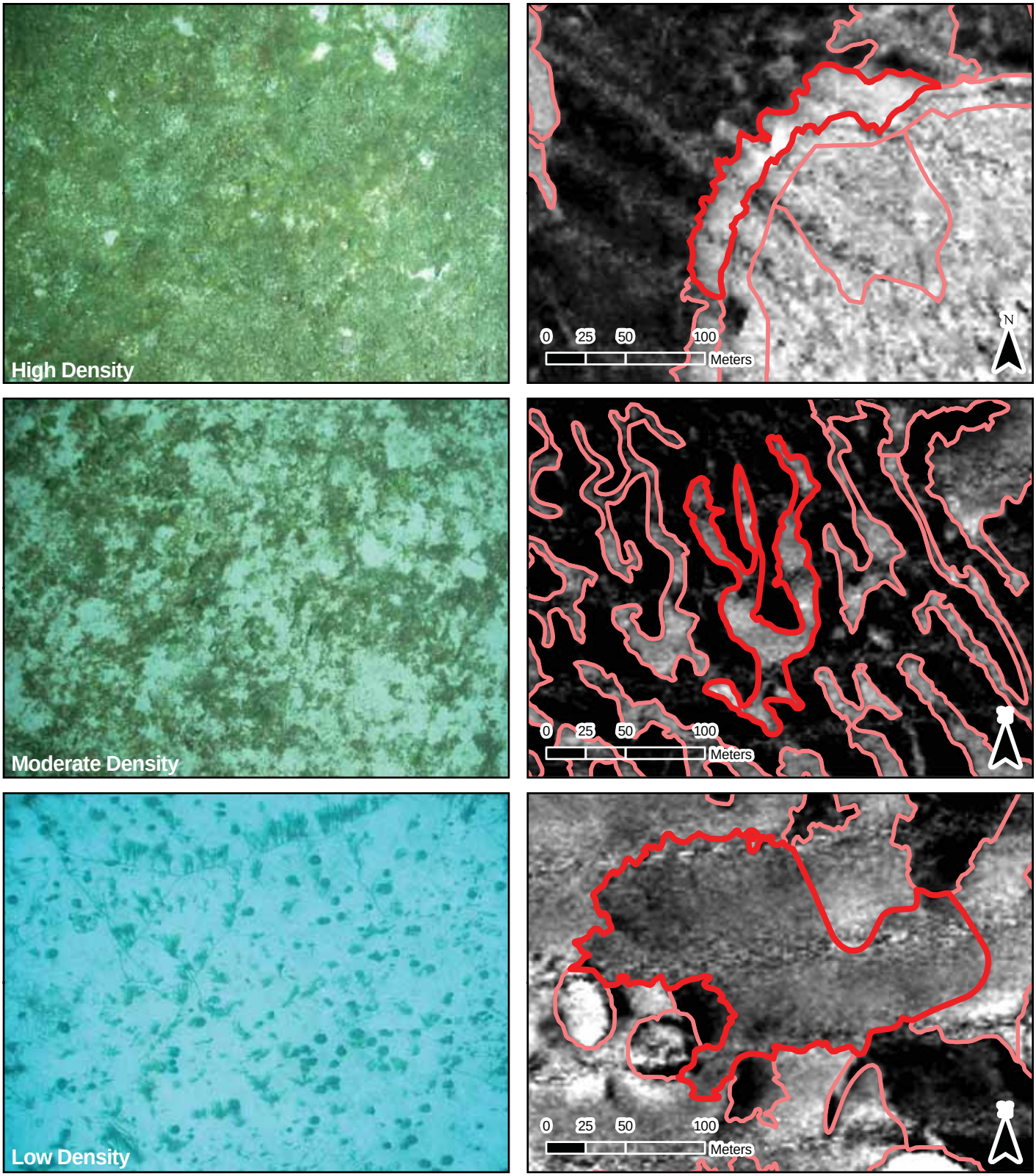

Figure 1.14. Underwater photos (left) and associated polygons highlighted in red (right) depicting the three different densities (high, moderate and lowe) of biological cover.

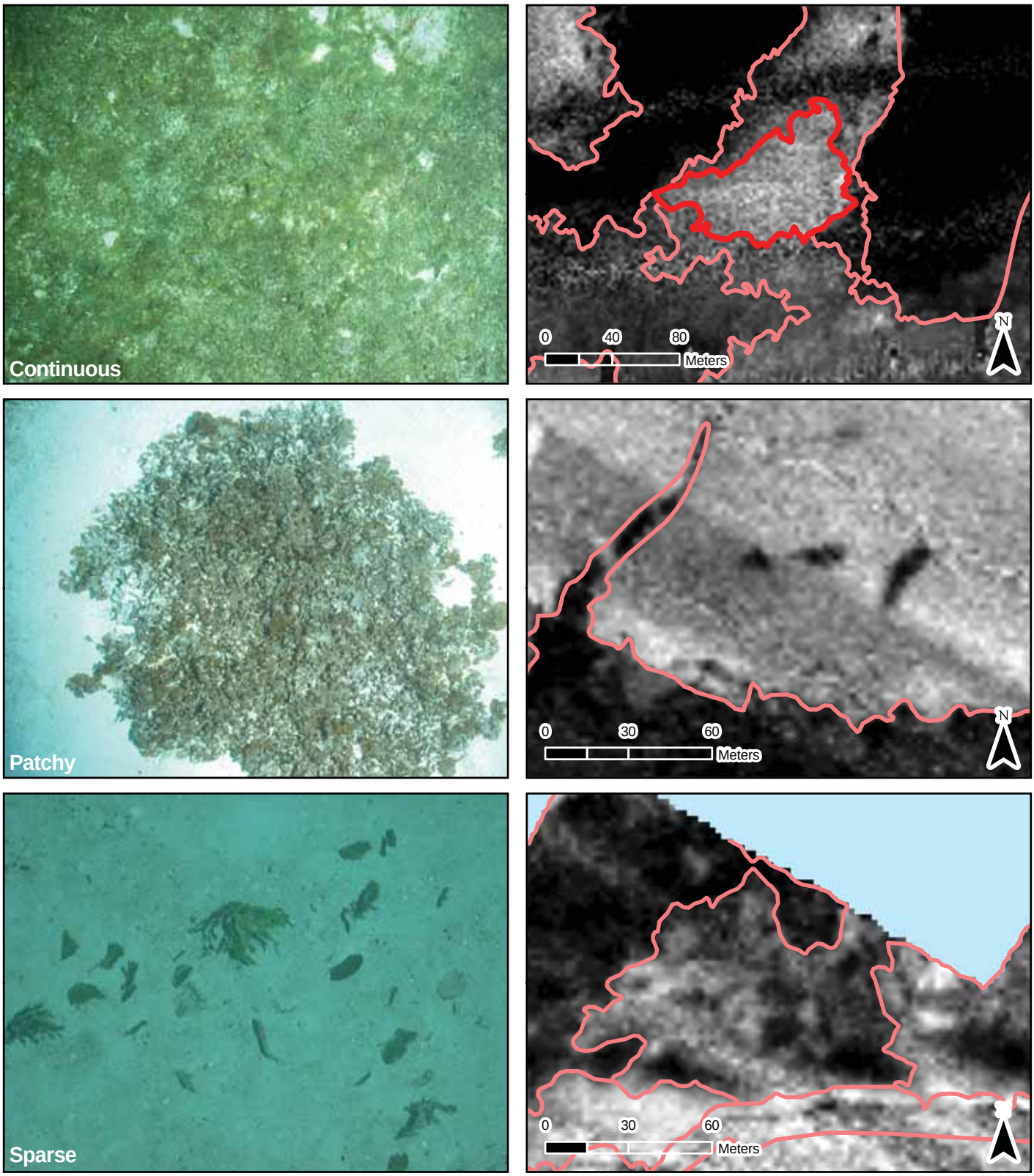

Figure 1.15. Underwater photos (left) and associated polygons highlighted in red (right) depicting the three different degrees (continuous, patchy and sparse) of biological cover patchiness.

Major Cover

Algae (1)
Substrates dominated by any combination of numerous species of red, green, or brown algae. These algae may be turf, fleshy, filamentous or crustose coralline species. This cover type occurs throughout many zones, especially on hard bottoms with low coral densities and soft bottoms in deeper waters on the *Bank/Shelf* zone. In some instances, habitat features with *10% - <50% Algae* were attributed as such, albeit the habitat feature had more uncolonized area than colonized area. This *10% - <50%* modifier was retained to explicitly denote that some *Algae* existed within a habitat feature (Figure 1.16).

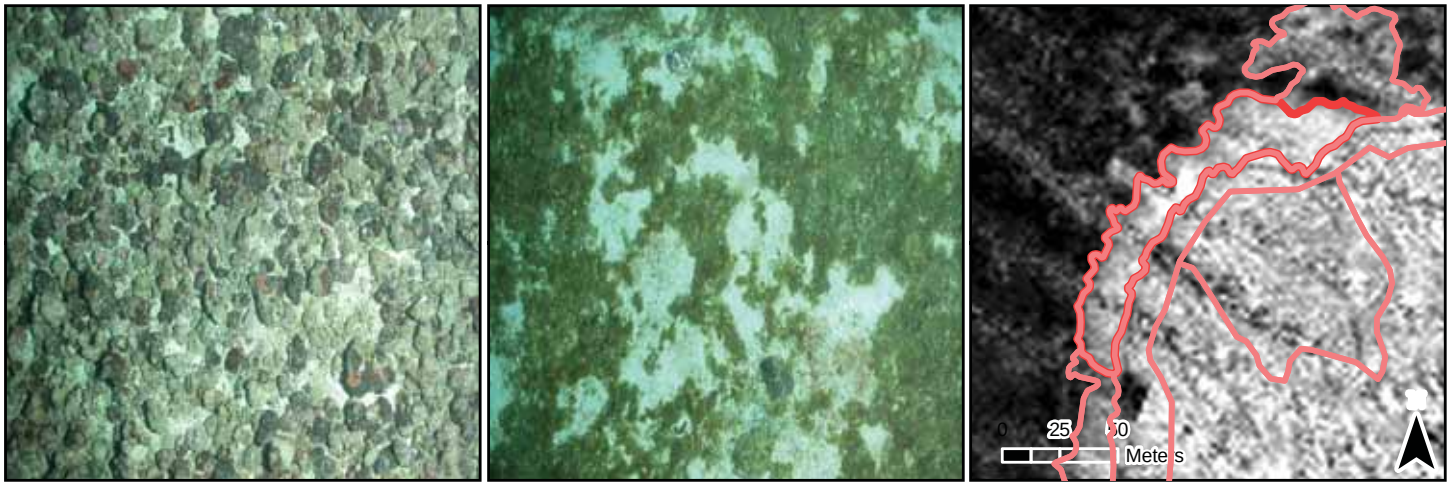

Figure 1.16. Underwater photographs depicting the major biological cover type: *Algae*. This class includes any combination of numerous species turf, fleshy, filamentous or crustose coralline species. A red polygon outlines the feature in the acoustic imagery (right).

Seagrass (2)
Habitat dominated by any single species of seagrass (e.g. *Syringodium* sp., *Thalassia* sp., and *Halophila* sp.) or a combination of several species (Figure 1.17).

Figure 1.17. Underwater photographs depicting the major biological cover type: *Seagrass*. Turtle Grass (*Thalassia testudinum*) (left) and Manatee Grass (*Syringodium filiforme*) (middle) are both common in shallow-waters, but not in waters deeper than approximately 30 m. Red polygons outline the features in the acoustic imagery (right).

Live Coral (3)
Habitat dominated by live reef building corals, including scleractinian (e.g., *Acropora* sp.) and octocorals (e.g., *Briareum* sp.) (Figure 1.18).

Figure 1.18. Underwater photographs depicting the major biological cover type: *Live Coral*. This biological cover type includes both scleractinian corals (left) and octocorals (middle). A red polygon outlines the feature in the acoustic imagery (right).

No Cover (4)
Substrates (usually *Sand*) covered with < 10% of any of the other biological cover types. In some instances, habitat features with *10% - <50%* biological cover were attributed as such, albeit the habitat feature had more uncolonized area than colonized area. This *10% - <50%* modifier was retained to explicitly denote that some biological cover existed within a habitat feature. The user may assume that the remainder of these polygons (*50% - <90%*) has no biological cover (Figure 1.19).

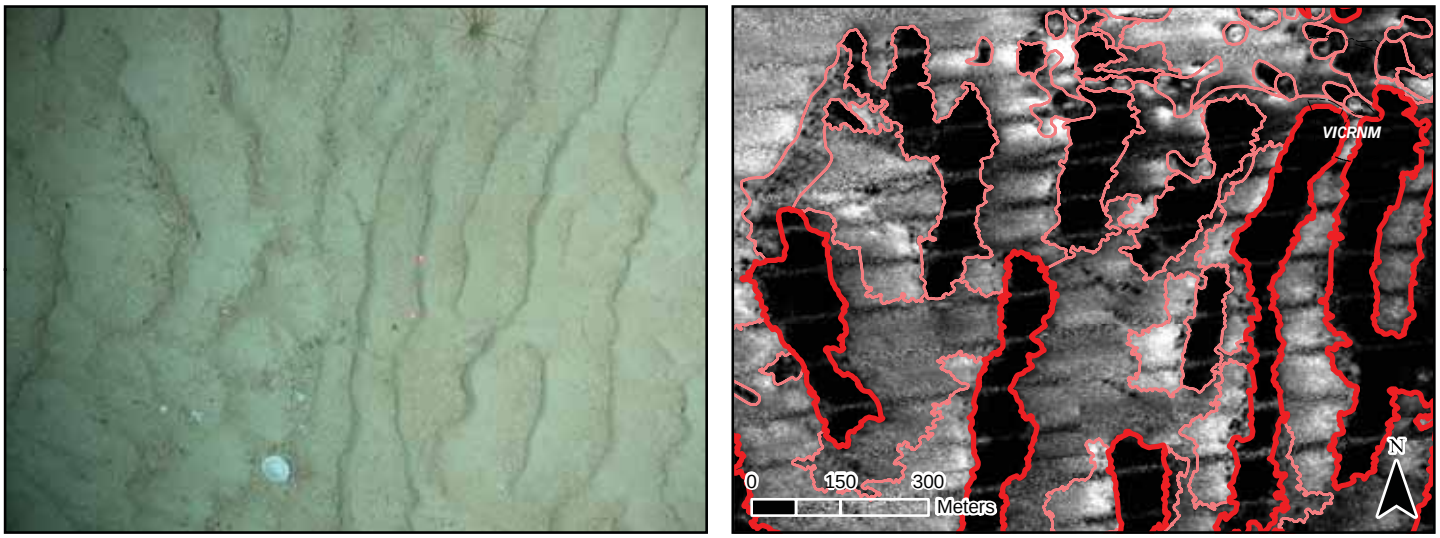

Figure 1.19. Underwater photographs depicting the major biological cover type: *No Cover*. Red polygons outline the features in the acoustic imagery (right).

Unknown (5)
Biological cover is indistinguishable due to random or systematic noise in the bathymetry and/or backscatter, or other interference with an acoustic signature of the seafloor.

Percent Major Cover

10% - <50% (1)
Continuous, low-density biological cover *or* patchy, moderate-density biological cover with uncolonized breaks in coverage that are too small (< 1,000 m^2) to be mapped as discrete habitat features. These uncolonized areas make up 90% or less of the habitat feature's total area. The overall combined density/patchiness of the major biological cover type is estimated to be 10% - <50% of the polygon feature (Figures 1.14 and 1.15).

50% - <90% (2)
Continuous, moderate-density biological cover *or* patchy, high-density biological cover with uncolonized breaks in coverage that are too small (< 1,000 m^2) to be mapped as discrete habitat features. These uncolonized areas make up 50% or less of the habitat feature's total area. The overall combined density/patchiness of the major biological cover type is estimated to be 50% - <90% of the polygon feature (Figures 1.14 and 1.15).

90% - 100% (3)
Continuous, high-density biological cover with uncolonized breaks in coverage that are too small (< 1,000 m^2) to be mapped as discrete habitat features. These small uncolonized areas make up 10% or less of the habitat feature's total area. The overall combined density/patchiness of the major biological cover type is estimated to be 90% - 100% of the polygon feature (Figures 1.14 and 1.15).

Unknown (4)
Percent estimate of the biological cover is indistinguishable due to random or systematic noise in the bathymetry and/or backscatter, or other interference with an acoustic signature of the seafloor.

1.5. LIVE CORAL COVER CLASSES

Four distinct and non-overlapping percent live coral classes were mapped using a combination of semi-automated classification and visual interpretation of acoustic imagery. This attribute is an additional biological cover modifier used to denote information about the percent cover of live coral (both scleractinian and octocorals) (Figure 1.20), when it was not the dominant cover type. In order to provide resource managers with additional information about corals, four range classes were used (*0% - <10%, 10% - <50%, 50% - <90%*, and *90% - 100%*). Unlike the biological cover modifier, live coral cover simply describes the density of coral on hardbottom features at the 4 m^2 pixel scale. It does not denote patchiness of coral at the scale of the habitat feature. For this reason, extensive *in situ* data is critical to correct attribution of the live coral cover modifier. As a result of these varying scales of interpretation, the percent biological cover and percent live coral cover modifiers are not additive properties within the same mapping unit. In many cases, they will sum to greater than 100%. For example, an *Aggregate Reef* may be covered by *Algae 90% - 100%*, as well as have *10% - <50%* coral densities at the fine-scale.

Figure 1.20. Both scleractinian (hard) corals (left) and octocorals (soft) corals (right) are aggregated together when classifying live coral cover. Typical corals of St. John include the scleractinian boulder coral (*Montastraea annularis*) and several octocorals including sea fans (*Gorgonia sp.*).

0% - <10% (1)
Live coral covering of less than 10% of the seafloor at the the 4 m^2 pixel scale (Figure 1.21).

10% - <50% (2)
Live coral covering 10% to 50% of the seafloor at the 4 m^2 pixel scale (Figure 1.22).

50% - <90% (3)
Live coral covering 50% to 90% of the seafloor at the 4 m^2 pixel scale (Figure 1.23).

90% - 100% (4)
Continuous live coral covering 90% or more of the seafloor at the 4 m^2 pixel scale.

Unknown (5)
Percent estimate of coral cover is indistinguishable due to random or systematic noise in the bathymetry and/or backscatter, or other interference with an acoustic signature of the seafloor.

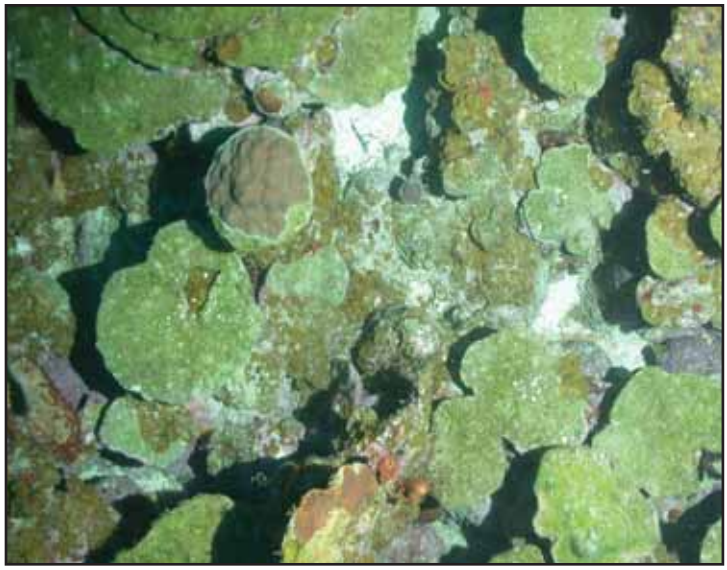

Figure 1.21. Photograph depicting the presence of live coral in the 0% - 10% cover range.

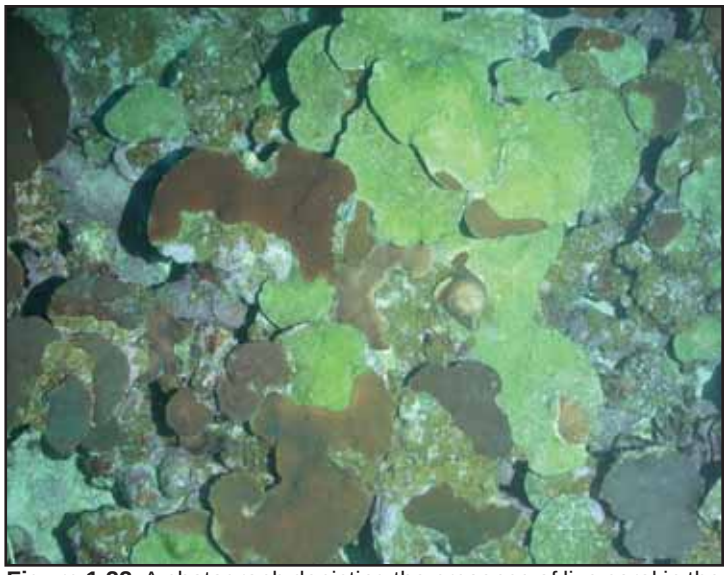

Figure 1.22. A photograph depicting the presence of live coral in the 10% - 50% cover range.

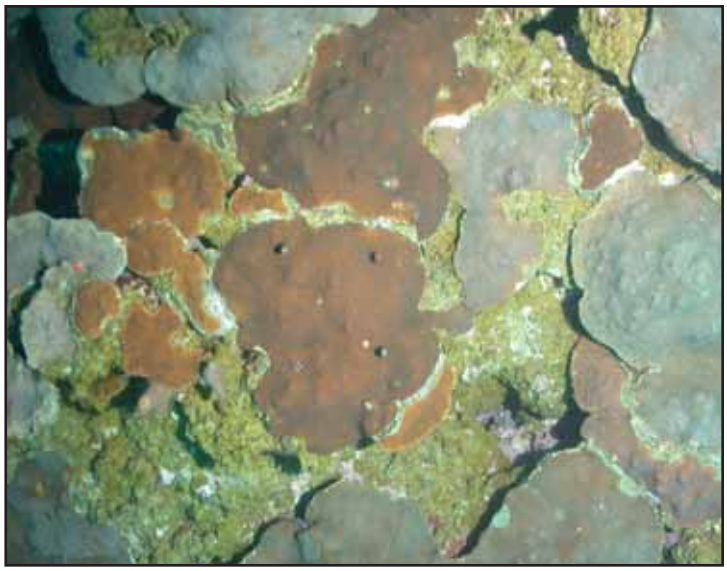

Figure 1.23. A photograph depicting the presence of live coral in the 50% - 90% cover range.

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