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A Recommendation for a Comprehensive Habitat and Land Use Classification System for the National Estuarine Research Reserve System

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I. Introduction:

A. Status of the SWMP

In 1995, the NERRS began implementing the System-wide Monitoring Program (SWMP) to address short-term variability and long-term change in estuarine habitats (Wenner 2002). The three phases of the SWMP plan relate to abiotic parameters (Phase I), biotic parameters (Phase II), and parameters of land use and habitat change (Phase III). Implementation of the three phases is a concurrent process because implementation strategies within each phase evolve in response to changes in technology and imagery, and because mapping efforts inherent in Phases II and III must be coordinated. Thus, while Phase I of the SWMP has matured significantly since 1995, current implementation strategies address geographic expansion, acquisition of real-time data, and more effective dissemination of data to the user communities. Implementation of SWMP phases II and III require coordination since both will rely on acquisition of remotely sensed imagery, common classification schemes, and address management-driven issues that relate changes in habitat quality and quantity within reserves to changes in habitat and land uses in adjacent watersheds.

Monitoring biotic communities within reserves (Phase II) was initiated in FY02 with the monitoring of nutrients and chlorophyll a—a measure of algal biomass and an excellent indicator of eutrophication (Wenner, 2002). Currently, the reserve system is phasing in mapping and monitoring of Submerged Aquatic Vegetation (SAV) and emergent vegetation. As a first step in implementing monitoring of SAV and emergent vegetation, the research community in the NERRS is investigating remote sensing technology and ground survey strategies on a small scale to evaluate their effectiveness for system-wide applications.

Since remotely sensed imagery is the primary source of information for mapping all reserve and watershed habitats and land uses, the reserve system is initiating Phase III of the SWMP concurrent with Phase II to promote coordination of mapping efforts on a variety of scales for a variety of purposes. The basic question to be addressed by Phase III, articulated in the SWMP plan, is “What is the magnitude and extent of habitat change in estuarine systems and how is the change linked to watershed land use practices?" Implementing Phase III requires clarification of local, regional, and national management driven issues, and associated trends analyses that will be addressed by monitoring reserve habitats and associated land uses over time. A key outcome of Phase III will be a proactive strategy to most effectively target investment of system-wide and reserve-specific resources to acquire remotely sensed data and associated hardware and software.

The reserve system created a Habitat Mapping and Change (HMC) Workgroup to develop a strategy to implement the HMC plan. The HMC committee created a technical sub-committee to recommend a reserve-wide habitat classification system and outline for site-specific habitat mapping and change plans that will drive the priorities for acquiring imagery to support system-wide mapping efforts. This is a complex task, as the strategy must integrate the existing classification systems in use among the 27 reserves while addressing the nationally, regionally and locally relevant management issues. *The goal of this paper is to recommend to the reserve system, a common classification system to facilitate the mapping and inventorying of reserve habitats and adjacent watersheds.*

B. Habitat Mapping and Change Vision

The HMC committee outlined the vision, goals, and objectives to be addressed by a system-wide HMC strategy. The vision of the HMC committee is to address coastal management issues by elucidating the inter-relationship of trends in habitats and land use over time, in reserves and their associated watersheds. Two goals identified by the HMC committee to this effort include: 1) inventorying reserve resources and how they are changing; and 2) examining the causes and effects of observed changes. The first goal requires mapping and inventorying, at consistent time frames (system-wide) and locally relevant scales, land use and habitat cover at the watershed (or sub-watershed) level at a coarser resolution, and within each reserve at a finer resolution, to examine national, regional, and local trends. Once implemented, the HMC committee will recommend strategies to promote research that investigates the causes of observed trends. Some of the objectives identified by the HMC committee include:

1) Answer ecological questions:
   - a) What land uses and habitats are in reserve boundaries and how can reserves qualify habitat conditions?
   - b) How are land uses and habitat extent and quality changing within reserves and watersheds?
   - c) How sensitive are reserve habitats to changes in the adjacent landscape and oceanic/estuarine conditions?

2) Track trends in the system:
   - a) Examine parallels in the changes in quality of coastal marsh habitat and submerged aquatic vegetation and adjacent demographics and land-use over time.
   - b) Analyze the relationships between water quality and land use over time.
   - c) Monitor the status of restoration reference sites.

d) Monitor the success of reserve restoration efforts and model the potential for the success of future efforts.

3) Communicate trends that impact Coastal Management:
   a) Portray coastal issues in a more provocative way.
   b) Facilitate the transfer of our observations and understanding of trends to coastal decision makers at national and local levels.
   c) Catalyze policy change at a national level by bringing emerging threats to national attention.
   d) Provide information that will enable researchers to conduct inter-disciplinary research in coastal areas that link habitat change and land use and explore the interrelation between global climate change, coastal development and estuarine health.
   e) Provide the foundation to support modeling to empower managers to proactively examine impacts of future management actions.

These objectives provide the local, regional and national context for implementing the land use and habitat change plan of the NERR system. Addressing these requires a NERRS habitat and land use classification system that will address NERR-specific context and issues, such as transitional habitats between intertidal and upland environments, habitat degradation and modification, salinity gradients within waters and soils, and the transitions of estuarine to freshwater habitats.

C. HMC Technical Committee Recommendation

The proposed NERRS Classification Scheme presented in this paper integrates aspects of the Cowardin et al. (1979) and Anderson et al. (1976) systems, and NOAA's Coastal Services Center Coastal Change Analysis Program (Dobson et al. 1995). The recommendation proposes incorporating the following:

- Cowardin for wetland and deepwater habitats within the reserve boundary;
- An expanded form of Cowardin for reserve upland habitats;
- Anderson for cultural land use and snow and ice habitat systems within reserve boundaries; and
- The C-CAP scheme for coarse level mapping of watershed habitats and land uses.

This strategy is designed to specifically meet the needs of the Reserve System in providing researchers and managers with an effective framework to address the management driven issues identified by the HMC Committee.

The supporting rationale presented in this paper demonstrates that the proposed classification system:

- Is compatible with existing classification efforts within the system and enables simple crosswalking with existing datasets;
- Is fully capable of classifying all cover types, logically organizing all deepwater, wetland, upland habitat and cultural land use data into a seamless dataset;

- Is effective over the entire geographic extent of the NERRS;
- Utilizes universally accepted and applied structure and terminology;
- Is simple to use, providing the intuitive utility of a multinomial key;
- Is useful for communicating data with scientists and non-scientists;
- Allows cross-walking between coarse-level and fine-level datasets;
- Allows vastly detailed upland, wetland, and deepwater habitat classification;
- Provides a basis for runoff and infiltration modeling;
- Is compatible with GIS software and with accepted methods of data collection and classification;
- Facilitates data analysis at numerous ecologically significant levels of interest;
- Is compatible with remotely-sensed imagery;
- Employs parameters that can indicate habitat quality; and
- Describes habitats in the transition zone between intertidal and uplands.

II. UTILITY OF CLASSIFICATION SCHEMES

It has become standard practice for natural resource managers to organize geospatial data into classification schemes to facilitate addressing the types of objectives described by the HMC Committee. An effective classification scheme serves a data user in numerous ways. It standardizes terminology and levels of data application, organizes data in a logical manner, allows data to be coded for data management, and facilitates communication among data users.

The most effective classification schemes for geospatial data are organized in a nested hierarchy, which allows data to be folded up or expanded to the level of detail desired by the user. A nested hierarchy is structured like a family tree, where each top level class is subdivided into dedicated second level classes and each second level class into dedicated third level classes and so on. Each lower level describes the data at a higher degree of detail. Data can be viewed and analyzed across each level with no change in total area from any other complete level. Each level represents a useful and logical break in some parameter of the community, such as hydrologic system or vegetative structure (such as plant physiognomy). All users organize their data identically at each level, which allows for analyses across datasets and facilitates communication at all levels of detail.

The application of a strictly numeric heading system to a classification system can further enhance its utility (Anderson et al. 1976). In GIS and spreadsheet formats, a numeric header system can organize data into the same logical order as the classification scheme with a single sorting command. It also provides a meaningful code for data entry and makes possible numeric queries of data by the heading value.

III. DEVELOPMENT OF A NERRS CLASSIFICATION SCHEME

To address the objectives of the HMC Committee, such as quantifying habitat extent and quality changes (1a and 1b), and impacts to reserve habitats from adjacent land use change (1c, 2a and 3e), a NERRS classification will need to classify both habitat and land use cover types. A habitat type describes the vegetation and/or substrate covering an area of land, while a land use type describes "man's activities on the land that relate directly to the land" (Anderson et al. 1976). Simultaneous inventory of both cover types, with the input of all data to a single seamless classification system, is desirable for landscape applications because it provides consistency between independent (land use) and dependent (habitat) variables in methodologies, analysis and interpretation, and inherently contains no overlaps or voids for % cover and other analyses. It also makes it generally easier for a user to view, analyze, map, and conceptualize data.

Addressing the HMC objectives also requires that data be collected at two geographic scales: broad-scale, low resolution data for characterizing entire watersheds, and detailed, fine-scale, high resolution data for characterizing reserve properties. Watershed-level data will be used to address HMC objectives that require quantification of cover types over large areas of land, such as measuring habitat and land use change in the watershed (1b), assessing the sensitivity of reserve habitats to changes in adjacent uplands (1c), and analyzing the relationship between land use and water quality over time (2b). Watershed data will likely be derived from 30m Landsat TM (inexpensive digital satellite imagery with high temporal resolution) or other similar coarse imagery, with an expected classification accuracy of around 85% using an objective automated classification protocol. Automated classification is expected to render only about 25-30 classes that will not fall into any one logical level of a nested hierarchical scheme (C-CAP 2004).

Reserve-level, fine-scale data will be applied to address all HMC objectives. It will also act as a useful ecological baseline for natural resource management and for facilitating a host of research analyses such as species-habitat associations and landscape ecology queries. These data will likely be derived from photointerpretation or supervised automated classification of high-resolution imagery. Polygon attribute accuracy will feasibly approach 100% after ground-truthing, while polygon border accuracy will depend on the mapping scale and quality assurance methods. Fine-level data are not expected to be limited in detail by classification resources and the number of classes may only limited by the number of habitat and land cover types in the system—there may be hundreds. At this level, a data user would certainly benefit by utilizing a logical, nested hierarchical system for organizing and analyzing these data.

While no single classification scheme will ever address every need, an appropriate classification for any application is designed to meet the needs of the users. To meet the needs of the NERRS, specific criteria must apply. First, the classification should be compatible with existing classification efforts within the system, providing an easy crosswalk with existing data from NWI, Anderson LU/LC, C-CAP, FNAI, FLUCCS, NLCD, and NHESP projects. It should also be compatible with other national classification initiatives such as the CMECS (Madden et al. 2005) and the TNC scheme (Grossman et al. 1998). It must be comprehensive enough to inventory any habitat or land use (by extent and quality) in the reserve system into one seamless data layer. It must allow crosswalking between coarse-scale and fine-scale datasets. It also must facilitate detailed upland, wetland, and deepwater habitat classification to meet the reserve system's ecological needs and estuarine focus. It must be compatible with GIS software and with accepted methods of data collection and classification, such as C-CAP (and NLCD) terrestrial and SAV protocols, and NWI protocol. It must be simple to use and useful to communicate data with scientists and non-scientists. It would also be very useful if it were structured in an ecologically based, nested hierarchy with a numeric heading to facilitate analyses at various logical levels of interest for answering both our stated and unforeseen questions.

To determine the classification most compatible with data already utilized in the Reserve System, the Habitat Mapping and Change Technical Committee (HMCTC) sent out an e-mail query soliciting information from Reserve Managers, RC's and SC's. Staff members were asked to disclose information about mapping activities at their reserves, and in their watersheds, regarding classification systems used, the level of detail at which the habitats were described, minimum mapping units, source data, resolution of source data, frequency of data collection and suitability of the data for the desired level of classification. Reserves were also asked to provide an outline of the schemes they use, comments on the benefits and drawbacks of their schemes and information on whether and when the NWI had been conducted.

Thirteen responses were received and analyzed by the HMCTC. At the reserve level, the Cowardin system (Cowardin et al. 1979) was overwhelmingly used to classify wetlands, The Anderson system (Anderson et al.1976) was almost unanimously used to classify cultural land use, and expanded Anderson (five reserves) and expanded Cowardin (four reserves) systems were used most to classify uplands. At the watershed level, Cowardin (NWI), Anderson, and C-CAP classifications were the most widely used.

For coarse-scale (watershed-wide) classification, NWI protocol requires resources and methods beyond practical application for the NERRS objectives. C-CAP protocol, however, has been developed to meet needs nearly parallel to those of the Reserve System. C-CAP is a Landsat TM based land cover change analysis protocol, initiated in 1995 by NOAA Coastal Services Center, with complete data collection and classification methodologies in place. Data have been collected, classified and analyzed for most of the coastal United States, twice, in five-year intervals. C-CAP has also expressed a specific interest to work with the HMC Committee to develop classification methods consistent with NERRS requirements. The C-CAP classification is basically a two-level hierarchy of 29 discernable classes that has effectively refined the Anderson classification for automated classification of coarse imagery in coastal applications (Appendix 3). The HMCTC recommends that coarse-level data be classified to C-CAP or similar classes that will easily crosswalk into the recommended classification for fine-scale data through the use of a simple relational table.

Upon reviewing responses to the e-mail query regarding reserve-level mapping, the HMCTC recommends that a NERRS classification incorporate the Cowardin classification to classify upland, wetland and deepwater habitat systems, and the Anderson classification to classify cultural and snow-and-ice systems. The Cowardin system provides a geographically comprehensive, universally accepted, detailed, nested hierarchical classification scheme for wetland and deepwater habitats that has intuitive, useful and logical class breaks based on ecological parameters, while the Anderson system contains universally accepted land use classes crucial for runoff and infiltration analyses. The Anderson system is less useful to characterize detailed upland habitats, however. Classes are general and are not based on logical ecological parameters, as they are in the Cowardin system. So to facilitate parallel data organization among all habitats from upland to wetland to deepwater habitats, the Cowardin system was expanded, for the use of the NERRS, to include upland habitats, using the same simple, logical class breaks and universally accepted and familiar terminology as the rest of the Cowardin system.

Other upland schemes utilized in the Reserve System were considered for application to the scheme, but were rejected. The Nature Conservancy (TNC) Classification (Grossman et al. 1998), while used by the National Park System and other national agencies, does not utilize a strictly nested hierarchy, which makes it somewhat difficult to apply to GIS multi-level analyses. It is also bulky, complicated (seven levels and as many as over 100 classes within each level) and requires an intimate knowledge of the classification including special knowledge of vegetation associations. The TNC scheme classifies urban systems using the Anderson system, but classifies agricultural data using the FGDC system, which was still under development at the scheme's inception (USGS, 1994). The FNAI (1990) and NHESP upland schemes are not comprehensive enough to apply to the entire Reserve System.

An expert classification advisory committee reviewed and provided input on the design of the NERR Classification. The committee included Dr. Frank Golet, Professor of Wetland Ecology, URI and co-author of the Cowardin et al. classification; Dr. Peter August, Professor of Landscape Ecology and GIS Application, and Chairman of the Coastal Institute, URI; and Dr. Y. Q. Wang, Professor of Remote Sensing, URI. Particular attention was given to the application of the upland system to the Cowardin format, and the utility of combining the Anderson and Cowardin classifications into a single comprehensive system. The HMC Technical Committee also ensured that the recommended classification system for the NERRS responds to the issues raised by the five reserves who piloted the NOAA classification schemes (Allee et al. 2002, and Brown et al. 2002) to assess their applicability to reserve issues in 2002 (Tijuana River, Elkhorn Slough, Hudson River, ACE Basin, and Apalachicola River).

IV. The Proposed Classification (refer to Appendix 1, *Proposed NERRS Classification*)

A. Structure and Content

The *NERRS Classification Scheme*, as it is referred to in this section, is intended for use in classifying and inventorying fine-scale data within reserve boundaries. Technical and financial limitations associated with classifying vast areas of land will require the use of automated classification to characterize large watersheds. Thus, watershed-wide (coarse-scale) classes will be determined by the capabilities of that technology to discriminate between cover classes. The NERR Remote Sensing Committee is currently developing appropriate technology protocols to determine course-scale (watershed-wide) classes. The HMCTC expects coarse-scale classes to easily crosswalk with the recommended classification for fine-scale data through the use of a relational table.

The recommended NERRS Classification Scheme consists of a merger of two well-accepted and utilized classification schemes, Cowardin et al. (1979) and Anderson et al. (1976), applied to a five-level, nested hierarchical framework with a strictly numeric heading system. For consistency in terminology, levels 1-4 are adopted from Cowardin et al.: *System* (L1)*, Subsystem* (L2)*, Class* (L3)*,* and *Subclass* (L4). The lowest level, *Descriptor* (L5), was added to facilitate communication and crosswalking with other classification systems. Characterization of land cover by all five levels may be required to realize the objectives of the HMC Initiative, although this remains to be determined..

There are eight *systems* in the classification. Five wetland and deepwater habitat *systems* (including their associated *subsystems, classes,* and *subclasses*) are adopted directly from Cowardin. A cultural land use *system* and a snow-and-ice habitat *system* are adopted directly from Anderson, and an upland habitat *system* is based on Cowardin (Fig. 1). For the purposes of habitat and land use differentiation in the NERRS classification, *land use* cover types are defined as those modified by mechanical or chemical manipulation more than once per growing season, regularly grazed by livestock, or modified to a condition that prohibits natural community succession (Kutcher et al. 2004). *Habitat* cover types are those in a sustained or reclaimed *natural* state. Even if they are highly influenced by previous or existing historic modifications, cover types should be classified as habitats if they are not regularly modified and in turn exhibit natural successional progression. Furthermore, to encourage an ecological approach in mapping, habitats occurring within broad land use types (e.g. shrublands within parks or residential areas) should be classified as habitats.

For wetland, deepwater and upland habitat *systems*, *System* designation is essentially based on the most influential water source (e.g., *Marine*). *Subsystem* is based on some hydrologic influence on the habitat (e.g., *Intertidal*), *Class* is based on vegetation or substrate structure (e.g., *Forested* or *Rocky Shore*), and *Subclass* is based on vegetation life strategy or particle size (e.g., *Broad-leaved Deciduous* or *Sand*).

The *Upland Habitats system* is based on the Cowardin hierarchy and class breaks for wetland habitats. Two *subsystems* are defined to accommodate NERRS needs. The first, *Supratidal Upland* is defined as any upland occurring in the zone that ranges from the intertidal zone to the storm event log line, and is directly affected by coastal processes such as storm event flooding, salt spray, erosion and coastal winds (FNAI 2004), while *Inland Uplands* constitute all other upland habitats. Five *classes* for *rocky, unconsolidated*, *herbaceous*, *scrub-shrub*, and *forested* upland habitats parallel Cowardin wetland *classes*: *rocky shore, unconsolidated shore, emergent, scrub-shrub, and forested*, respectively. NERRS *subclasses* are the same as in Cowardin for each respective *class*, except *grasslands/broad-leaved herbaceous* replaces the *persistent/nonpersistent* subdivision for *herbaceous*, and *clay* and *loam* replace *mud* for the *unconsolidated* class.

For the *Cultural Land Use system*, *subsystem* designation is divided between urban and agricultural uses (Anderson Level I), and *class* designation is based on the type of development or agriculture employed in each (Anderson Level II). The Anderson classification was designed to be open ended to allow for further subdivision at regional levels. Anderson offered vague guidelines for a third level, and many state agencies have interpreted those guidelines and applied a third level to their land cover mapping efforts. Perhaps the most crucial subdivision regarding HMC objectives is that of residential property. The HMCTC recommends subdividing the *residential* class by low, med-low, med, med-high, and high-density residential subclasses described by units per acre (RIGIS 1998) for compatibility with NRCS infiltration and runoff modeling, and to facilitate crosswalking with C-CAP datasets. All other cultural subclasses were taken directly from the Ohio Level III land use classification (Schaal 1988), as it closely follows Anderson's guidelines.

The *Snow and Ice Habitat system* is only subdivided once into *Glaciers* and *Perennial Snow subsystems* as adopted from Anderson. No suggestions for further subdivision are offered here.

Descriptors for all data are applied at the fifth level (numbered by two decimal places to allow for 99 possible types within each *subclass*). *Descriptors* are descriptive, defined and well-accepted, common habitat or land use names, preferably previously defined in national or regional scientific literature. A habitat descriptor can characterize a habitat dominated by a single species (e.g., *Atlantic White Cedar Swamp*), by multiple species (e.g., *Pitch Pine-Oak Forest*), or by substrate (e.g., *Inland Sand Barren*). For cultural land use data, *descriptors* may simply be reiterations of the *subclass* or *class*. They will serve to facilitate communication between data providers and users. *Descriptors* will also allow crosswalking between classification systems, since they represent a link that is commonly utilized in the various classification systems of the Reserve System. Each *descriptor* and a standardized detailed definition will be filed and maintained on the intranet to avoid name overlap within the Reserve System. Refer to Table 1 for an example of a *Descriptor* standardized definition.

Modifiers beyond the hierarchy of the classification may be added as fields (columns) to a dataset attribute table to add greater descriptive/analytical detail or to facilitate crosswalking with different classification systems that use other criteria or codes. The HMCTC will recommend, define and provide an active list of appropriate ecological habitat modifier fields (column headings) and modifiers to be posted on the NERR intranet website for system-wide application (Appendix 2). Modifiers will include many of those suggested by Cowardin et al. (1979), which further describe each habitat by dominant species (by scientific name), water regime (and soil moisture), water chemistry (e.g., by salinity classes in ‰) and certain cultural modifications. Water/soil water chemistry modifiers will address concerns regarding differentiation between *salt* and *brackish* estuarine wetland types, while cultural modifiers will enable users to identify historic anthropogenic pressures affecting habitats, with terms such as *Impounded, Diked,* or *Excavated*. Invasive species modifiers are also recommended to identify the presence and percent cover of invasive species within each habitat. Certain modifiers may be either required or optional for establishing a national inventory baseline and will be determined when methods are developed at a later date. Any in-system user may present proposals for additions to the system-wide list of modifier fields or modifiers to the HMCTC, where they will be reviewed and added to the official intranet list as appropriate. Site specific modifiers may also be added locally or regionally to allow GIS queries relevant to regional studies, or other scheme class parameters, names, or codes such as *Mesic Uplands* for Florida's FNAI, or *681* for PALIS ID codes in MA water bodies.

B. Amendments to Cowardin

1. Tidal Fresh Habitats

Cowardin et al. (1979) classifies wetlands and deepwater habitats influenced by ocean derived freshwater tides in the *Riverine* system, *Tidal* subsystem. This classification is deficient in addressing the needs of the NERRS in two ways. First, it does not allow for differentiation between subtidal and intertidal habitats, which are clearly discernable in many of our tidal fresh ecosystems, some of which have tide ranges approaching two meters. Second, the Cowardin classification entirely lacks classes for tidal fresh habitat types dominated by persistent emergent and woody vegetation. Furthermore, Cowardin defines estuarine habitats as extending upstream to waters of <0.5‰ salinity during annual low water, which agrees with the Prichard (1967) definition for estuaries. However, more recent functional definitions, which define estuaries as extending to the head of tide (Fairbridge, 1980; Day et al. 1989), better suit NERRS estuarine systems with extensive tidal fresh zones, such as those of Hudson River and Chesapeake Bay. To address these issues, the NERRS adaptation modifies Cowardin in the following ways:

- The extent of the *Estuarine* system is redefined as extending upstream and landward to the upper limit of tidal rise during spring tide and mean annual low river flow, to include freshwater wetlands and deepwater habitats flooded by ocean driven tides. The Estuarine system is also extended to include non-tidal wetlands with ocean derived salts >0.5‰, such as dune swales occurring in the supratidal zones of maritime and estuarine coastlines.
- The above allows the *Tidal* subsystem to be moved from the *Riverine* system into the *Estuarine* system.
- The *Tidal* subsystem is then split into *2400. Subtidal Fresh* and *2500. Intertidal Fresh* subsystems with appropriate class divisions.
- The subclass *2551. Persistent Emergent*, and *2560. Scrub-shrub* and *2570. Forested* classes and the appropriate associated subclasses are inserted into *2500. Intertidal Fresh* to address those deficiencies in Cowardin. .
- Original *Subtidal* and *Intertidal* habitats of the *Estuarine* system (those with >0.5‰ salinity) are renamed *2100. Subtidal Haline* and *2200. Intertidal Haline* to differentiate them from tidal fresh subsystems.

2. Estuarine Supratidal Wetlands

Recent literature and scientific investigation has incorporated the use of the term *supratidal* to describe the coastal shore zone from spring high water to the storm *log line*, or the highest reach of storm event water (FNAI 2004). While the *Supratidal Uplands subsystem* (heading 6100 in Appendix 1) will handle the classification of supratidal upland habitats such as dune grasslands and shrublands, wetlands within the supratidal zone that transiently or permanently contain ocean-derived salts >0.5‰ necessitate expansion of the Cowardin classification to include a *Supratidal Haline subsystem* (heading 2300 in Appendix 1) and appropriate associated *classes* and *subclasses* within the *Estuarine system*. Note that the *Supratidal Haline subsystem* only applies to nontidal *true* wetlands (i.e. those dominated by hydrophytes, containing hydric soils, or submerged or saturated for some time during the growing season [Cowardin et al. 1979]) lying within the supratidal zone, such as dune swales or nontidal ponds that are periodically breached by haline storm water. Under the Cowardin methodology, supratidal upland habitats cannot be classified as estuarine since the *Estuarine* habitat *system* is defined as a wetland and deepwater habitat system. The division of the supratidal zone into estuarine and upland systems will require only a single extra step in analyses, while retaining the well-accepted definitions of the Cowardin system. This addition will not affect the rest of the classification.

3. Palustrine Open Water

Palustrine habitats are essentially all non-tidal persistent freshwater wetlands, and unvegetated and nonpersistent freshwater wetlands that are not in a river channel or lake basin (Cowardin et al. 1979). The NWI has consistently used *Palustrine Open Water* as a subsystem when applying the Cowardin classification to describe small ponds (less than 8 ha and less than 2 m deep at low water) with unknown submergent vegetation or sediment. However, palustrine open water habitats are not officially divided from other palustrine habitats in the Cowardin system. To facilitate cross walking with NWI, the NERRS *Palustrine* system has been subdivided into *Open Water* and *Terrestrial Wetland* subsystems with associated logical grouping of the lower classes. All else remains the same.

4. Faunal Aquatic Bed

The Cowardin classification does not provide a *Faunal* subclass for marine and estuarine aquatic beds. Florida's FNAI classification identifies sponge and octocoral beds, which require that addition. This will not affect the rest of the classification.

5. Algal Aquatic Bed

The Cowardin *subclass Algal* was split into the *subclasses Rooted Algal* and *Floating Algal* to differentiate between the two algal types in the *Marine* and *Estuarine* habitat *systems*.

6. Artificial Reef

Large submerged artificial reefs, such as shipwrecks and discarded bridges, require a special exception to the rule differentiating habitats from cultural land uses because a dominant ecological function is provided by the structure itself, which will likely begin providing habitat for flora and fauna within a single season. Thus, the subclass *Artificial* was inserted into *Subtidal subsystems* of the *Marine* and *Estuarine* habitat *systems*.

7. Cobble and Gravel

The Cowardin *subclass Cobble-gravel* was split into the *subclasses Cobble* and *Gravel* to differentiate between the two unconsolidated types. Each type is defined by particle size in Cowardin et al. (1979).

V. Conclusions

A. Benefits for the Reserve System

The recommended NERRS Classification Scheme was designed to specifically meet the needs of the Reserve System in providing data users with a valuable tool to address the objectives of the HMC Initiative. It is compatible with existing classification efforts within the system and will allow simple crosswalking with existing datasets. It is also compatible with the finer levels and modifiers of the CMECS and the TNC national classification initiatives due to certain parallel classes and its open-ended *modifier* structure. It is fully capable of classifying all cover types, logically organizing all deepwater, wetland, upland habitat and cultural land use data into a seamless dataset. It is effective over the entire geographic extent of the NERRS. It utilizes universally accepted and applied structure and terminology, making it simple to use and useful for communicating data with scientists and non-scientists. It allows crosswalking between coarse-level and fine-level datasets. It allows detailed upland, wetland, and deepwater habitat classification. It can provide a basis for runoff and infiltration modeling. It is compatible with GIS software and with accepted methods of data collection and classification, such as C-CAP/NLCD terrestrial and SAV protocols, and NWI protocol. Finally, the nested hierarchy and numeric heading system facilitate data analysis at numerous ecologically significant levels of interest and provide the intuitive utility of a multinomial key.

The classification system as presented will address the management issues identified by the reserve system and build upon NERR site-based GIS capacity, implementation of SWMP phase II methodologies, and will be facilitated by NOAA's priority on acquisition and improvement of remotely sensed imagery to address estuarine and near shore habitat issues.

B. Limitations of the Classification System

The primary caveat regarding geospatial data classification is that each classification system is designed for a particular set of uses. No single classification is ever likely to meet the host of demands required by all geospatial data users. The NERRS scheme was designed specifically to meet the needs of the NERRS. The scheme requires a cursory knowledge of the Cowardin and Anderson system definitions and terminology. Of the two, the Cowardin terminology is the more specialized, but as a group comprised primarily of estuarine scientists, the NERRS will generally be familiar with the term definitions. Otherwise, *Classification of Wetland and Deepwater Habitats of the United States* (Cowardin et al. 1979) defines all terms and class breaks, and is available on-line through the US Fish and Wildlife Service. Anderson terminology is defined in *A land cover and land use classification system for use with remote sensor data* (Anderson et al. 1976), which is available on-line from the USGS.

Just as a classification scheme is designed to meet the needs of the user, technology also must be applied to meet the needs of the user (Wang, personal communication). The NERRS classification scheme does not necessarily allow for all classification limitations inherent in technology for high resolution automated classification, but instead is intended to address objectives that require detail and comprehensiveness. The interpretation of multiple data types plus ground-truthing may be necessary to classify land cover types to the lower levels, depending on how newer technology serves the needs of the Reserve System. The Cowardin and Anderson classifications were originally intended for photointerpretation and ground truthing, which may still be the most appropriate methodology for inventorying fine-scale geospatial data in the Reserve System at this time.

For unsupervised coarse scale classification (such as in the C-CAP effort), the Anderson classification has been refined to classes limited to those discernable through automated classification. Computer generated classes tend not to fall at one set logical level, while many non-discernable classes written into the Anderson classification go unutilized. A C-CAP based classification for coarse scale data will meet the Reserve System’s needs for watershed data and can be easily crosswalked into the NERRS classification for analyses requiring comparisons to fine-scale data.

Subterranean habitat classes are not included in the NERRS classification. Mapping of subterranean habitats requires different data collection technologies and methods, and may require a separate GIS layer due to overlap of terrestrial and subterranean habitats. A separate data layer with a suitable subterranean classification system may be most appropriate for this application, which is currently being considered beyond the scope of this project. Any proposals for a standardized system-wide classification and monitoring protocol for subterranean habitats should be brought to the HMC Committee.

While the NERRS classification is based on two classification systems that have been designed and tested to be nearly comprehensive, there remains a possibility that a class occurring within the reserve system has been overlooked. Any deficiency in the classification should be brought to the attention of the HMCTC Classification Subgroup for verification and amendment.

C. Next Steps

One of the next steps will be to develop a system-wide policy that outlines how the NERRS Classification Scheme will be used for mapping purposes by individual reserves. When the reserve system agrees on a system-wide classification strategy, this policy will be posted on the intranet with the corresponding scheme, metadata, modifiers and descriptors. The Technical Committee has solicited feedback from all sectors during the 2005 winter meetings as well as from throughout NOAA to ensure it is consistent with NOAA-wide remote sensing, management, and mapping priorities. The HMC will discuss a formal process for seeking system-wide approval with the 2005 Strategic Committee. However, the following steps will be pursued to test the applicability of the proposed NERRS Classification Scheme.

- The five sites who originally piloted the Allee and Brown schemes (Apalachicola, Ace Basin, Hudson River, Tijuana River, and South Slough) will pilot the proposed NERR classification system and the revised Allee schemes during the summer of 2005. Each site will submit an analysis of the proposed NERR scheme as well as its ability to integrate with the Allee scheme.
- Definitions of classes and terminology will be distributed to the pilot participants and other parties interested in applying the scheme before summer of 2005.
- Draft protocols for implementing this classification will be distributed to the system for review in…
- A summary of the pilot analysis will be presented to all sectors at the 2005 October Meeting. Depending on the comments at that time, the scheme will be recommended for adoption or modified accordingly.
- The Technical Committee will report out to the Habitat Mapping and Change (HMC) Committee at the October meeting at which time the HMC Committee will provide comments and discuss next steps towards developing site-based HMC plans.

Figure 1: Content sources for the proposed NERRS Classification System.

Source Classification System	NERRS *System* and *Subsystem*
Cowardin et al.	1000. Marine Habitats
	1100. Subtidal
	1200. Intertidal
	2000. Estuarine Habitats
	2100. Subtidal Haline
	2200. Intertidal Haline
	2300. Supratidal Haline*
	2400. Subtidal Fresh*
	2500. Intertidal Fresh*
	3000. Riverine Habitats*
	3100. Lower Perennial
	3200. Upper Perennial
	3300. Intermittent
	4000. Lacustrine Habitats
	4100. Limnetic
	4200. Littoral
	5000. Palustrine Habitats
	5100. Palustrine Open Water*
	5200. Terrestrial Wetland*
Cowardin et al. (expanded)	6000. Upland Habitats
	6100. Supratidal Upland
	6200. Inland Upland
Anderson et al.	7000. Perennial Snow And Ice Habitats
	7100. Perennial Snowfields
	7200. Glaciers
	8000. Cultural Land Uses
	8100. Urban or Built-up Land
	8200. Agricultural Land

*Amended subdivisions as explained in section IV B of this document.

Table 1. Sample *Descriptor* definition for the proposed NERRS Classification.

Descriptor:	*New England Low Salt Marsh*
NERR Code:	2261.01
General Habitat Description:	Highly productive (what if in a restricted marsh and productivity is therefore low?), low energy (what about like in Nauset Marsh where there is Sa low marsh on high-energy, erosional edges that slough off?) estuarine wetland habitat dominated by *Spartina alterniflora* and subject to daily tidal flooding. Distinguished by the accumulation of a peat substrate from *Southern Low Salt Marsh*, which accrete exclusively by sedimentation. Distinguished from *New England Fringe Salt Marsh* by containment within or continuous connectivity with proper marsh systems.
Source:	Bertness, Mark D. 1999. *The Ecology of Atlantic Shorelines*. Sinaur Associates, Inc. Sunderland, MA
System:	Estuarine
Subsystem:	Intertidal
Class:	Emergent
Subclass:	Persistent
Dominant Species:	*Spartina alterniflora*
% cover range:	30-100%
Salinity Range:	Mesohaline-Euhaline
Water Regime / Range:	Irregularly Exposed to Regularly Flooded
Other Distinguishing Features:	Occurs within the boundaries of a salt marsh proper
Associated Plant Species:	*Distichlis spicata*
.	*Salicornia europea*
.	*Sueda maritima*
.	*Sueda linearis*
Associated Animal Species:	*Gaukensia demissa*
.	*Pagurus longicarpus*
.	*Fundulus heteroclitus*

Acronyms

BLD	Broad-leaved Deciduous
BLE	Broad-leaved Evergreen
C-CAP	NOAA Coastal Change Analysis Program
CMECS	Coastal/Marine Ecological Classification Standard
CSC	NOAA Coastal Services Center
FGDC	Federal Geographic Data Committee
FNAI	Florida Natural Areas Inventory
FLUCCS	Florida Land Use Land Cover Classification System
GIS	Geographic Information Systems
HMC	Habitat Mapping and Change
HMCTC	Habitat Mapping and Change Technical Committee
LU/LC	Land use and land cover
L1	Level one
NERRS	National Estuarine Research Reserve System
NHESP	Natural Heritage and Endangered Species Program
NHNHP	New Hampshire Natural Heritage Program
NLCD	USGS National Land Cover Data
NLD	Needle-leaved Deciduous
NLE	Needle-leaved Evergreen
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWI	National Wetlands Inventory, US Fish and Wildlife Service
PALIS	Pond and Lake Identification System
RC	Research Coordinator
RIGIS	Rhode Island Geographic Information System
SAV	Submerged aquatic vegetation
SC	Stewardship Coordinator
SWMP	System-wide Monitoring Program, NERRS
TM	Thematic Mapper
URI	University of Rhode Island
USGS	United States Geological Survey

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Appendix 1

The Proposed NERRS Classification

1000. Marine Habitats
    1100. Subtidal
        1110. Rock Bottom
            1111. Bedrock
            1112. Rubble
        1120. Unconsolidated Bottom
            1121. Cobble
            1122. Gravel
            1123. Sand
            1124. Mud
            1125. Organic
        1130. Aquatic Bed
            1131. Rooted Algal
            1132. Drift Algal
            1133. Rooted Vascular
            1134. Faunal
        1140. Reef
            1141. Mollusk
            1142. Coral
            1143. Worm
            1144. Artificial
    1200. Intertidal
        1210. Aquatic Bed
            1211. Rooted Algal
            1212. Drift Algal
            1213. Rooted Vascular
        1220. Reef
            1221. Coral
            1222. Worm
        1230. Rocky Shore
            1231. Bedrock
            1232. Rubble
        1240. Unconsolidated Shore
            1241. Cobble
            1242. Gravel
            1243. Sand
            1244. Mud
            1245. Organic
2000. Estuarine Habitats
    2100. Subtidal Haline
        2110. Rock Bottom
            2111. Bedrock
            2112. Rubble
        2120. Unconsolidated Bottom
            2121. Cobble
            2122. Gravel
            2123. Sand
            2124. Mud
            2125. Organic
        2130. Aquatic Bed
            2131. Rooted Algal
            2132. Drift Algal
            2133. Rooted Vascular
            2134. Floating Vascular
            2135. Faunal
        2140. Reef
            2141. Mollusk
            2142. Worm
            2143. Artificial
    2200. Intertidal Haline
        2210. Aquatic Bed
            2211. Rooted Algal
            2212. Drift Algal
            2213. Rooted Vascular
            2214. Floating Vascular
        2220. Reef

        - 2221. Mollusk
        - 2222. Worm
    - 2230. Streambed
        - 2231. Bedrock
        - 2232. Rubble
        - 2233. Cobble
        - 2234. Gravel
        - 2235. Sand
        - 2236. Mud
        - 2337. Organic
    - 2240. Rocky Shore
        - 2241. Bedrock
        - 2242. Rubble
    - 2250. Unconsolidated Shore
        - 2251. Cobble
        - 2252. Gravel
        - 2253. Sand
        - 2254. Mud
        - 2255. Organic
    - 2260. Emergent Wetland
        - 2261. Persistent
        - 2262. Nonpersistent
    - 2270. Scrub-Shrub Wetland
        - 2271. BLD
        - 2272. NLD
        - 2273. BLE
        - 2274. NLE
        - 2275. Dead
    - 2280. Forested Wetland
        - 2281. BLD
        - 2282. NLD
        - 2283. BLE
        - 2284. NLE
        - 2285. Mixed
        - 2286. Dead
- 2300. Supratidal Haline
    - 2310. Rock Bottom
        - 2311. Bedrock
        - 2312. Rubble
    - 2320. Unconsolidated Bottom
        - 2321. Cobble
        - 2322. Gravel
        - 2323. Sand
        - 2324. Mud
        - 2325. Organic
    - 2330. Aquatic Bed
        - 2331. Rooted Algal
        - 2332. Drift Algal
        - 2333. Rooted Vascular
        - 2334. Floating Vascular
    - 2340. Emergent Wetland
        - 2341. Persistent
        - 2342. Nonpersistent
    - 2350. Scrub-Shrub Wetland
        - 2351. BLD
        - 2352. NLD
        - 2353. BLE
        - 2354. NLE
        - 2355. Dead
    - 2360. Forested Wetland
        - 2361. BLD
        - 2362. NLD
        - 2363. BLE
        - 2364. NLE
        - 2365. Mixed
        - 2366. Dead

- 2400. Subtidal Fresh
  - 2410. Rock Bottom
    - 2411. Bedrock
    - 2412. Rubble
  - 2420. Unconsolidated Bottom
    - 2421. Cobble
    - 2422. Gravel
    - 2423. Sand
    - 2424. Mud
    - 2425. Organic
  - 2430. Aquatic Bed
    - 2431. Rooted Algal
    - 2432. Drift Algal
    - 2433. Rooted Vascular
    - 2434. Floating Vascular
    - 2435. Aquatic Moss
  - 2440. Reef
    - 2441. Mollusk
- 2500. Intertidal Fresh
  - 2510. Aquatic Bed
    - 2511. Rooted Algal
    - 2512. Drift Algal
    - 2513. Rooted Vascular
    - 2514. Floating Vascular
    - 2515. Aquatic Moss
  - 2520. Streambed
    - 2521. Bedrock
    - 2522. Rubble
    - 2523. Cobble
    - 2524. Gravel
    - 2525. Sand
    - 2526. Mud
    - 2527. Organic
  - 2530. Rocky Shore
    - 2531. Bedrock
    - 2532. Rubble
  - 2540. Unconsolidated Shore
    - 2541. Cobble
    - 2542. Gravel
    - 2543. Sand
    - 2544. Mud
    - 2545. Organic
  - 2550. Emergent Wetland
    - 2551. Persistent
    - 2552. Nonpersistent
  - 2560. Scrub-Shrub Wetland
    - 2561. BLD
    - 2562. NLD
    - 2563. BLE
    - 2564. NLE
    - 2565. Dead
  - 2570. Forested Wetland
    - 2571. BLD
    - 2572. NLD
    - 2573. BLE
    - 2574. NLE
    - 2575. Mixed
    - 2575. Dead

3000. Riverine Habitats

- 3100. Lower Perennial
  - 3110. Unconsolidated Bottom
    - 3111. Gravel
    - 3112. Sand
    - 3113. Mud
    - 3114. Organic
  - 3120. Aquatic Bed

                    - 3121. Aquatic Moss
                    - 3122. Rooted Vascular
                    - 3123. Floating Vascular
                - 3130. Rocky Shore
                    - 3131. Bedrock
                    - 3132. Rubble
                - 3140. Unconsolidated Shore
                    - 3141. Cobble
                    - 3142. Gravel
                    - 3143. Sand
                    - 3144. Mud
                    - 3145. Organic
                - 3150. Emergent Wetland
                    - 3151. Nonpersistent
            - 3200. Upper Perennial
                - 3210. Rock Bottom
                    - 3211. Bedrock
                    - 3212. Rubble
                - 3220. Unconsolidated Bottom
                    - 3221. Cobble
                    - 3222. Gravel
                    - 3223. Sand
                    - 3224. Mud
                - 3230. Aquatic Bed
                    - 3231. Algal
                    - 3232. Aquatic Moss
                    - 3233. Rooted Vascular
                    - 3234. Floating Vascular
                - 3240. Rocky Shore
                    - 3241. Bedrock
                    - 3242. Rubble
                - 3250. Unconsolidated Shore
                    - 3251. Cobble
                    - 3252. Gravel
                    - 3253. Sand
                    - 3254. Mud
                    - 3255. Organic
                - 3260. Emergent Wetland
                    - 3261. Nonpersistent
            - 3300. Intermittent
                - 3310. Streambed
                    - 3311. Bedrock
                    - 3312. Rubble
                    - 3313. Cobble
                    - 3314. Gravel
                    - 3315. Sand
                    - 3316. Mud
                    - 3317. Organic
                    - 3318. Vegetated
- 4000. Lacustrine Habitats
    - 4100. Limnetic
        - 4110. Rock Bottom
            - 4111. Bedrock
            - 4112. Rubble
        - 4120. Unconsolidated bottom
            - 4121. Cobble
            - 4122. Gravel
            - 4123. Sand
            - 4124. Mud
            - 4125. Organic
        - 4130. Aquatic Bed
            - 4131. Algal
            - 4132. Aquatic Moss
            - 4133. Rooted Vascular
            - 4134. Floating Vascular
    - 4200. Littoral

- 4210. Rock Bottom
  - 4211. Bedrock
  - 4212. Rubble
- 4220. Unconsolidated Bottom
  - 4221. Cobble
  - 4222. Gravel
  - 4223. Sand
  - 4224. Mud
  - 4225. Organic
- 4230. Aquatic Bed
  - 4231. Algal
  - 4232. Aquatic Moss
  - 4233. Rooted Vascular
  - 4234. Floating vascular
- 4240. Rocky Shore
  - 4241. Bedrock
  - 4242. Rubble
- 4250. Unconsolidated Shore
  - 4251. Cobble
  - 4252. Gravel
  - 4253. Sand
  - 4254. Mud
  - 4255. Organic
- 4260. Emergent Wetland
  - 4261. Nonpersistent

5000. Palustrine Habitats
- 5100. Perennial Water
  - 5110. Rock Bottom
    - 5111. Bedrock
    - 5112. Rubble
  - 5120. Unconsolidated Bottom
    - 5121. Cobble
    - 5122. Gravel
    - 5123. Sand
    - 5124. Mud
    - 5125. Organic
  - 5130. Aquatic Bed
    - 5131. Algal
    - 5132. Aquatic Moss
    - 5133. Rooted Vascular
    - 5134. Floating vascular
  - 5140. Emergent Wetland
    - 5141. Nonpersistent
- 5200. Intermittent or Saturated
  - 5210. Unconsolidated Shore
    - 5211. Cobble
    - 5212. Gravel
    - 5213. Sand
    - 5214. Mud
    - 5215. Organic
  - 5220. Moss-Lichen Wetland
    - 5221. Moss
    - 5222. Lichen
  - 5230. Emergent Wetland
    - 5231. Nonpersistent
    - 5232. Persistent
  - 5240. Scrub-Shrub Wetland
    - 5241. BLD
    - 5242. NLD
    - 5243. BLE
    - 5244. NLE
    - 5245. Dead
  - 5250. Forested Wetland
    - 5251. BLD
    - 5252. NLD
    - 5253. BLE

            - 5254. NLE
            - 5255. Mixed
            - 5256. Dead
- 6000. Upland Habitats
    - 6100. Supratidal Upland
        - 6110. Rocky Upland
            - 6111. Bedrock
            - 6112. Rubble
        - 6120. Unconsolidated Upland
            - 6121. Cobble
            - 6122. Gravel
            - 6123. Sand
            - 6124. Clay
            - 6125. Loam
            - 6126. Organic
        - 6130. Herbaceous Upland
            - 6131. Grassland
            - 6132. Broad-leaved Herbs
        - 6140. Scrub-Shrub Upland
            - 6141. BLD
            - 6142. NLD
            - 6143. BLE
            - 6144. NLE
            - 6145. Dead
        - 6150. Forested Upland
            - 6151. BLD
            - 6152. NLD
            - 6153. BLE
            - 6154. NLE
            - 6155. Mixed
            - 6156. Dead
    - 6200. Inland Upland
        - 6210. Rocky Upland
            - 6211. Bedrock
            - 6212. Rubble
        - 6220. Unconsolidated Upland
            - 6221. Cobble
            - 6222. Gravel
            - 6223. Sand
            - 6224. Clay
            - 6225. Loam
            - 6226. Organic
        - 6230. Herbaceous Upland
            - 6231. Grassland
            - 6232. Broad-leaved Herbs
        - 6240. Scrub-Shrub Upland
            - 6241. BLD
            - 6242. NLD
            - 6243. BLE
            - 6244. NLE
            - 6245. Dead
        - 6250. Forested Upland
            - 6251. BLD
            - 6252. NLD
            - 6253. BLE
            - 6254. NLE
            - 6255. Mixed
            - 6256. Dead
- 7000. Perennial Snow and Ice Habitats
    - 7100. Perennial Snowfields
    - 7200. Glaciers
- 8000. Cultural Land Cover
    - 8100. Developed Upland
        - 8110. Impervious Cover
            - 8111. Paved Lot
            - 8112. Paved Roadway

        - 8113. Large Building
        - 8114. Impervious Complex
    - 8120. Built-up Cover
        - 8121. Commercial or Service Complex
        - 8122. Industrial Complex
    - 8130. Residential Cover
        - 8131. Low Density
        - 8132. Medium Density
        - 8133. High Density
    - 8140. Rocky Cover
        - 8141. Rocky Revetment
        - 8142. Open Quarry
    - 8150. Unconsolidated Cover
        - 8151. Cleared Land
        - 8151. Dirt/gravel Lot
        - 8152. Dirt/gravel Road
        - 8153. Railway Corridor
        - 8154. Mining Operation
        - 8155. Landfill Operation
    - 8160. Herbaceous Cover
        - 8161. Managed Turf
        - 8162. Managed Garden
        - 8163. Managed Old Field
    - 8170. Shrub Cover
        - 8171. Managed Shrubs
    - 8180. Tree Cover
        - 8181. Managed Trees
- 8200. Agricultural Upland
    - 8210. Rocky Cover
        - 8211. Rocky Revetment
    - 8220. Unconsolidated Cover
        - 8221. Unvegetated Farmland
    - 8230. Herbaceous Cover
        - 8231. Turf
        - 8232. Pasture
        - 8233. Hay Meadow
        - 8234. Crops/Cover Crops
    - 8240. Shrub Cover
        - 8241. Shrub Nursery
        - 8242. Grazed Shrub Upland
    - 8250. Tree Cover
        - 8251. Tree Farm
        - 8252. Orchard
        - 8253. Grazed Wooded Upland
- 8300. Developed and Managed Wetlands and Water
    - 8310. Impervious Cover
        - 8311. Impervious Bottom
        - 8312. Impervious In-water Structure
    - 8320. Built-up Cover
        - 8321. Pervious In-water Structure
        - 8322. In-water Commercial or Service Complex
        - 8323. In-water Industrial Complex
        - 8324. Shellfish Aquiculture
        - 8325. Finfish Aquiculture
    - 8330. Residential Cover
        - 8331. In-water Residential Complex
    - 8340. Rocky Cover
        - 8341. Rocky Shoreline Structure
        - 8342. Rocky In-water Structure
    - 8350. Unconsolidated Cover
        - 8351. Managed Unconsolidated Bottom
        - 8352. Managed Unconsolidated Shore
    - 8360. Herbaceous Cover
        - 8361. Managed Herbaceous Wetland
        - 8362. Agricultural Herbaceous Wetland
        - 8363. Grazed Herbaceous Wetland

8370. Shrub Cover
- 8371. Managed Wetland Shrubs
- 8372. Agricultural Wetland Shrubs
- 8373. Grazed Shrub Wetland

8380. Tree Cover
- 8381. Managed Wetland Trees
- 8382. Agricultural Wetland Trees
- 8383. Grazed Wooded Wetland

Appendix 2

Some suggested **modifier types** and modifiers to NERRS *descriptors* (in progress)

1. **Dominant Species**: The scientific name, by genus and species, of the dominant floral or sessile faunal cover (examples below)
    - *Acer rubrum*
    - *Spartina alterniflora*
    - *Mytilus edulis*
    - N/A (for non-vegetated habitats)
2. **Invasive Species**: The scientific name and percent cover (by class) of the most influential invasive species present in the habitat (examples below)
    - *Celastrus orbiculatus* <1%
    - *Polygonum cuspidatum* 1-5%
    - *Elaeagnus umbellata* 6-25%
    - *Rosa multiflora* 26-50%
    - *Lonicera japonica* 51-75%
    - *Phragmites australis* 76-100%
3. **Water Regime**: Hydroperiod modifiers from Cowardin et al. (1979). * Tidal; all others are nontidal
    - Subtidal*
    - Irregularly Exposed*
    - Regularly Flooded*
    - Irregularly Flooded*
    - Permanently Flooded
    - Intermittently Exposed
    - Semipermanently Flooded
    - Seasonally Flooded
    - Saturated
    - Temporarily Flooded
    - Intermittently Flooded
    - Artificially Flooded
4. **Salinity**: Surface and wetland soil water salinity in classes defined by Cowardin et al. (1979). * Ocean derived salts; all others are inland derived
    - Hyperhaline (>40‰*)
    - Euhaline (30.0-40‰*)
    - Polyhaline (18.0-30‰*)
    - Mesohaline (5.0-18‰*)
    - Oligohaline (0.5-5‰*)
    - Hypersaline (>40‰)
    - Eusaline (30.0-40‰)
    - Polysaline (18.0-30‰)
    - Mesosaline (5.0-18‰)
    - Oligosaline (0.5-5‰)
    - Fresh (<0.5‰)
5. **Cultural**: Historic modifications influencing the habitats (from Cowardin et al. 1979 *Special Modifiers*)
    - Excavated
    - Impounded

- Diked
- Partially drained
- Artificial
- Dredged

6. **Managed**: Reflect management actions affecting the habitats, and the number if growing seasons between the action and the inventory (examples below)
    - Burned 0
    - Burned 1
    - Burned 2
    - Mowed 0
    - Mowed 1
    - Mowed 2
    - Tidally Restored 0
    - Tidally Restored 1
    - Tidally Restored 2

Other suggestions for optional **modifier types** and modifiers:

1. **Prehistoric Sites**: Sites with prehistoric substrate or landscape modifications existing beneath contemporary habitat types (examples below)
    - Ceremonial Mounds
    - Middens
    - Scatter Sites
2. **Historic Sites**: Sites with historically significant cultural modifications existing beneath or within contemporary habitat types (examples below)
    - Earthworks
    - Event Sites
3. **Erosion Control**: Features contained within or along shoreline habitats that affect the forces of tides, drift, wave action, etc.
    - Bulkhead
    - Sill
    - Revetment
    - Rip-rap

For 1, 2, and 3, note that only two dimensional (polygonal) features will be appropriate for incorporation directly into a habitat mapping inventory, as the dataset will be designed to assess extent (area, location, and to a lesser degree, perimeter) of features. Line and point features should be inventoried as separate datasets. However, modifiers can be applied to indicate that linear or small features lie within, or have an effect on a habitat or land use.

4. **Cultural Structural Cover**: Subdivisions or modifiers of *Cultural Land Use* cover types by structural, homogeneous cover classes (examples below).
    - Lawn
    - Cement or Blacktop
    - Permeable roadway/trail/lot
    - Shrubs (manicured)
    - Structure

- Trees (over manicured lawn)

Note that minimum mapping unit (TBD) will dictate the applicability of these to analysis against the dataset.

5. **Keystone Species**: Identifies species within a habitat that may be important ecologically, but perhaps not numerically or physically dominant, in e.g. individuals per area or volume (examples below).
    - *Littorina littorea* 20 m^{-2}
    - *Fundulus heteroclitis* 15 m^{-2}
    - *Lumbricus* sp. 50 m^{-2}
6. **Natural Disturbance**: Identifies natural disturbances that have had an effect on the habitat, and number of growing seasons since the disturbance. (examples below)
    - Fire 4
    - Flooding 2
    - Tornado 3

Appendix 3

The C-CAP Classification Scheme (taken directly from C-CAP 2004)

The following information provides explicit descriptions of the land cover classes used for C-CAP land cover mapping projects. Information included in these definitions explain the types of land cover features that are found in each class as well as threshold values for percent imperviousness and percent canopy coverage. These descriptions have been revised from the original *NOAA Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation*, which summarizes original C-CAP methods and procedures. The definitions provided also reflect changes in the original C-CAP classification scheme that have occurred as a result of a partnership between NOAA and the U.S. Geological Survey (USGS). This partnership establishes NOAA as the provider of land cover data for the coastal regions of the National Land Cover Database (NLCD).

0 Background – areas within the image file limits but containing no data values

1 Unclassified – areas in which land cover cannot be determined; these include clouds and deep shadow.

Uplands

Consisting of areas above sea level where saturated soils and standing water are absent. Also, the Hydrologic regime is not sufficiently wet to support vegetation associated with wetlands. Upland features are divided into classes such as High, Medium, Low Intensity Development, Cultivated land, Grassland, Pasture/ Hay, Barren land, Scrub/Shrub, Dwarf Shrub, Deciduous, Evergreen and Mixed Forest.

2 Developed, High Intensity – Includes highly developed areas where people reside or work in high numbers. Impervious surfaces account for 80 to 100 percent of the total cover.

Characteristic land cover features: Large commercial/industrial complexes and associated parking, commercial strip development, large barns, hangars, interstate highways, and runways.

3 Developed, Medium Intensity – Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50 to 79 percent of the total cover.

Characteristic land cover features: Small buildings such as single family housing units, farm outbuildings, and large sheds.

4 Developed, Low Intensity – Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 21 to 49 percent of total cover.

Characteristic land cover features: Same as Medium Intensity Developed with the addition of streets and roads with associated trees and grasses. If roads or portions of roads are present in the imagery they are represented as this class in the final land cover product.

5 Developed, Open Space – Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover.

Characteristic land cover features: Parks, lawns, athletic fields, golf courses, and natural grasses occurring around airports and industrial sites.

6 Cultivated Crops – Areas used for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

Characteristic land cover features: Crops (corn, soybeans, vegetables, tobacco, and cotton), orchards, nurseries, and vineyards.

7 Pasture/Hay – Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle and not tilled. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

Characteristic land cover features: Crops such as alfalfa, hay, and winter wheat.

8 Grassland/Herbaceous – Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Characteristic land cover features: Prairies, meadows, fallow fields, clear-cuts with natural grasses, and undeveloped lands with naturally occurring grasses.

9 Sedge / Herbaceous – (Alaska only) Areas dominated by sedges and forbs, generally greater than 80 percent of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra and sedge tussock tundra.

10 Deciduous Forest – Areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

Characteristic species: Maples (*Acer*), Hickory (*Carya*), Oaks (*Quercus*), and Aspen (*Populus tremuloides*).

11 Evergreen Forest – Areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

Characteristic species: Longleaf pine (*Pinus palustris*), slash pine (*Pinus ellioti*), shortleaf pine (*Pinus echinta*), loblolly pine (*Pinus taeda*), and other southern yellow (*Picea*); various spruces and balsam fir (*Abies balsamea*); white pine (*Pinus strobus*), red pine (*Pinus resinosa*), and jack pine (*Pinus banksiana*); hemlock (*Tsuga canadensis*); and such western species as Douglas-fir (*Pseudotsuga menziesii*), redwood (*Sequoia sempervirens*), ponderosa pine (*Pinus monticola*), Sitka spruce (*Picea sitchensis*), Engelmann spruce (*Picea engelmanni*), western red cedar (*Thuja plicata*), and western hemlock (*Tsuga heterophylla*).

12 Mixed Forest – Areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

Characteristic species: Those listed in 9 and 10.

13 Scrub/Shrub – Areas dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

Characteristic species: Those listed in 9 and 10 as well as chaparral species such as chamise (*Adenostoma fasciculatum*), chaparral honeysuckle (*Lonicera interrupta*), scrub oak (*Quercus beberidifolia*), sagebrush (*artemisia tridentate*), and manzanita (*Arctostaphylos spp.*).

14 Dwarf Scrub – (Alaska only) Areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20 percent of total vegetation. This type is often associated with grasses, sedges, herbs, and nonvascular vegetation.

15 Barren Land – (rock/sand/clay) Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earth material. Generally, vegetation accounts for less than 10 percent of total cover.

Characteristic land cover features: Quarries, strip mines, gravel pits, dunes, beaches above the high-water line, sandy areas other than beaches, deserts and arid riverbeds, and exposed rock.

Wetlands

Areas dominated by saturated soils and often standing water. Wetlands vegetation is adapted to withstand long-term immersion and saturated, oxygen-depleted soils. These are divided into two salinity regimes: Palustrine for freshwater wetlands and Estuarine for saltwater wetlands. These are further divided into Forested, Shrub/Scrub, and Emergent wetlands. Unconsolidated Shores are also included as wetlands.

16 Palustrine Forested Wetland – Includes all tidal and nontidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent.

Characteristic species: Tupelo (Nyssa), Cottonwoods (*Populus deltoids*), Bald Cypress (*Taxodium distichum*), American elm (*Ulmus Americana*), Ash (*Fraxinus*), and tamarack.

17 Palustrine Scrub/Shrub Wetland – Includes all tidal and non tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent. The species present could be true shrubs, young trees and shrubs, or trees that are small or stunted due to environmental conditions (Cowardin et al. 1979).

Characteristic species: Alders (*Alnus spp*.), willows (*Salix spp*.), buttonbush (*Cephalanthus occidentalis*), red osier dogwood *(Cornus stolonifera*), honeycup (*Zenobia pulverenta*), spirea (*Spiraea douglassii*), bog birch (*Betula pumila*), and young trees such as red maple (*Acer rubrum*) and black spruce (*Picea mariana*).

18 Palustrine Emergent Wetland (Persistent) – Includes all tidal and nontidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Plants generally remain standing until the next growing season. Total vegetation cover is greater than 80 percent.

Characteristic species: Cattails (*Typha spp*.), sedges (*Carex spp.*), bulrushes (*Scirpus spp.*), rushes (*Juncus spp*.), saw grass (*Cladium jamaicaense*), and reed (*Phragmites australis*).

19 Estuarine Forested Wetland – Includes all tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.

Characteristic species: Red Mangrove (*Rhizophora mangle*), Black Mangrove (*Avicennia germinans*) and White Mangrove (*Languncularia racemosa*)

20 Estuarine Scrub / Shrub Wetland – Includes all tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.

Characteristic species: Sea-myrtle (*Baccharis halimifolia*) and marsh elder (*Iva frutescens*).

21 Estuarine Emergent Wetland – Includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens). Wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and that are present for most of the growing season in most years. Perennial plants usually dominate these wetlands. Total vegetation cover is greater than 80 percent.

Characteristic species: Cordgrass (*Spartina spp.*), needlerush (*Juncus roemerianus*), narrow leaved cattail (*Typha angustifolia*), southern wild rice (*Zizaniopsis miliacea*), common pickleweed (*Salicornia virginica*), sea blite (*Suaeda californica*), and arrow grass (*Triglochin martimum*).

22 Unconsolidated Shore – Unconsolidated material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms representing this class.

Characteristic land cover features: Beaches, bars, and flats.

23 Open Water – All areas of open water, generally with less than 25 percent cover of vegetation or soil.

Characteristic land cover features: Lakes, rivers, reservoirs, streams, ponds, and ocean.

24 Palustrine Aquatic Bed – Includes tidal and nontidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is below 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages. Total vegetation cover is greater than 80 percent.

Characteristic species: Vascular – Pondweed, horned pondweed (*Zannichellia palustris*), ditch grass (*Ruppia*), wild celery, waterweed (*Elodea*), riverweed (*Podostemum ceratophyllum*), water lilies (*Nymphea, Nuphar*), floating-leaf pondweed (*Potamogeton natans*), and water shield (*Brasenia schreberi*), water smartweed (*Polygonum amphibium*). Floating Surface – Duckweeds (*Lemna, Spirodela*), water lettuce (*Pista stratiotes*), water hyacinth (*Eichhornia crasspies*), water nut (*Trapa natans*), water fern (*Salvinia spp.*), and mosquito ferns (*Azolla*). Floating Below Surface – Bladderworts (*Utricularia*), coontails (*Ceratophyllum*) and watermeals (*Wolffia*).

25 Estuarine Aquatic Bed – Includes tidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, kelp beds, and rooted vascular plant assemblages. Total vegetation cover is greater than 80 percent.

Characteristic species: Kelp (*Macrocystis and Laminaria*), rockweeds (*Fucus* and *Ascophyllum*), red algae (*Laurencia*), green algae (*Halimeda* and *Penicillus, Caulerpa, Enteromorpha* and *Ulva*), stonewort (*Chara*), turtle grass (*Thalassia testudinum*), shoal grass (*Halodule wrightii*), manatee grasses (*Cymodocea filiformis*), widgeon grass (*Ruppia maritime*), sea grasses (*Halophila spp.*), and wild celery (*Vallisneria americana*).

26 Tundra – Treeless cover beyond the latitudinal limit of the boreal forest in poleward regions and above the elevation range of the boreal forest in high mountains. In the United States, tundra occurs primarily in Alaska, several areas of the western high mountain ranges, and isolated enclaves in the high mountains of New England and northern New York.

27 Perennial Ice/Snow – All areas characterized by a perennial cover of ice and/or snow, generally greater than 25 percent of total cover.

28 Moss – (Alaska only) Areas dominated by mosses, generally greater than 80 percent of total vegetation.

29 Lichens – Areas dominated by fruticose or foliose lichens, generally greater than 80 percent of total vegetation.