Mapping Guide for Partners of the Florida Reef Tract

Report for the
Coordinated Coral and Hardbottom Ecosystem
Mapping, Monitoring and Management Project
(DEP AGREEMENT NO. CM619)

Prepared by the Florida Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute

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The *Mapping Guide for Partners of the Florida Reef Tract* was designed to serve as a "best practices guide" for mapping the Florida Reef Tract. The goals of this document are to promote consistent methods among partners and ensure mapping efforts meet management needs. Mapping partners and managers can use this guide as a reference for optimizing current methods, and as a standards of practice for mapping projects. These recommendations will benefit long term maintenance of the Unified Reef Map (URM) by resolving inconsistencies among maps and increasing efficiency of map integration. These recommendations also support cooperative research efforts and coordinated monitoring of the Florida Reef Tract.

This Guide is organized based on four primary mapping needs for the Florida Reef Tract. Recommendations were based on 1) guidance from mapping partners, 2) participant feedback during mapping coordination meetings, and 3) lessons learned throughout the Unified Reef Map integration process. This effort is supported by the invaluable contributions of our mapping partners and funding from the Florida Department of Environmental Protection's Coastal Management Program under NOAA's Coastal Zone Management (CZM) program. A list of partners and the URM study area is shown in Table 1 and Figure 1.

1) Improve consistency in mapping scale and minimum mapping unit (MMU)

<u>Issue:</u> Reported map scale and MMU does not correspond to true mapping scale. The resolution of source imagery is a more reliable indicator of true mapping scale.

<u>Issue:</u> Map scale and MMU vary considerably among maps throughout the URM (Table 2). Differences in mapping scale limit spatial comparisons across the Reef Tract and create inconsistent linework and classification along seams between neighboring maps.

<u>Recommendations:</u>

- Mapping partners will adhere to a clearly defined mapping scale and MMU.
- At a minimum, metadata should include mapping scale, MMU, detailed image information (resolution, acquisition dates, sensor type) and any additional information used during the classification process (i.e. bathymetry, historic maps, field data, etc.)
- Adopt the following mapping scale guidelines for all new mapping efforts in the Florida Reef Tract
    - **Recommended digitizing scale = 1:4,000, no more than 1:3,000**
        - Average resolution of newer imagery and source data = 0.5m to 1.0m
        - # pixels/cells to distinguish between spatial features = 4 pixels *(Rohmann and Monaco, 2005)*
        - Digitizing scale is a function of resolution and size of smallest detectable feature = 1000* resolution * smallest detectable feature *(Tobler, 1987)*
    - **Recommended MMU for all features = 0.1ha**
        - Based on NOVA Southeast university's SEFL 2013 updated maps
        - Likely approximates National Park Service's true mapping scale and MMU
        - Is reasonable in most areas considering coverage of higher resolution imagery
        - Will likely improve discrimination between problematic classes
    - **Recommended MMU for patch reefs = 150sqm**
        - Based on Unified Patch Reef v1.3

2) Resolve classification issues

Issue: Classification of seagrass mixed with hardbottom differs among maps using NOAA's GeoForm/BioCover scheme (Zitello et al 2009) and maps classifying habitats based on the SCHEME system (e.g. NPS, NSU, Florida Bay). When GeoForm and BioCover are not classified as separate attributes often only BioCover information (i.e. seagrass) is retained while presence of hard bottom is not documented.

Issue: Classification of certain habitats such as patch reefs and seagrass is sensitive to MMU size and mapping scale. For example, identifying a patch reef as either an individual or aggregated patch reef, will vary among maps with different MMUs. A group of small patch reefs would be delineated separately and classified as individual patch reefs at a smaller MMU, whereas, the same group of patch reefs at a larger MMU would be grouped together and classified as aggregated patch reefs. Delineation between sediment and seagrass is also influenced by map scale and MMU. For example, at a coarser scale an area may be classified as discontinuous seagrass, whereas, at a finer scale that same area would be subdivided into patches of continuous seagrass and sediment.

Issue: Hardbottom classes such as pavement, aggregate and patch reef are often not mapped consistently throughout the URM. Differences among hardbottom classes are often subtle both in situ and from aerial imagery. Because of these similarities it is often difficult to consistently apply current classification schemes, especially because current schemes lack clear thresholds among classes. Additionally, information necessary for discriminating among types of hardbottom is either not available or not mapped at a scale fine enough to inform classification. For example, high resolution bathymetry would likely improve consistent classification between low relief pavement and higher relief reef habitat, which often appear very similar in aerial imagery when pavement is heavily colonized.

Issue: Difficultly distinguishing sediment from seagrass when seagrass cover is sparse and near the 10% cover classification threshold. This is particularly challenging in the presence of algae which is easily confused with seagrass.

Recommendations

- Modify existing classification schemes and encourage mapping partners to implement proposed changes for new mapping efforts. Proposed classification criteria are listed in Tables 3 and Figure 3 and include;
    - Addition of Pavement with Seagrass at UC Level 0 and modified decision rules which identifies both GeoForm and BioCover in the initial phases of classification (Figure 2). This modification will ensure that both seagrass and pavement are represented at the coarsest level of the Unified Reef map, which is the default display for online map viewers and the most practical scale for conducting reef-tract wide assessments. For maps using the GeoForm and BioCover classification method, this modification will be largely superficial, only changing the way data are symbolized at the Unified Reef Maps coarsest UC Levels. In the remaining areas of the URM where hardbottom has not been traditionally mapped if seagrass was present, maps should be updated or reclassified to include hardbottom using the new Pavement with Seagrass class (i.e. Florida Bay, NSU, NPS).
    - Clear decision thresholds for hardbottom classes based on unique characteristics such as relief, feature size, presence of grazing halo, and extent of coral cover (Table 3 and Figures 2 and 3).

  - Classification rules which are independent of map scale or MMU for patch reefs and seagrass (i.e. presence of shared halo for patch reefs).
- Expand collection of ancillary data which can improve discrimination between similar habitats including high resolution bathymetric data and increased field verification observations, particularly for classes which cannot easily be delineated from aerial imagery alone (e.g. hardbottom classes and seagrass v. algae)

3) Assess and improve map accuracy

Issue: Currently, there is no estimate for the overall accuracy of the entire URM map. Accuracy assessments have been conducted in portions of the Florida Reef Tract, however, gaps among studies and differences in accuracy assessment methods limit comparisons among maps. Maps requiring accuracy assessments include; Boca Grande, Hawk's Channel, North Keys/Backcountry, and the Unified Patch Reef dataset.

Issue: Disagreement between field and map results due to disparity between the resolution of *in situ* observations and mapping scale (Walker et al 2013; Estep et al 2014; Waara et al 2011). Additionally, disagreement is more likely to occur due to time lags between field observations and image acquisition. Collectively these issues can limit usefulness of survey data and the reliability of accuracy assessment results.

Recommendations:

- Conduct accuracy assessments in recently mapped areas including Hawk's Channel, Boca Grande, North Keys/Backcountry, and the Unified Patch Reef dataset.
- Conduct a comprehensive accuracy assessment of the URM.
- Develop field verification methods and accuracy assessment standards for mapping partners. These standards should include the following;
  - Encourage collection of groundtruth and/or accuracy assessment data as close to collection of source imagery as possible to reduce errors due to temporal changes in benthic communities (see Walker et al 2014).
  - Reference data should be collected at a scale as close to the MMU as possible (Walker et al 2014; Waara et al 2011). The scale of field observations should also take into account the type of benthic class being evaluated and variability of benthic features within that class.

4) Continued support for the Unified Reef Map and future mapping efforts

- The URM is a dynamic map which requires continued maintenance to ensure data are current and publicly accessible. GIS editing will be necessary as maps are updated and provided by URM partners. The URM website and web mapping services will require maintenance as needed and web server support.
- There are various gaps throughout the Florida Reef Tract, these areas are represented as voids in the URM or features which were delineated but have not been classified. Gaps in map coverage typically occur where there are gaps in source imagery or where imagery cannot be interpreted due to cloud cover, high turbidity, sun glint or glare, or other atmospheric conditions. There are also gaps between the benthic coverage of the URM and intertidal and terrestrial maps.
- Advances in remote sensing technology have created opportunities to expand the URM to include areas and features which have historically been unmapped such as deep water corals, turbid channels, and fine scale hardbottom features. Reduced acquisition costs enable more frequent

and current source imagery which may improve map accuracy for ephemeral habitats such as seagrass and low relief hardbottom. Collection of high resolution bathymetric data (LiDAR and side scan/multibeam) can improve accuracy of smaller habitat features, enable discrimination between low relief and high relief hardbottom, help resolve visually similar classes, and allow species-level identification (Walker et al 2014).

<u>Recommendations:</u>

- Updates are recommended for the following areas/habitats; Florida Bay, NOAA Keys and Marquesas.
- Expand the URM to include the following;
    - Dry Tortugas Eco Reserves
    - Offshore deeper water reefs using new acoustic technologies such as multi-beam or side-scan sonar (60 – 100ft deep)
    - Bays and estuaries north of Biscayne Bay, shoreward of the reef tract
    - Gaps between the URM coverage and intertidal or terrestrial maps. Filling these gaps will enable integration of the benthic URM with terrestrial maps to create a continuous "land-to-sea" map.
- Expand collection of high resolution bathymetric data (LiDAR and acoustic) throughout URM.
- Expand mapping of *Acropora* and other coral species of concern
- Additional field monitoring of areas where *Acropora* and other species of concern are expected. These habitats are difficult to map from aerial imagery and require additional field verification. Survey methods developed by Walker and others (2014) provide an ideal framework for mapping and monitoring these communities over time. Implementing a citizen science-based program may provide a cost effective solution to increasing collection of ground truth and accuracy assessment data.
- Improve integration of field data with benthic maps by cross-walking observations to the URM Unified Class scheme where possible.

Table 1. List of Florida Reef Tract mapping partners, v2016

Partner[1]	**Points of Contact**	**Areas mapped in the URM**
Biscayne Bay National Park	Andy Davis, andy_davis@nps.gov Amanda Bourque, Amanda_bourque@nps.gov Caryl Alarcon, caryl_alarcon@nps.gov	Biscayne Bay
Dry Tortugas National Park	Rob Warra, Rob_Waara@nps.gov	Dry Tortugas National Park
Everglades National Park	Matt Patterson, matt_patterson@nps.gov	Florida Bay (2016)
FWC Fish and Wildlife Research Institute (FWRI)	Renee Duffey (primary) Renee.Duffey@myfwc.com Richard Flamm, Richard.Flamm@myfwc.com Paul Carlson (seagrass mapping) Paul.Carlson@myfwc.com	Florida Bay (2004) Biscayne Bay (portions) Marquesas, Boca Grande Channel, Hawk's Channel Northern Keys/ Backcountry
NOAA-NCCOS Center for Coastal Monitoring and Assessment (CCMA)	Steve Rohmann, Steve.Rohman@noaa.gov Mark Monaco, mark.monaco@noaa.gov	Florida Keys National Marine Sanctuary (FKNMS)
Nova Southeastern University (NSU)	Brian Walker, walkerb@nova.edu	Martin County Palm Beach County Broward County Miami-Dade County
Martin County	Kathy Fitzpatrick, kfitzpat@martin.fl.us Jessica Garland, jmeinard@martin.fl.us	
Palm Beach County	Janet Phipps, jphipps@pbcgov.org	
Broward County	Ken Banks, kbanks@broward.org	
Miami-Dade County	Jamie Monty, montyj@miamidade.gov Josh Mahoney, mahonj@miamidade.gov Sara Thanner, ThannS@miamidade.gov	
FDEP Coastal Management Program (CMP)	Lauren Waters, lauren.waters@dep.state.fl.us Francisco Pagan, francisco.pagan@dep.state.fl.us	
Florida Keys National Marine Sanctuary (FKNMS)	No contact person designated	
South Florida Water Management District (SFWMD)	No contact person designated	

[1]Includes primary points of contact responsible for mapping or subcontracting map efforts, does not include managers or other map end users.

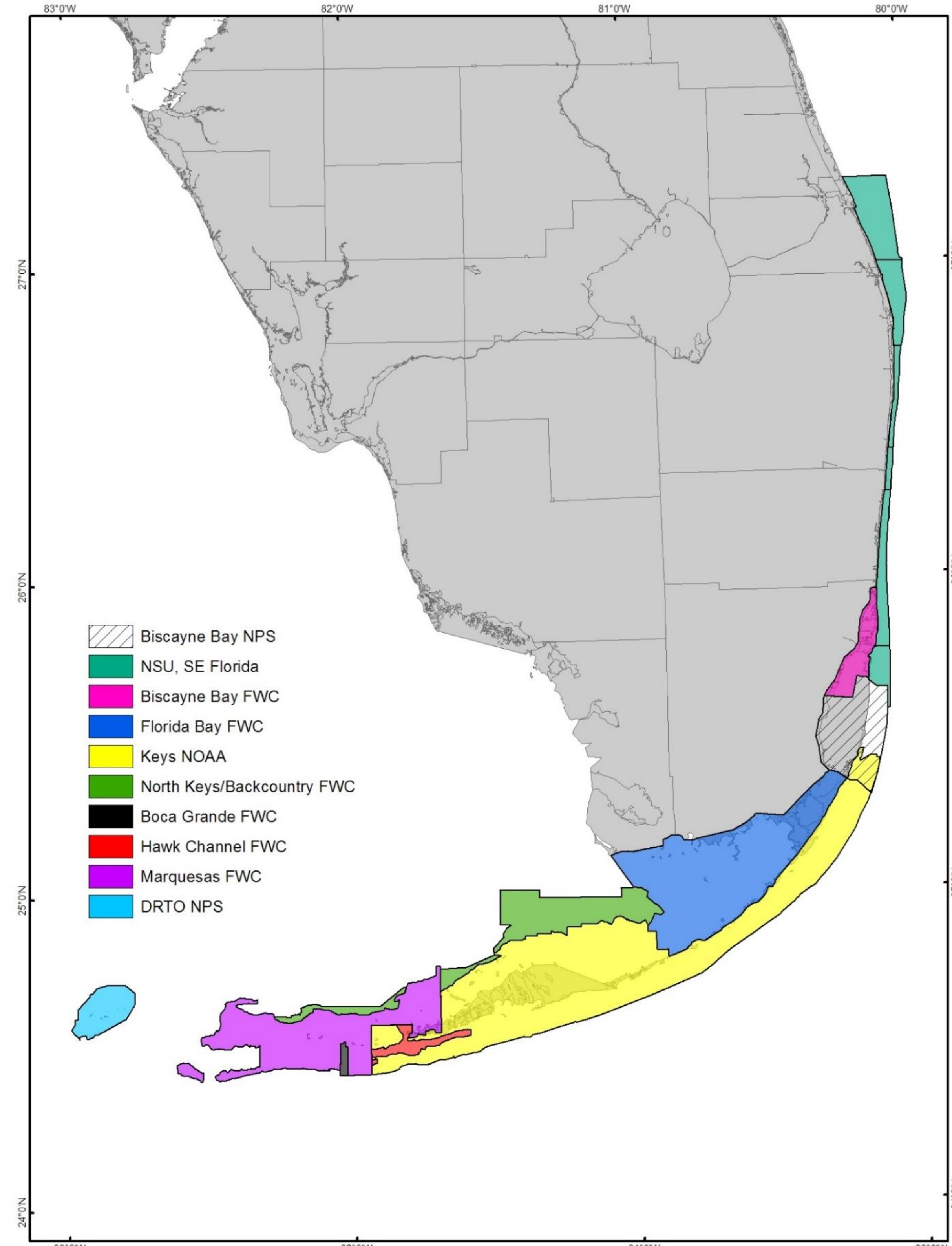

Figure 1. Unified Reef Map data sources and mapping partners.

Table 2. Metadata summary of Unified Reef Map (URM) mapping partners, v2016.

URM Name	Data Provider[1]	Minimum Mapping Unit	Mapping Scale	Source Imagery
Martin County	NSU	1 acre and smaller for patch reefs	1:6,000	LiDAR, 2008-2009 (4m)
Palm Beach County	NSU	1 acre and smaller for patch reefs	1:6,000	LiDAR, 2002 QTC Acoustic, 2006
Broward County	NSU	1 acre and smaller for patch reefs	1:6,000	LiDAR, 2002 QTC Acoustic, 2003-04
Miami-Dade County	NSU	1 acre and smaller for patch reefs	1:6,000	Aerial image, 2005 (1ft) LiDAR, 2002 (4m)
Southeast Florida (Key Biscayne to Hillsboro Inlet)	NSU	0.1 ha (~0.2 acre)	1:1,000	Aerial image, 2013 (1ft) LiDAR, 2008-2009 (4m)
Biscayne Bay (v2011)	NPS	~1 acre, all discernible patch reefs	ns	Aerial image, 2005 (30cm) LiDAR, 2008 (3m)
Florida Bay	FWRI	0.5 acre	1:24,000	Aerial image, 2004
Florida Keys & Backcountry	NOAA	~1 acre	1:6,000	IKONOS, 2006 (4m)
Marquesas	FWC	~1 acre and 0.154 acre for patch reefs	ns	IKONOS, 2006 (1-4m)
Dry Tortugas (v2010)	NPS	~1 acre and all discernible patch reefs	ns	NAIP, 2007 (1m) IKONOS, 2006 (4m) LiDAR, 2004 (1m) Side scan, 2008 (30cm)
Hawk Channel	FWC	1 acre & patch reefs 0.154 acre	ns	WV2, 2010-2013 (0.5m) Side scan, 2012-13 (30cm)
Boca Grande	FWC	1 acre and 0.154 acre for patch reefs	1:3,000	WV2, 2013 (0.5m) GE1, 2011 (1.8m) LiDAR, 2012 (3m) Side scan, 2012-13 (30cm)
North Keys/ Backcountry	FWC	1 acre	1:3,000	Aerial 2012-13 (0.5ft), WV2, 2010, 2013 (0.5m), GE1, 2011-2012 (1.8m), LiDAR, 2012 (3m)

[1]Subcontractors not listed.
***NSU:** Nova Southeastern University (NSU)*
***FWC:** Florida Fish & Wildlife Commission, Fish & Wildlife Research Institute*
***NPS:** National Park Service, South Florida/Caribbean Network (SFCN)*
***NOAA:** NOAA National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment (CCMA)*
***WV2** = WorldView-2 Satellite*
***GE1** = GeoEye-1 Satellite*
***ns** = not specified by data provider*

Table 3. Proposed changes to URM classification methods to be adopted in the Mapping Guide for Partners of the Florida Reef Tract.

Unified Class (UC)	**NOAA[1]**	**SCHEME[2]/ NSU[3]**	**Proposed**
Individual or Aggregated Patch Reef *UC Level 1*	Coral formations that are isolated from other coral reef formations by bare sand, seagrass, or other habitats and that have no organized structural axis relative to the contours of the shore or shelf edge. They are characterized by a roughly circular or oblong shape with a vertical relief of one meter or more in relation to the surrounding seafloor	Irregularly shaped reef communities. They may range in size from tens to thousands of square meters. Patches are separated from each other by uncolonized hardbottom, sand, or colonized substrate with SAV, macroalgae, gorgonians or sponges. Most often the patches are surrounded by a halo of bare substrate created by foraging, obligate reef inhabitants.	***Individual or Aggregated Patch Reef* class will be replaced by subclasses *Individual Patch Reef* and *Aggregated Patch Reef*.**
Individual Patch Reef **New class at UC Level 1, previously at UC Level 4*	Distinctive single patch reefs that are **larger than or equal to the MMU**	Isolated, **single reef (larger than the MMU)** without associated halo area. These individual reefs may have an associated halo, however **if large enough (>MMU)** to be delineated the halo will be mapped as its own subclass.	**Smaller (<1ha)** distinctive single coral formation that is isolated from other coral reef formations with a vertical relief of one meter or more. Most patches are often surrounded by a halo of bare substrate created by foraging, obligate reef inhabitants. **Larger, neighboring patch reefs close enough that halos coalesce should be classified as *Aggregated Patch Reefs*.**
Aggregated Patch Reef **New UC Level 1*	Clustered patch reefs that individually are **too small (<MMU) or are too close together to map separately**	Clustered patch reefs that individually are **too small (<MMU) or are too close together to map separately or where halos coalesce**	Clustered coral formations that are **too small or are too close together to map separately** **as *Individual Patch Reefs*.** Clustered patches are often surrounded by a halo of bare substrate created by foraging, obligate reef inhabitants. **Includes larger, individual patch reefs sharing a halo with 1 or more patch reefs.**
Aggregate Reef UC Level 1	Continuous, high-relief coral formation of variable shapes lacking sand channels of Spur and Groove. Includes linear reef formations that are oriented parallel to shore or the shelf edge. This class is used for such commonly referred to terms as linear reef, fore reef or fringing reef	Linear Reef (under Platform Reef): Linear, contiguous coral formations. Reef crest, fore reef, and back reef zones could be mapped as Linear Reef. Most often has associated spur and groove and reef rubble habitats.	Contiguous, high-relief **(>1m)** coral formation of variable shapes lacking sand channels of *Spur and Groove*. Includes linear reef formations that are oriented parallel to shore or the shelf edge. Reef crest, fore reef, and back reef zones could be mapped as Aggregate Reef. Also referred to as fringing **or bank** reef formations. **Reefs smaller than 1ha should be classified as patch reefs.**
Reef Rubble UC Level 1	Dead, unstable coral rubble often colonized with filamentous or other macroalgae. This habitat often occurs landward of well-developed reef formations in the reef crest, ridges and swales, or back reef zone.	*Rare occurrences of reef rubble in the SEFL mapping area are classified as Colonized Pavement.	Dead, unstable coral rubble often colonized with filamentous or other macroalgae. This habitat often occurs landward of well-developed reef formations in the reef crest, ridges and swales, or back reef zone.
Scattered Coral/Rock in Unconsolidated Sediment UC Level 1	Primarily sand bottom with scattered rocks or small, isolated coral heads that are too **small to be delineated individually (i.e., smaller than individual patch reef)**. If the density of small coral heads is greater than 10% of the entire polygon, this structure type is described as Aggregated Patch Reefs.	Areas of primarily sand, submerged aquatic vegetation (SAV), or low relief rock covered with a sand veneer. Often adjacent to spur and groove habitats, these areas contain small, individual corals or rocks that are distinctive yet a very low percentage of the total cover (**and certainly <MMU**).	Primarily sand bottom with **<10% of the area** consisting of scattered colonized rocks or small, live coral heads that are too small to be delineated individually.

Table 3, continued.

Unified Class (UC)	**NOAA[1]**	**SCHEME[2]/ NSU[3]**	**Proposed**
Pavement UC Level 1	Flat, low-relief, solid carbonate rock with coverage of macroalgae, hard coral, zoanthids, and other sessile invertebrates that are dense enough to begin to obscure the underlying surface. On less colonized Pavement features, rock may be covered by a thin sand veneer or turf algae.	Flat, low-relief, solid carbonate rock	Flat, low relief (**<1m**), solid carbonate rock often colonized by macroalgae, hard coral, zoanthids, and other sessile invertebrates. Contiguous underlying rock **can often be obscured by a sediment veneer supporting turf algae and seagrass. Pavement with greater than 10% seagrass cover should be mapped as *Pavement with Seagrass*.**
Pavement with Seagrass (Proposed)	GeoForm = Pavement BioCover = Seagrass % BioCover = >10% *UC Level 1 = Pavement*	Hardbottom & seagrass both present (>10%) AND: **Hardbottom is dominant = Pavement with SRV Modifier** Or, **Seagrass is dominant = Discontinuous Seagrass, Pavement may be noted depending on data provider**	Flat, solid carbonate rock with **greater than 10% seagrass** cover. Typically consists of intermittent seagrass patches occurring in areas where underlying pavement rock is covered by sediment. Exposed or semi-exposed hard-bottom is often colonized by sessile invertebrates including hard coral, zoanthids, and sponges.
Continuous Seagrass UC Level 1	GeoForm = Unconsolidated Sediment BioCover = Seagrass % BioCover = >90% *UC Level 1 = Continuous Seagrass*	**SCHEME:** This includes continuous beds of any shoot density (i.e. sparse continuous, dense continuous or any combination). These areas appear as continuous seagrass signatures; however, **small (< 0.5 acres)** bare sediment areas may be observed as infrequent features within the area. **NSU:** Seagrass community covering 90% or greater of the substrate. May include blowouts of less than 10% of the total area that are too small to be mapped independently (less than the MMU).	**Unconsolidated sediment colonized by** continuous seagrass covering 90% or greater of the substrate. May include patches of bare substrate covering less than 10% of the total area that are too small to be mapped independently.
Discontinuous Seagrass UC Level 1	GeoForm = Unconsolidated Sediment BioCover = Seagrass % BioCover = 10-90% *UC Level 1 = Discontinuous Seagrass*	**SCHEME:** Areas of SRV with breaks in coverage that result in isolated patches of SRV, usually in unconsolidated bottom but also exist in hard bottom areas. **If the hardbottom is more abundant than the SRV the polygon should be recorded as Reef/Hardbottom Class and SRV can be noted with Modifiers.** Generally, these grass features appear as semi-round patches or elongated strands separated by bare sediment. **NSU:** Seagrass community with breaks in coverage that are too diffuse, irregular, or result in isolated patches that are too small (smaller than the MMU) to be mapped as continuous seagrass.	**Unconsolidated sediment** colonized by intermittent seagrass **covering 10-90%** of the total area. Seagrass community with breaks in coverage that are too diffuse, irregular, or result in isolated patches **that are too small (smaller than the MMU)** to be mapped as continuous seagrass.

[1]Zitello et. Al 2009, [2]Madley et. al. 2002, [3]Walker et al 2014

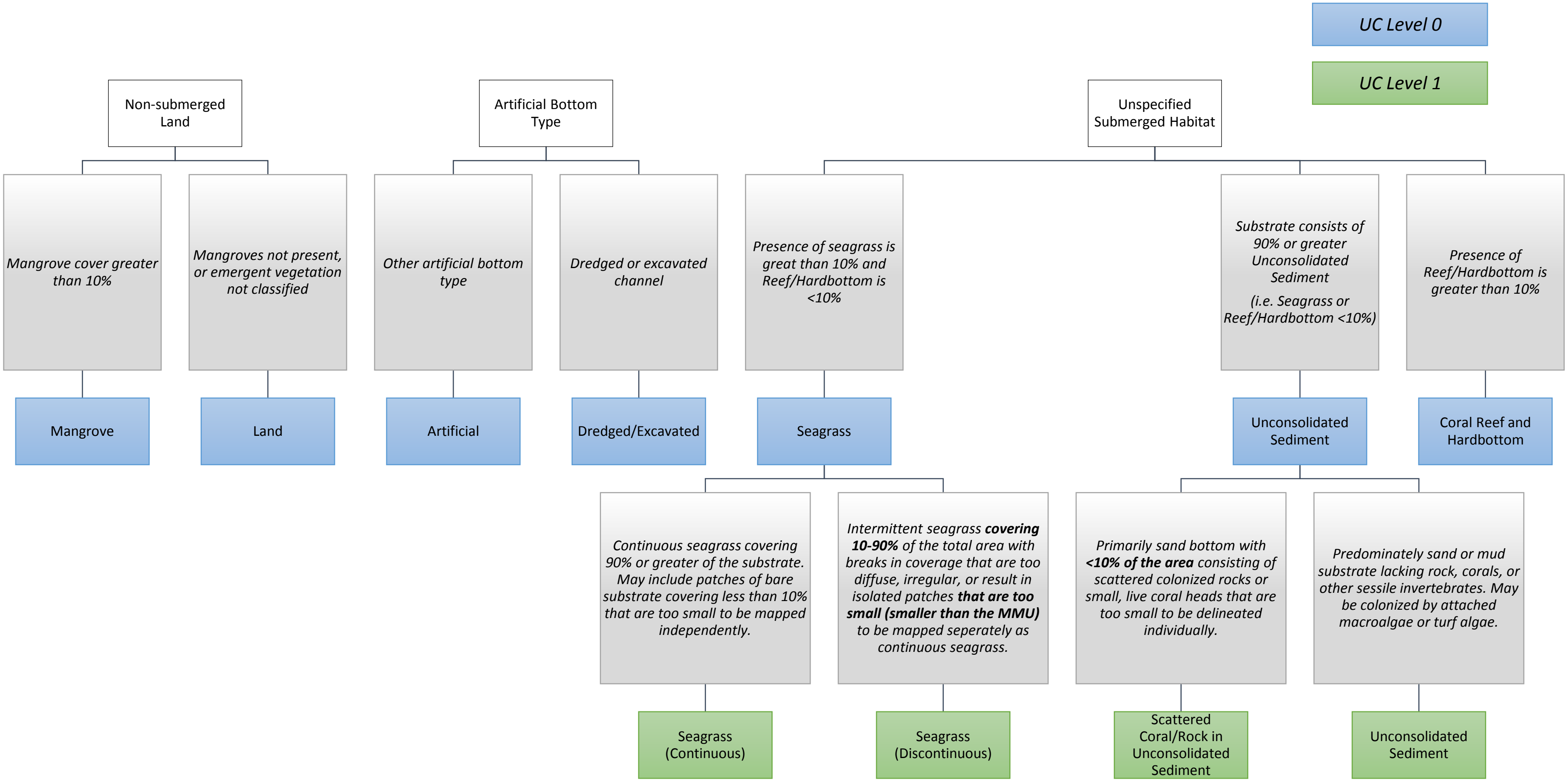

Figure 2. Recommended classification tree for mapping of the Florida Reef Tract. Figure indicates decision rules for UC Level 0 and Level 1 classes modified from NOAA (Zitello et. al 2009), SCHEME (Madley et. al. 2002), and NSU (Walker et al 2014) classification schemes. Coral Reef and Hardbottom continued in Figure 3.

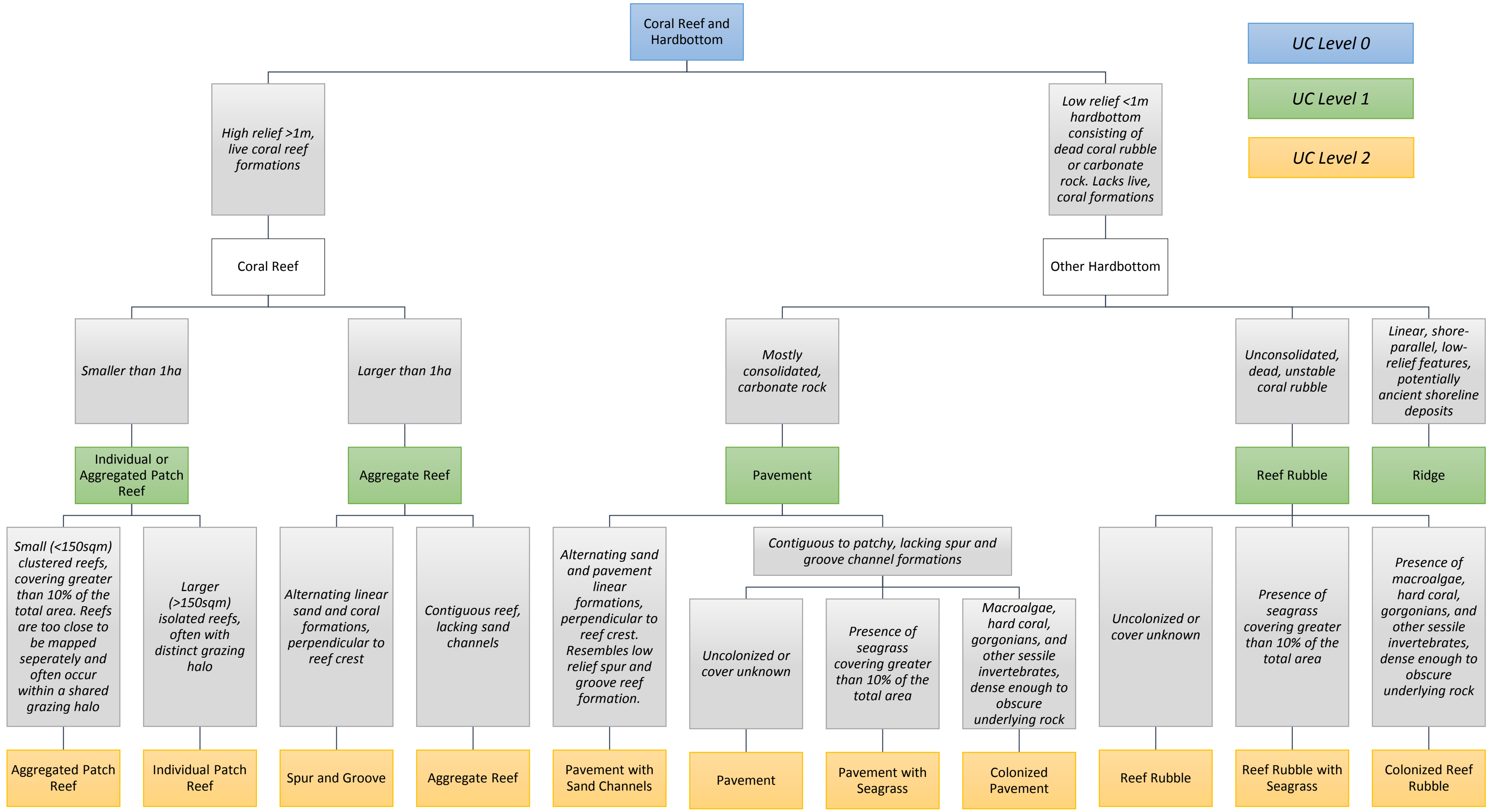

Figure 3. Recommended classification tree for mapping of the Florida Reef Tract. Figure indicates decision rules for UC Level 1 and Level 2 Coral Reef and Hardbottom classes modified from NOAA (Zitello et. al 2009), SCHEME (Madley et. al. 2002), and NSU (Walker et al 2014) classification schemes.

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