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Development of a System for Classification of Habitats in Estuarine and Marine Environments (SCHEME) for Florida

Report to U.S. EPA – Gulf of Mexico Program

From

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Florida Marine Research Institute

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Preface

The Gulf of Mexico Program (GOMP) and the Florida Marine Research Institute (FMRI) have been involved with research of marine and estuarine habitats throughout Florida and the entire Gulf of Mexico for many years. This experience has made apparent a need for a standardized method for classifying landscape scale marine and estuarine habitats. More than 15 benthic habitat classification systems have been used in Florida within the past 25 years and various other systems are in use throughout the other Gulf of Mexico states. Such a variety in classification systems makes comparison of mapping results and compilation of regional maps for statewide or Gulf wide reporting problematic. Evidence of the desire for a standardized, hierarchical classification system was gained from results of a 1998 workshop in which researchers and marine resource managers ranked creation of standard mapping protocols and a hierarchical classification system as the top two priorities (FMRI, Seagrass and Aquatic Habitat Workshop Summary 1998).

With GOMP funding support, FMRI has worked on reviewing classification systems used within Florida as well as throughout the world in attempt to recommend one system or create a hybrid system as a state of Florida standard. A draft hybrid system was formed and mailed to marine resource professionals for review in early June 2002. Background materials relaying the intent of the project were included with mailed invitations to attend a workshop in July 2002. Copies of the workshop materials have been included in the final report to the Gulf of Mexico Program.

Comments and recommendations provided during and after the July workshop were reviewed and researched. The System for Classification of Habitats in Estuarine and Marine Environments (SCHEME) has been improved as a result of the workshop and exists now as a more focused product. We consider SCHEME to be complete enough to be useable for the intended classification of marine and estuarine habitats of Florida, although this revised version of SCHEME will now be provided to the previous workshop participants as well as additional resource managers and mapping experts for a second review. In addition, as is the case with all classification systems, application of this system will certainly result in modifications and enhancements. As SCHEME is applied we should all, "… continuously question the classification system [we] are using. Look for flaws and weaknesses, and strengths, in the classification. Seek out [items] which do not easily fit into it, and ask, 'Why?', and, 'How could the classification be improved?' A classification is not only an end that we work for, it is also a beginning - a beginning of testing to find out if the classification in fact works in the real world (From http://csmres.jmu.edu/geollab/Fichter/SedRx/Classtheory.html). "

Introduction

Florida's expanding population, especially along the coastline, has increased the threats of water quality degradation, habitat loss, and direct harmful encounters with marine and estuarine plants and animals. An ecosystem approach to conservation has often been used in terrestrial systems, however, this has been less true for marine and estuarine ecosystems (Allee et al.2000). As the ecosystem evaluation of Florida coastal waters has gained interest and necessity, the need for a common language for inventorying marine and estuarine habitats has become evident.

In Florida, habitat mapping and inventorying is performed through a variety of government agencies at state, federal, and local levels as well as private industry. The methods employed are varied and at times used in conjunction. Interpretation of aerial photography is the most common method of regional scale habitat inventorying in near shore waters, although underwater videography, snorkel/SCUBA dive observations, and single beam acoustic sensors are also common methods. More recently hyperspectral imaging and LIDAR (Light Detection and Ranging) have gained more research attention and seem to be promising tools in benthic habitat interpretation. With thought toward the array of mapping agencies and variety of research tools the following objective and guiding principles were deemed appropriate. These were created or gathered from the variety of classifications systems discussed throughout this report.

Objective

Form a standardized system for classification of marine and estuarine benthic habitats of Florida. The intent is to create a system that will provide common language for description and consistent inventory and reporting of Florida's estuarine and marine benthic habitats.

Guiding Principles (in no certain order):

- The classification should be applicable for all marine and estuarine waters surrounding Florida. The intended geographic scope of this draft stretches from the extreme high tide line of influence out through the seaward edge of the continental shelf.

- Intent will be to create objective definitions of all habitat categories.

- Application of the classification should be repeatable and consistent.

- The classification scheme will be hierarchical in design so that habitat classifications can be performed at a variety of scales and levels of detail, yet still be comparable to all other classifications determined with this scheme.

- The hierarchical design of the classification will make the system dynamic, thus capable of future category additions.

- The classification system will be intended for use with classical mapping techniques as well as techniques in development. Newer technologies will be considered while forming this system in attempt to accommodate data produced from these technologies and proposed technologies of the near future.

- The classification categories should be mutually exclusive and encompassing of all landscape level benthic habitats of Florida.

- The classification is intended to describe habitats existing at the time of examination; no consideration of potential future or past habitat types is accommodated by this scheme.

- Development of the classification scheme will include consideration of previous and current classification schemes used throughout Florida. Attempts should be made to crosswalk with all other classification schemes used for habitats of Florida's coastal waters.

- Attempts should be made to compare and contrast similar terminology of previous classifications to aid users with classification crosswalks.

- The classification scheme should be created with intent to fit within the national effort to form a national marine and estuarine classification system.

- The classification will be cooperatively developed through invitation of the widest range of individuals and institutions known to have stake and expertise in Florida habitat classifications.

Review of Classification Systems

The initial stage of this project involved gathering existing classification systems for review. More than forty classification systems were reviewed with the intent to find one that would meet the aforementioned project goals or provide components from several that would be used for forming a hybrid system. No systems were found that provided means to classify all of Florida's benthic habitats while also allowing for the level of detail needed for managing these resources. Brief reviews of relevant classification systems used throughout the United States or Florida are presented here.

<u>Anderson et al. (1976), US Geological Survey</u> -- Land use and land cover classification system that has been widely used within the United States, however, the system was not designed for, nor capable of mapping benthic habitats. Estuarine areas are mapped at the general level of "Bays and Estuaries" only to the extent of "inlets or arms of the sea that extend inland". Categories for marine waters do not exist.

<u>Cowardin et al. (1979), US Fish and Wildlife Service</u> -- The first national classification system to incorporate major marine habitats (Allee et al. 2000). While this system does not provide for mapping all the habitat components necessary for resource management in Florida it is a good framework for hierarchical levels and classification organization. SCHEME Classes are roughly similar to the Cowardin et al. Classes; however, the Subclass level and Modifier lists have been expanded significantly more in SCHEME.

<u>Dobson et al. (1995), National Oceanic and Atmospheric Administration Coastal Change Analysis Program (C-CAP)</u> -- The C-CAP classification does not provided for mapping at levels of detail past broad reef and submersed aquatic vegetation levels. SCHEME has expanded the levels beyond those available with the C-CAP system, yet has provided for categories of the two systems to crosswalk.

Allee et al. (2000), National Oceanic and Atmospheric Administration -- The thirteen level structure (Table 1) provided in Allee et al. (2000) report seems to be the framework supporting the ongoing effort to develop a national standard for marine and estuarine ecosystem classification. The Allee et al. system allows for mapping at geographic extents greater than the whole of Florida, such as temperate or polar zones. SCHEME was developed to fit into Levels 11-13 of the thirteen level Allee et al. system. The intention is to be able to easily crosswalk SCHEME categories with those provided in the final national marine and estuarine ecosystem classification system. Creating SCHEME to nest inside the thirteen level structure of Allee et al. (2000) allows the system to be used on regional/local levels for landscape scale mapping while providing the pathway to easily incorporate their data into the national inventory framework.

Florida Department of Transportation (1985) -- The Florida Land Use, Cover and Forms Classification System (FLUCCS) is widely used in Florida. Many of the aquatic vegetation mapping programs use the FLUCCS system to classify seagrasses. The system does not include all the benthic habitats of Florida or expand to levels of detail desired even for the few included categories such as submersed aquatic vegetation.

Florida Natural Areas Inventory (FNAI) (1990) -- The community descriptions are well described and the document serves as a good source of information regarding common plant and animal associations in each habitat. Categories are slightly rearranged for SCHEME and additional Subclasses have been added to make it a more robust classification. Rearrangement of the categories structure resulted in 7 Classes and 18 Subclass 1 categories as opposed to the analogous 12 Natural Communities and 12 unnamed category divisions within the Natural Communities of the FNAI system.

Classification Development and Design

General Overview

The levels assigned to SCHEME are as follows:

X Class
  XX Subclass 1
    XXX Subclass 2
      XXXX Subclass 3
        XXXXX Subclass 4

The Class categories are similar to the Cowardin et al. (1979) Classes by design to allow for crosswalk and comparisons between the two systems. As in the Cowardin et al. system the Classes describe the general dominant life forms or the physiography and composition of the substrate. The Classes are capable of being applied without detailed field measurements. Subclasses define habitats with finer resolution descriptions or with geographic extents that require field measurements for verification.

Some Subclasses are of interest to researchers and managers but are not feasible to map at the landscape scale. For instance, SCHEME includes the ability to map grain size characteristics that are not determined at the landscape scale. This is an example of our attempt to expand the usefulness of SCHEME to address needs of various resource managers and researchers. Although a few of these finer resolution habitat mapping units are accounted for in this early version of SCHEME, it is expected that most additions and alterations will be needed at the fine resolution units (i.e. Subclasses and Modifiers), not at the Class level. Further review and use will promote possible addition of other habitat characteristics.

Tides and Salinity

Many marine/estuarine classification schemas use tidal characteristics and salinity values to define categories. For example, the Cowardin et al. schema has Subsystem categories of Subtidal and Intertidal. This has the disadvantage of forcing users to describe the tidal characteristics of all habitats delineated even though the scope of the research project may only encompass a short time period (i.e. month or less) and is absent of salinity measurements. Building tidal characteristics and salinity values into Class or Subclass definitions would exclude some projects from classifying data with SCHEME or force data collection of these variables into research projects. SCHEME has avenues to include salinity and tidal information through General Modifiers.

Scale Issues

For landscape level benthic mapping, photographic scale normally ranges from 1:12,000 to 1:48,000 (Finkbeiner et al. 2001). A 1:12,000 scale may be necessary in areas of low water clarity. It is possible that chronic turbidity or water color issues may prevent acquisition of useful aerial photographs in some regions regardless of scale. Conversely, 1:48,000 scale photography is a viable alternative for relatively clear water areas such as the Florida Keys.

For coral habitat mapping of high-priority areas, 1:12,000 to 1:48,000 scale aerial photography is recommended for high resolution maps required by state agencies. These scales will allow delineation of features less than or equal to 5 meters in size (U.S. Coral Reef Task Force, Mapping and Information Synthesis Working Group 1999).

Most programs currently conducting routine SAV mapping in Florida are using 1:24,000 scale photography. The appropriate scale for a particular project will be a compromise between issues of the water quality conditions, geographic extent of the study area, the level of habitat delineation desired, and the budget available to support project completion.

A 0.03 ha (0.5 acre) minimum mapping unit is recommended for 1:24,000 scale photography (Finkbeiner et al. 2001). It should be noted that data collected by techniques other than aerial photography are not constrained to the same minimum mapping units. For instance, sediment grain size data collected from discreet point locations much smaller in size than 0.5 acres may still be classified with SCHEME. Also, some of the Subclass categories and most of the Modifiers can't be classified with the use of aerial photography alone. Observer measurements or observations in the field will be necessary to justify use of many of the Subclasses and Modifiers. In addition to in situ observations, pre-existing data, such as artificial reef locations or habitat restoration locations could be classified with SCHEME and utilized as ancillary data or added to a map of newly acquired data with a GIS.

Classification System

A hierarchical structure with five levels and two lists of modifiers were developed. The hierarchical nature allows the classification to be applied at appropriate levels depending on the level of detail of the data (Vegetation Classification Panel of the Ecological Society of America 2000). The modifiers allow detailed information to be included at all levels of the structure.

The flow chart shown in Figure 1 illustrates the SCHEME protocol for classifying Unconsolidated Sediments, Submersed Aquatic Vegetation, and Coral/Hardbottom habitats when more than one type may be present. Examples of SCHEME application are provided in the following sections along with information specific to each Class listed.

Unconsolidated Sediments

The categories for Unconsolidated Sediments were modeled after the commonly used Wentworth size classes (Locker 1999). Particle size fractionation classification is desirable for research related to benthic infauna, sediment movement, and artificial reef placement. These category distinctions are most accurately made with sieve tests although Subclasses (i.e. mud versus sand versus pebble) distinctions are commonly estimated with observer sight and touch during field visits.

Example 1: A code of 1 would indicate an area of unconsolidated sediments of unknown composition or origin.

Example 2: A code of 122-Z2 would be used to represent an intertidal bank of fine sand with 50% or more of the particulates sieving out to 0.125-.25mm.

Example 3: A code of 122-X(3-5) would be used to indicate an area of fine sand with 50% or more of the particulates sieving out to 0.125-.25mm and a sediment depth range of 3-5m.

Submersed Aquatic Vegetation (SAV)

SAV is monitored as a biological indicator for Florida coastal waters as well as elsewhere in the world. Seagrass biomass often decreases as a result of decreases in water quality. Alternatively, abundance of certain macroalgal species increase in response to increased nutrient pollution. Thus, being able to detect changes in SAV biomass or abundance is important to coastal managers. Continuous seagrass beds that are changing to discontinuous beds through time may indicate a detioration of water quality. On the other hand, occurrences of discontinuous seagrass in areas where it was absent could indicate an increase in water quality allowing for seagrass colonization (Finkbeiner et al. 2001).

As seen in Table 1, a variety of mapping programs classify SAV according to percent cover categories. The percent cover categories vary widely between these programs, with the range from two to six SAV categories. The category ranges are not based on ecological function or value but assigned arbitrarily with the goal of attaining finer resolution in the data to interpret the increase or decrease of SAV percent cover. In some cases the ranges are set after accuracy assessments involving randomized field verification checkpoints indicate ranges that are delineated with high accuracy and ranges that produce errors in percentages too high for reliable reporting. The legitimacy, repeatability, and accuracy of photographic interpretation associated with all percent cover ranges will vary with water quality conditions, species compositions, epiphyte cover, tidal stage, aspect of the seagrass blades, and brightness of substrate. The South Florida Water Management District's Surface Water Improvement and Management Program and the United States Geological Survey's Biological Resources Division each tested SAV classification systems with five categories of percent cover. After separate analyses they reported that the five categories were not interpreted with acceptable accuracy and reducing the number of categories to two or three increased the accuracy (D. Tomasko and L. Handley, personal communications). While interpretation of seagrass densities has been performed with inconsistent results, morphological classification (i.e. continuous versus patchy) of seagrass habitats has been possible (Handley 1992).

Figure 1. SCHEME Decision Support Key for SAV, Reef/Hardbottoms, and Unconsolidated Sediments Classes.

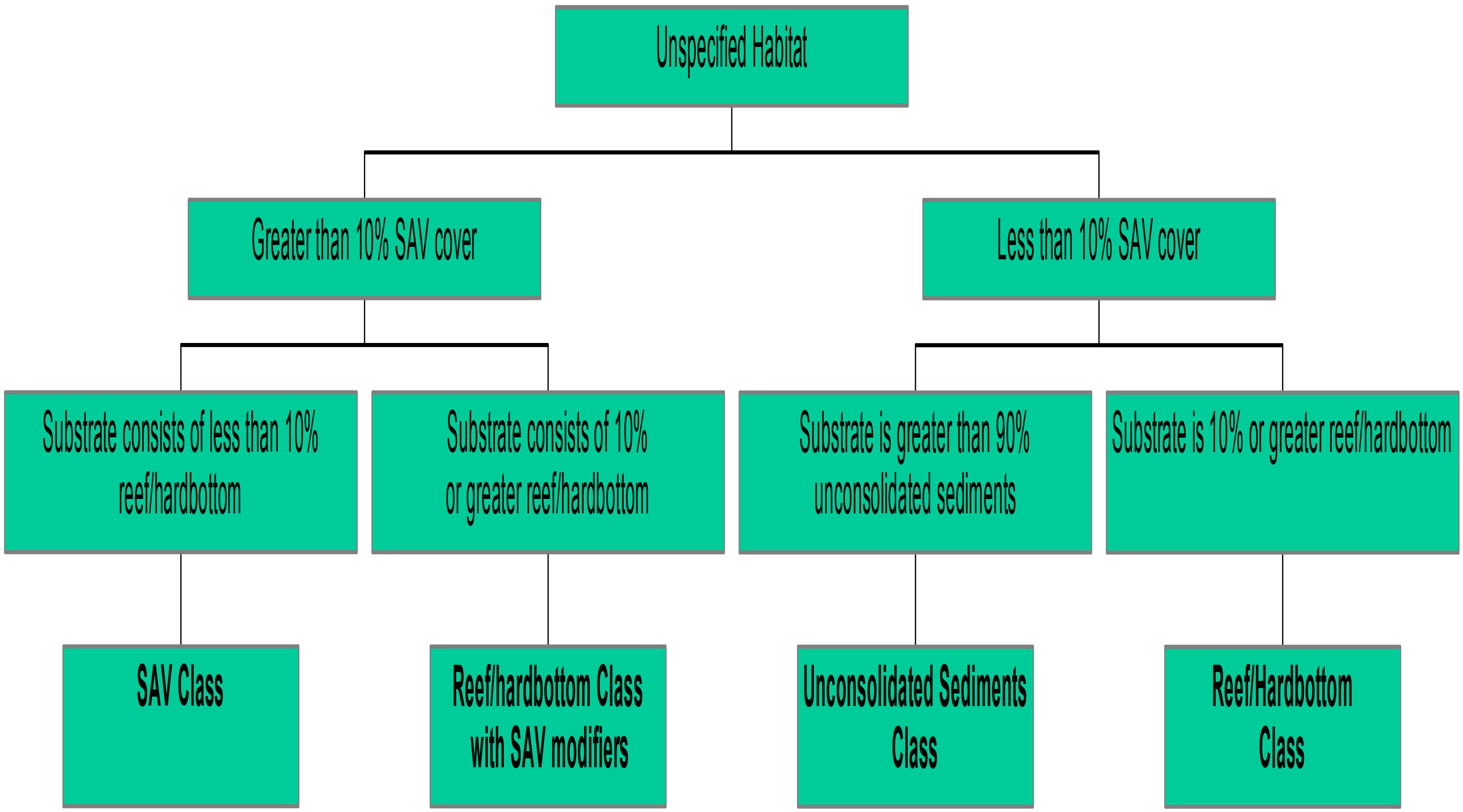

Table 1. This is a partial presentation of seagrass classification systems to illustrate the variation of categories. Some of the agencies listed have previously employed more than one classification. *Note that the percent cover value listed in the SWFWMD column are not actually a part of the formal category descriptions but are commonly used by the District and contractors to assess seagrass.

	1	2	3	4	5	6	7	8	9
	SJRWMD	**SWFWMD**	**SFWMD**	**FMRI/NOAA Florida Keys**	**USGS-BRD**	**CSA, Inc. and MMS**	**Palm Beach Co.**	**Chesapeake Bay**	**NOAA Puerto Rico and USVI**
	>10 - 50%		>10 - 85%	> 50% - 90% in sand/mud	1-10%	0-10%	less than 10%	Very sparse <10% coverage	>10 - < 30%
				> 50% in hardbottom	15-40%	10-70%	11-40%	sparse 10-40%	>30 - < 50%
				< 50% in sand/mud	45-70%		41-70%	moderate 40-70%	>50 - < 70%
				< 50% in hardbottom	75-85%				>70 - < 90%
Contin-uous seagrass	>50%	> 75%*	> 85%	> 90% Moderate-Dense	> 90%	>70%	greater than 70%	dense 70-100%	>90%
				>90% Sparse (Dense patches in continuous sparse seagrass)					
PHOTO SCALE	1:24,000	1:24,000	1:24,000	1:48,000	1:24,000			1:24,000 (B and W)	1:20,1:28 and 1:48k
MIN. MAP UNIT(acres)	0.25	0.5	0.25	1	1		0.25	?	1

In order for the statewide classification system to crosswalk with each of the pre-existing programs, SCHEME has been simplified to two SAV categories absent of any density interpretation limitations. In this fashion, data created with the variety of classification systems previously in use will be capable of classification with SCHEME, thus enabling comparison between programs and regions. However it must be realized that direct comparisons of SAV trends between data from mapping programs will contain error because of the variations in definitions of continuous and patchy categories employed by the various mapping entities. New mapping programs will be able to use SCHEME SAV classifications resulting in estimates of continuous and discontinuous seagrass areas. Leaders of new mapping project should consult Finkbeiner et al. 2001, Handley 1992, and Dobson et al. 1995 for guidelines in SAV mapping.

In order to classify Unconsolidated Sediments and SAV with one classification system a lower limit for SAV classification had to be set. Dobson et al. (1995) stated,

> "If vegetation (except pioneer species) covers 30% of the substrate, classes are distinguished on the basis of the life form of the plants that constitute the uppermost layer of vegetation and that occupy an area coverage 50% of vegetative cover."

For SCHEME the following version has been adopted,

> "If vegetation covers 10% of the substrate, Subclasses are distinguished on the basis of the life form of the plants that constitute the uppermost layer of vegetation and that occupy an areal coverage 50% of vegetative cover. Taxonomic modifiers will be listed in order of decreasing percent cover."

The lower limit of 10% cover of the substrate has been chosen for SCHEME because, 1) the majority of mapping programs in Florida already employ that minimum limit (Table 1), and 2) it minimizes the instances when sparse SAV would be classified as Unconsolidated Sediments, thus creating underestimates of SAV habitat.

SCHEME provides mechanisms for labeling SAV from the very broad Class level "Submersed Aquatic Vegetation" through the level of species identification. Species identification is not possible from 1:24,000 scale aerial photography except in rare instances when monospecific stands of turtle grass can be interpreted because of a darker signature (Handley 1992). FMRI and other groups are currently researching the possibility to detect SAV species and hardbottom community types with hyperspectral imagery. Species information will be designated with taxonomic modifiers as described in this document only when field verification has taken place. Following the SCHEME Decision Support Key (Figure 1), SAV noted in coral or hardbottom habitats should be noted with a seagrass modifier (i.e. H in the General Modifier list). Using the codes on the Classification Key, a few examples are provided below for clarification.

Example 1: A code of 2 would be used to represent an SAV habitat when more detailed knowledge is unknown. This code would indicate that SAV was present but no information as to the mix of macroalgae and seagrass is present and species are unresolved.

Example 2: A code of 212-Hwri,Sfil would be used to indicate a polygon of discontinuous (i.e. patchy) seagrass containing a known greater percentage of shoal grass, Halodule wrightii, and a lesser percentage of manatee grass, Syringodium filiforme.

Example 3: A code of 341-I would be used to indicate an area of bedrock habitat with a percent cover of greater than 10% seagrass.

Although, providing a method for indicating seagrass at the Subclass levels along with General and Taxonomic modifiers adds complexity to the classification system this seems necessary to create opportunities to classify complex habitats with mixed geological and biological components. The Decision Support Key (Figure 1) is provided to aid users in consistently classifying the SAV and Coral/Hardbottom Classes.

Corals and Hardbottom

The corals and hardbottom categories were developed to crosswalk with the classification system used for the Benthic Habitats of the Florida Keys (1998) product created by NOAA and FMRI. This has been the only regional landscape classification in Florida to include coral and hardbottom dominated habitats and has been recommended to serve as a prototype for desired research and management of coral reef ecosystems (U.S. Coral Reef Task Force, Mapping and Information Synthesis Working Group 1999). In addition, various classifications (Coyne et al. 2001, Holthus and Maragos 1995, Kendall et al. 2002, Mumby et al. 1998, Mumby and Harborne 1999) and characterizations (Ault et al. 2002, FNAI 1990, Jaap 1984, Jaap and Hallock 1991) of tropical and subtropical coral habitats were reviewed and influenced SCHEME design.

Using the codes on the SCHEME Classification Key, a few examples are provided below for clarification.

Example 1: A code of 31 would represent a coral reef without further definition of structure or species presence.

Example 2: A code of 311-Ovar would be used to indicate a platform reef feature with *Oculina varicosa* as the dominant coral species.

Example 3: A code of 31122-Acer,AGAR would represent a low relief spur and groove area dominated by Acropora cervicornis also containing noticeable fire coral, Agaricia spp. Because the species is not identified, the first four letters of the Genus are listed in all capitals to distinguish the code from a Genus species abbreviation, such as used for the Acropora cervicornis in this example.

Tidal Marsh and Tidal Swamp

These Classes will likely be used in conjunction with Taxonomic Modifiers. Florida marshes are often delineated according to the dominant indicator species, either black needlerush or smooth cordgrass.

Example 1: A code of 4-Salt would represent a tidal marsh dominated by *Spartina alterniflora.*

Discussion

"Systems of classification are not hatracks, objectively presented to us by nature. They are dynamic theories developed to express particular views..." Stephen Jay Gould (From http://csmres.jmu.edu/geollab/Fichter/SedRx/Classtheory.html)

In the current format SCHEME is complete enough to be employed with habitat classification projects. As SCHEME is used weaknesses will be exposed and modifications can be devised. SCHEME has already been tested by NOAA Coastal Services Staff in the Dry Tortugas, Florida and they are intending to use a form of it for a mapping project in Long Island, New York. The Florida Marine Research Institute has initiated efforts to engage SCHEME for two habitat delineation projects in Broward County, Florida and the Florida Keys. Results of these uses will need to be assessed and modifications to SCHEME may result.

Although thought toward cartography and database design elements have been considered, issues such as how the coding system, which can be bulky if the level of mapping is detailed, will aid or hinder habitat maps will best be examined through utilization. Database design and GIS issues regarding the category coding (i.e. numbering systems and modifier codes) of SCHEME will become evident with application. Creation of a database and digital forms and spreadsheets will be prepared and tested through project application. The resulting forms could then be shared with interested agencies to aid standardization.

Because many agencies are actively mapping benthic habitats for various reasons, habitat data will continue to be collected with differing specifications and protocols. Metadata records need to be consistently recorded and made accessible for purposes of comparing reports, products and raw data. Further evolution of SCHEME should include development of standards and protocols for the common techniques of data collection. Complete specifications of aerial photography collection, processing, and analysis should be recommended, such as in the previously mentioned Dobson et al. (1995) and Finkbeiner et al. (2001) documents. The specifications explained in these documents could be enhanced with description of regional recommendations for Florida. We are monitoring activities of the U.S. Coral Reef Task Force as they synthesize coral habitat mapping plans and recommend protocols and procedures for data collection with newer technologies leading to coral habitat maps of the United States.

SCHEME will be shared with interested agencies for purposes of review, use and enhancement. Comments or inquiries should be addressed to Kevin Madley, (727) 896-8626, kevin.madley@fwc.state.fl.us.

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Appendix 1. Proposed national marine and estuarine ecosystem classification system as outlined in Allee et al. (2000).

1. Life Zone –
    - 1a. Temperate
    - 1b. Tropical
    - 1c. Polar

2. Water/Land
    - 2a. Terrestrial
    - 2b. Water

3. Marine/Freshwater
    - 3a. Marine/Estuarine
    - 3b. Freshwater

4. Continental/Non-Continental
    - 4a. Continental
    - 4b. Non-Continental

5. Bottom/Water Column
    - 5a. Bottom (Benthic)
    - 5b. Water Column

6. Shelf, Slope, Abyssal
    - 6a. Shallow – on or over the continental shelf; <200m
    - 6b. Medium – on or over the continental slope; 200 - 1000m
    - 6c. Deep – on or over the rise and deeper features; >1000m

7. Regional Wave/Wind Energy
    - 7a. Exposed/Open – open to full oceanic wave or wind energies
    - 7b. Protected/Bounded – protected from full wave or wind energies

8. Hydrogeomorphic or Earthform Features
    - 8a. Continental - Nearshore (surfzone); Inshore (rest of shelf); Straight or partially enclosed shorelines; Lagoons; Fjords; Embayments; Estuaries - Shore zone; Off shore zone; Delta; Carbonate settings; Outer continental shelf; Upper continental slope; Upper submarine canyon
    - 8b. Non-Continental - Island (Volcanic; Low); Atoll; Submerged reef types

9. Hydrodynamic Features
    - 9a. Supratidal – above high tides
    - 9b. Intertidal – extreme high to extreme low water
    - 9c. Subtidal – below extreme low water

Appendix 1 (continued). Proposed national marine and estuarine ecosystem classification system as outlined in Allee et al. (2000).

9. Hydrodynamic Features (Continued)
    - 9d. Circulation features – e.g., eddies

10. Photic/Aphotic
    - 10a. Photic
    - 10b. Aphotic

11. Geomorphic Types or Topography - Cliff; Bench; Flat; Reef flat; Spur-and-Groove; Sand bar; Crevice; Slump; Rockfall; Terrace; Ledge; Overhang; Steeply sloping; Riverine; Fringe; Inland; Beach face; Dunes

12. Substratum and Eco-type
    - 12a. Substratum (Not limited to this list) - Cobble; Pebble; Sand; Silt; Mud; Bedrock; Peat; Carbonate; Boulder; Biogenic; Organic; Anthropogenic
    - 12b. Eco-type (Not limited to this list) - Coastal; Soft bottom; Hard bottom; Water column; Beach; Mangrove; Wetland; Seagrass bed; Coral reef; Kelp bed; Mud flat

13. Local Modifiers and Eco-unit
    - 13a. Modifiers (Not limited to this list) - Temperature; Local energy regimes – waves, tides, current; Salinity; Nutrients; Alkalinity; Roughness/relief; Dynamism; Edge effects – from adjacent areas; Anthropogenic disturbances; Biological interactions; Extreme events – history
    - 13b. Eco-units - Unlimited representation of species resulting from modifiers applied at the above hierarchical levels.

Appendix 2. Florida System for Classification of Habitats in Estuarine and Marine Environments (SCHEME) key.

Classification categories are structured as follows:

X Class
  XX Subclass 1
    XXX Subclass 2
      XXXX Subclass 3
        XXXXX Subclass 4

Habitats:

1. Unconsolidated Sediments (zero to less than 10 percent colonization)
Unconsolidated sediments with less than 10 percent colonization by SAV or corals.

11. **Mud (i.e. silts and clays) [<0.0625mm grain sizes comprise greater than 50% of sediment]**
Sediments most often found in depositional environments that are protected from wind and wave energy.

12. Sand [0.0625-2mm grain sizes comprise greater than 50% of sediment]
Sediments usually found in areas exposed to wind and wave energy that causes silts and clays to be removed.

121. Very fine sand [0.0625-0.125mm grain sizes comprise greater than 50% of sediment]

122. Fine sand [0.125-.25mm grain sizes comprise greater than 50% of sediment]

123. Medium sand [0.25-.5mm grain sizes comprise greater than 50% of sediment]

124. Coarse sand [0.5-1mm grain sizes comprise greater than 50% of sediment]

125. Very coarse sand [1-2mm grain sizes comprise greater than 50% of sediment]

13. Mixed Fine
Mixture of sand and mud, possibly with sparse grains of larger size categories such as granules or pebbles (no one substrate type presence is greater than 50%)

14. Mixed Coarse
Granules, pebbles, cobbles are the possible components that comprise over 50% of the sediment (no one substrate type presence is greater than 50%)

141. **Shell hash** – substrate covered with a mixture of shell material from granules (2-4mm grain sizes) to whole shells.

15. Granule [2-4mm grain sizes comprise greater than 50% of sediment]

16. Pebble [4-64mm grain sizes comprise greater than 50% of sediment]

17. Cobble [64-256mm grain sizes comprise greater than 50% of sediment]
Note: Rocks larger than 256mm (=10 in) in diameter are classified as bedrock in the consolidated bottom category.

18. Detrital floor
Detrital material (e.g. seagrass, algae, leaf litter, etc.) that builds up in intertidal and shallow waters, often along windward shorelines. This semi-permanent feature creates an organic mud buildup under the newly deposited detrital material. More permanent feature than the Drift Wrack general modifier.

2. Submersed Aquatic Vegetation (SAV)
Any combination of SAV (i.e. seagrasses, oligohaline grasses, attached macroalgae and drift macroalgae) that covers 10 to 100 percent of a substrate. If reef or hardbottom is more abundant than the SRV the polygon should be recorded as Reef/Hardbottom Class and SRV should be noted with Modifiers.

21. Submersed Rooted Vascular Plants (SRV) (i.e. seagrasses and oligohaline grasses)
Habitat with 10 percent or more cover of SRV.

211. Continuous SRV
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 (less than 0.5 acres) bare sediment areas may be observed as infrequent features within the area.

2111. Dense patches of SRV in a matrix of continuous, sparse SRV
Continuous coverage of sparse SRV in which dense patches of SRV are clearly observed interspersed within the area. This pattern is often the result of effects from the sediment or underlying bedrock characteristics.

212. Discontinuous SRV
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.

22. Macroalgae

221. Attached Macroalgae

Habitat with 10 percent or more cover of mixed or monospecific macroalgae attached to the substrate with holdfasts, rhizomes, or other morphological feature.

2211. Continuous attached macroalgae

This includes continuous beds of any density (i.e. sparse continuous, dense continuous or any combination). These areas appear as continuous attached macroalgae or SRV signatures. Often macroalgae can't be interpreted from the imagery without field verification to detect the difference from SRV. Small (less than 0.5 acres) bare sediment areas may be observed as infrequent features within the area.

22111. **Dense patches of attached macroalgae in a matrix of continuous, sparse macroalgae**

Continuous coverage of sparse attached macroalgae in which dense patches of attached macroalgae are clearly observed interspersed within the area. This pattern is often the result of effects from the sediment or underlying bedrock characteristics.

2212. Discontinuous attached macroalgae

Areas of attached macroalgae with breaks in coverage that result in isolated patches, usually in unconsolidated bottom but also exist in hard bottom areas.

222. Drift Macroalgae

Habitat with 10 percent or more cover of mixed or monospecific macroalgae that is not attached to the substrate. Drift algae may move constantly with wind or wave forces or may be observed in one location for long periods of times (possibly months) because of lack of energy forces or due to becoming entangled on substrate features.

2221. Continuous drift macroalgae

This includes continuous beds of any density (i.e. sparse continuous, dense continuous or any combination). These areas appear as continuous attached macroalgae or SRV signatures. Often macroalgae can't be interpreted from the imagery without field verification to detect the difference from SRV. Small (less than 0.5 acres) bare sediment areas may be observed as infrequent features within the area.

2222. Discontinuous drift macroalgae

Areas of attached macroalgae with breaks in coverage that result in isolated patches, usually in unconsolidated bottom but also exist in hard bottom areas.

3. Reef/Hardbottom

Hardened substrate of unspecified relief formed by the deposition of calcium carbonate by reef building corals and other organisms or exposed bedrock, possibly with various degrees of concealment from attached plant and animal colonization. Unconsolidated bottom and SAV may occur within these habitats, although in less abundance than the reef/hardbottom.

31. Coral Reef

Hardened substrate formed by reef building corals. May be live coral or relict reefs. Often bedrock is the base for these reefs but the presence of coral or remnant coral on the surface is reason to categorize the dominant habitat as coral reef.

311. Platform Reef (also bank reef)

Hardened substrate formed by reef building corals that exist in a quasi-continuous structure along a shelf edge or similar dropoff removed from any coastline. These are typically elongate structures and may be referred to as bank reefs. The following Subclass categories may be present in various combinations within a platform reef.

3111. Linear 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.

31111. Reef Terrace (high profile)

Contiguous reef with high complexity and high relief (>2m).

31112. Remnant (low profile)

Reefs of relief less than 2m that lack distinctive spur and groove characteristics. These reefs consist of coral and hard bottom features; often support soft corals, sponges, seagrass; and are usually found growing parallel to the reef tract, though they may form transverse features that grow perpendicular to the reef tract.

3112. Spur and Groove

Distinct coral bands separated by sand or uncolonized hardbottom grooves. This habitat type usually occurs in the fore reef zone.

31121. High Relief Spur and Groove

Distinct coral bands separated by sand or uncolonized hardbottom grooves. The coral bands have 1.5- 4m relief.

31122. Low Relief Spur and Groove

Distinct coral bands oriented perpendicular to the shore or bank and separated by sand or uncolonized hardbottom grooves. The coral bands have <1.5m relief.

3113. Reef Rubble

Dead, unstable coral rubble that often occurs landward of platform reefs.

312. Patch Reefs

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 submersed aquatic vegetation (SAV), macroalgae, gorgonians or sponges. Most often the patches are surrounded by a halo of bare substrate created by foraging, obligate reef inhabitants.

3121. Individual Patch Reef

Isolated, single reef (larger than the minimum mapping unit of the project) without associated halo area. These individual reefs may have an associated halo, however if large enough (i.e. greater than the minimum mapping unit) to be delineated the halo will be mapped as its own subclass.

3124. Aggregated Patch Reefs (includes Halo areas if present)

Clustered patch reefs, usually too small (less than the minimum mapping unit) or too close together to map individually or where halos coalesce.

3125. Pinnacles

High complexity patch reefs that have high relief (up to 15m) from the sea floor. These structures may occur in clusters and are typically surrounded by large sand plains.

313. Patchy Coral and/or Rock in Unconsolidated Bottom

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 smaller than the minimum mapping unit).

32. Mollusk Reefs

Concentrations of sessile mollusks that attach to hard substrate and with the correct conditions will proliferate allowing the reef to grow. In Florida, these areas are most common in estuarine areas and are not known to occur in water deeper than 40 feet.

321. Bivalve Reefs (i.e. oyster reefs)

Mollusk reefs dominated by oysters; at times partially exposed during low tide.

322. Gastropod Reefs (i.e. Vermetid reefs)

Mollusk reefs created by a worm-like mollusk of the genus *Petaloconchus.* In Florida, these reefs are only known to be found in shallow waters seaward of the outer islands in the Ten Thousand Islands area of southwest Florida.

33. Annelid Reefs (i.e. Sabellariid reefs)

Structures formed from colonies of Sabellariid worm tubes. Commonly found in the tidal zone on the east coast of Florida, these structures are mostly formed on hard substrates and may be exposed at low tide. Storm events can break the sand structures thus changing the extent of the colony at the time of mapping. The reefs also expand as worm larvae settle on the mounds and build additional tubes.

34. Hardbottom

Hard substrate composed of exposed bedrock or created through syndepositional cementation of sediment.

341. Bedrock

Exposed bedrock and/or rocky outcrops with low to high relief and high complexity.

342. Pavement (i.e. low relief hardbottom)

Flat, low relief, mostly solid rock substrate.

4. Tidal Marsh (i.e. salt marsh, coastal marsh)

Communities of emerged halophytic vegetation along low-wave energy intertidal areas and river mouths. These areas are dominated by grasses, rushes and sedges (i.e cordgrass, needlerush, and sawgrass).

41. Salt pan

Exposed or water-filled depressions in a tidal marsh area. Often covered by layers of blue-green algae but possibly bare sediment only. Glassworts or saltworts may be present. Sand barrens most often exist in high marsh areas; conversely mud barrens may occur in the intertidal zone as water retention pools during low tide.

42. Salt marsh algae

Mud flats dominated by a mixture of benthic microalgae, phytoplankton, and macroalgae.

5. Tidal Swamp (i.e. mangrove, mangrove forest)

Dense, low forests primarily located along coastal areas. Various tidal marsh grasses and shrubs may be associated but these communities are dominated by a mix of red, black and white mangroves.

6. Land

Mainland, islands, causeways and other land normally above the high tide line. Depending on the mapping project the line delineating the water/land interface may be formed anywhere between the extreme low and extreme high tide marks.

7. Unknown benthic habitat (i.e. not lending to interpretation because of water quality, depth, or lack of field investigation)

71. Turbid plume

Area of dark colored water often associated with river mouths, bays and coastlines. The often brown water results from vegetation tannins leached into the rivers and/or organic particles carried seaward from the river water. Plumes varying in color from white to emerald green are also observed in areas with fine carbonate sediments (e.g. Florida keys). These plumes will often prevent mapping of benthic habitats from photography.

72. Phytoplankton bloom

Area of water that contains abnormally high concentrations of phytoplankton. These blooms can often be seen in aerial photography and will prevent mapping of benthic habitats by decreasing water clarity. The classes listed below should be used only if a distinct color is associated with the bloom when mapped.

721. Green bloom
722. Red bloom
723. Black bloom

General Modifiers–Modifier labels (e.g. A, B, C…) will be used to indicate more specific information about map categories. For instance, 123-E would represent a natural, submersed tidal channel with medium sand sediment type. Also, an area of flat, low relief hardbottom with dominant cover types of octocorals and sponges would be labeled 342-QR. Another example, 34-A22 would represent an artificial reef consisting of concrete culverts.

A. Artificial
- **1. Tires**
- **2. Concrete materials of opportunity**
  - **21. Concrete blocks**
  - **22. Culverts**
  - **23. Riprap**
- **3. Designed materials**
  - **31. Reef balls**
  - **32. PVC structures**
- **4. Vessels, automobiles, planes, military ordnance (whole or portions)**
- **5. Steel structures (i.e. oil rigs, lighthouses, etc.)**
- **6. Cables**
- **7. Pipelines**

B. Venetian canals-- anthropogenic canals landward of shoreline
C. Streams-- natural canals landward of shoreline
D. Island moats— deepwater canals wholly or partially surrounding islands
E. Submersed tidal canals— natural canals seaward of shoreline
F. Dredged/Excavation— anthropogenic canals seaward of shoreline or sediment borrow pits
G. Spoil/Fill – area of positive vertical relief created by placement of dredged sediments
H. Restoration-- area of restoration activity (e.g. previous salt marsh planting area)
I. Seagrass – this modifier can be used when seagrass is present in areas of 10% or greater cover of coral or hardbottom
J. Drift seagrass— accumulation of seagrass that may be drifting in water column or lying on the bottom

K. **Drift wrack—** mix of various materials (e.g. seagrass, macroalgae, mangrove litter, etc.) that may be drifting in water column or lying on the bottom
L. **Drift macroalgae--** accumulation of macroalgae that may be drifting in water column or lying on the bottom
M. **Mat algae—** thin veneer of algae on substrate
N. **Attached Macroalgae**
   1. **mixed browns**
   2. **mixed reds**
   3. **mixed greens and calcareous**
O. **Urchin Front—** congregation of urchins often dense enough to obscure the substrate in photography
P. **Boat propeller scars**
   1. **Light scarring**
      Scarring in less than 5% of an SAV polygon
   2. **Moderate scarring**
      Scarring in 5-20% of an SAV polygon
   3. **Heavy scarring**
      Scarring in more than 20% of an SAV polygon
Q. **Octocoral bed—**soft coral species attached to substrate
R. **Sponge bed—**sponge species attached to substrate
S. **Hard corals—**hard coral species attached to substrate
T. **Dead coral**
U. **Substrate ripples –** area containing troughs and ridges of substrate as opposed to flat substrate. Height range listed in meters e.g. (0.5-1.0m)**.**
V. **Carbonate substrate**
W. **Siliciclastic substrate--** Pertaining to clastic noncarbonate rocks or sediments which are almost exclusively silicon-bearing, either as forms of quartz or as silicates
X. **Sediment depth –** depth of the surface substrate material. Range listed in meters e.g. (0-2m)
Y. **Salinity (e.g. 32ppt)**
Z. **Tidal Status**
   1. **Subtidal –** Never exposed to the air.
   2. **Intertidal –** Exposed to the air even if only during the lowest spring tides.
   3. **Supratidal –** Normally exposed to the air, only submersed during flood or storm events.
AA. **Biological habitat modifications**
   1. **Fish excavations** (e.g. tilefish, grouper, stingrays)
   2. **Invertebrate bioturbation zones** (e.g. polychaetes, crabs, shrimps, etc.)
BB. **SAV epiphytes – presence of algal or animal epiphytes are visible on the surface of SAV. A relative abundance can be characterized with the sub-modifiers listed:**
   1. **Light**
   2. **Medium**
   3. **Heavy**

Taxonomic Modifiers– This is a partial list. The intent is to build this list from expert input or compilation of published Florida species lists. These taxonomic modifiers would be used similar to the General Modifiers list except labels would be composed of the genus and species abbreviations composed of the first letter of the genus and the first three letters of the species. This coding mechanism allows for inclusion of new species and manageable changes as taxonomic name changes occur through peer-reviewed literature.

Examples: 211-Ttes would represent an area of dense, continuous turtle grass (*Thalassia testudinum*) whereas 211 would represent an area of dense, continuous SRV of unknown species types. Likewise, an area of coastal needlerush marsh would be labeled 4-Jroe. These modifiers would be used in order of decreasing percent cover. For instance, 4-Jroe/Salt would indicate a polygon of tidal marsh with a mixture of needlerush (*Juncus roemerianus)* and smooth cordgrass (*Spartina alterniflora*); needlerush is more prevalent in this polygon because the Jroe modifier occurs first in the sequence.

Seagrasses
Thalassia testudinum
Halodule wrightii
Syringodium filiforme
Halophila engelmanni
Halophila johnsonii
Halophila decipiens

Tidal Marsh Plants
Ruppia maritima
Vallisneria americana
Juncus roemerianus
Spartina alterniflora
Spartina patens
Salicornia virginica
Cladium mariscoides
Batis maritima
Distichlis spicata
Salsola kali

Tidal Swamp Plants
Avicennia germinans
Laguncularia racemosa
Rhizophora mangle
Conocarpus erecta

Macroalgae
Argardhiella spp.
Avrainvellea spp.
Batophora spp.
Bryopsis spp.
Calothrix spp.
Caulerpa spp.
Chondria spp.
Cladophora spp.
Dictyota spp.
Digenia spp.
Gracilaria spp.
Halimeda spp.
Laurencia spp.
Oscillatoria spp.
Penicillus spp.
Rhipocephalus spp.
Sargassum spp.

Corals
Acropora cervicornis
Acropora palmata
Acropora spp.
Agaricia spp.
Montastrea annularis
Oculina varicosa
Porites porites
Porites spp.
Lophelia prolifera
Enallopsammia profunda
Siderastrea spp.

Appendix 3. Complete list of literature reviewed.

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