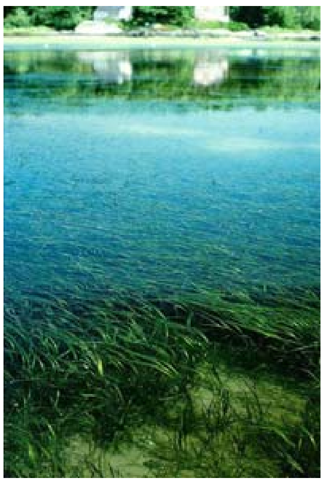
Habitat Classification Feasibility Study for Coastal and Marine Environments in Massachusetts



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Commonwealth of Massachusetts

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EXECUTIVE SUMMARY

Habitat classification is the process of identifying habitat types based on a set of standard terms and descriptors. While several marine habitat classification schemes are available and used by various researchers and resource management agencies, none are universally accepted because each scheme has unique benefits and challenges. For example, the most widely used habitat classification system was developed for wetlands by Cowardin et al. (1979), which does not adequately address subtidal marine habitats. Therefore, other classification schemes were developed to meet local needs and incorporate a wider range of coastal and marine habitats.

Habitat classification frameworks are typically designed to organize geospatial data in a nested hierarchy. Nested hierarchical classification divides major groups or classes into subordinate groups or classes and allows the necessary flexibility required for decision making and/or use of available data. However, existing classification schemes were developed with different goals, data organization structure and intended application. The differences in schemes result in particular frameworks suitable for defining broad scale (>km) systems or zones, such as estuary or deepwater basin, compared to other approaches more effective at delineating and describing specific fine-scale (cm to mm) habitat attributes (e.g., eelgrass bed and shellfish reef).

The Massachusetts Office of Coastal Zone Management (CZM) initiated this study to better understand published approaches to classify coastal and ocean habitats to facilitate mapping the state-wide distribution of habitats. CZM, in cooperation with the United States Geological Survey (USGS), initiated a seafloor mapping program in 2003 to produce high-resolution maps and geospatial data of seafloor topography and surficial sediments. These maps provide the foundation for a better understanding of oceanic benthic habitats. This study is the beginning of a process to identify appropriate habitat classification approaches for Massachusetts and evaluate the feasibility of applying the habitat classification approaches to the coastal and marine environments in Massachusetts.

An important resource for this study was the Coastal and Marine Ecological Classification Standard (CMECS; Madden et al. 2005), since CMECS included reviews and summaries of many habitat classification studies. CMECS was recently developed by NatureServe, National Oceanic and Atmospheric Administration (NOAA), and other partners to provide a national framework to classify estuarine, coastal and ocean environments of North America. CMECS and additional studies were reviewed during this study to identify and describe habitat classification schemes most pertinent for coastal and marine environments in Massachusetts. The following four habitat classification schemes are recommended for further consideration in Massachusetts:

- Greene, H.G., J.J. Bizzarro, V. O'Connell and C.K. Brylinsky. In press. Construction of digital potential marine benthic habitat maps using a coded classification scheme and their application. In H.G. Greene and B.J. Todd (eds.) , Mapping the Seafloor for Habitat Characterization. Geological Association of Canada, Special Paper 47.

- Kutcher, T.E., N.H. Garfield and K.B. Raposa. 2005 (draft). A recommendation for a comprehensive habitat and land use classification system for the National Estuarine Research Reserve System. National Estuarine Research Reserve, Estuarine Reserves Division. Draft report to NOAA/NOS/OCRM. Silver Spring, MD. 26 pp.

- Madden, C.J., D.H. Grossman and K.L. Goodin. 2005. Coastal and Marine Systems of North America: Framework for an Ecological Classification Standard: Version II. NatureServe, Arlington, VA.

- Valentine, P.C., B.J. Todd and V.E. Kostylev. 2005. Classification of marine sublittoral habitats, with application to the northeastern North America region. American Fisheries Society Symposium 41:183-200.

This report summarizes the goal, geographic focus, hierarchical or classification organization, classification coding system and data sources and scale for the four classification studies. The advantages and disadvantages of each classification were also evaluated in relation to determining the most suitable framework or combination of frameworks for classifying coastal and marine habitats in Massachusetts.

In addition to summarizing the four recommended classification frameworks, this study outlines the role of habitat classification in resource management, considerations for application to GIS (geographic information systems) and other related habitat classification activities in the region. Staff at the Massachusetts Division of Marine Fisheries (DMF), USGS, National Estuary Programs, US Environmental Protection Agency (USEPA) and the National Estuarine Research Reserve System not only informed this project, but could also be considered as future sources of technical advice. It is important to identify potential collaborations and overlapping efforts of these organizations and agencies.

The study also raises questions and recommends steps to consider before choosing a classification scheme, determining a pilot area to test classification schemes and after evaluating classification schemes. The application and examination of the four recommended schemes in the coastal and marine environments of Massachusetts is a particularly important step. The results of the pilot study will guide the process to ultimately identify an appropriate framework or hybrid of frameworks to create a singular and flexible classification system to classify coastal and marine habitats in Massachusetts.

OBJECTIVES

The goals of this feasibility study are to (1) identify and describe habitat classification schemes most pertinent for coastal, estuarine and marine environments in Massachusetts and (2) assess benefits, limitations, similarities and differences of select classification schemes recommended for consideration in Massachusetts. A thorough literature search and communication with contacts at federal and state agencies as well as academic researchers informed this study, which also provides an update on activities for the schemes most likely to be used by CZM. This report will also help inform the ocean management planning efforts in Massachusetts by identifying recommendations and next steps to ultimately produce a single classification framework for Massachusetts. While habitat classification is of interest to a wide variety of users, the audience for this feasibility study is coastal and marine resource managers to help them understand habitat mapping and classification issues and the referenced research and decide which classification approach(es) best meet resource management needs.

BACKGROUND

The coastal and marine environments in Massachusetts contain a relatively diverse mosaic of habitats. The types and functions of habitats are largely influenced by the position of Massachusetts at the intersection of northern waters of the Gulf of Maine and southern waters of the mid-Atlantic Bight. Managing coastal and marine resources requires a common understanding of the types of habitats within Massachusetts and a comprehension of terminology used to study and describe habitats. Habitat classification is a forthcoming and evolving tool to standardize technical jargon and organize habitat information to facilitate habitat management.

Estuarine and Marine Habitats in Massachusetts

Two biogeographic regions encompass Massachusetts, with Cape Cod marking the boundary between the Acadian and Virginian provinces (Figure 1). The provinces are distinguished by substantial differences in physical characteristics, weather patterns and biological communities. This variation exerts a strong influence on habitat abundance and function. Managing, mapping and classifying resources and habitats across biogeographic zones requires recognition of the variability in ecological features and human influences of each region.

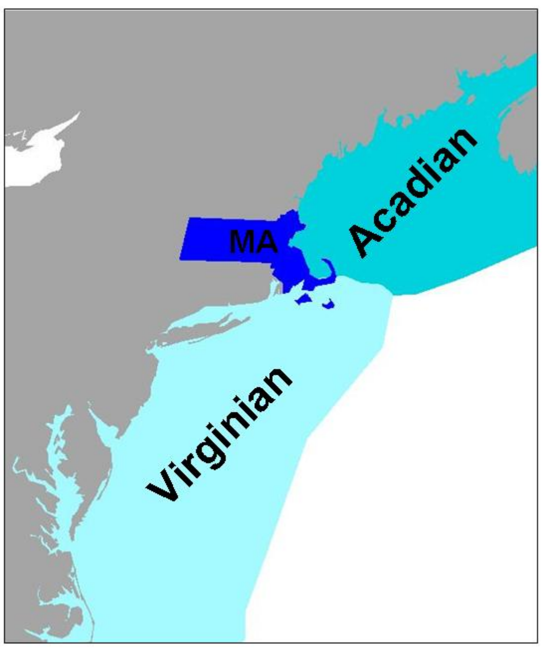

Figure 1: Location of Massachusetts, including the Acadian and Virginian Provinces.

During the last major glacial period in New England, 10,000 to 20,000 years ago, glaciers advanced to Cape Cod. Glaciers scoured landforms and deposited sediments, leaving markedly distinct environments in northern and southern Massachusetts. The coastline in northern Massachusetts is recognized for rocky shores, while southern Massachusetts is dominated by sandy beaches. These coastal features, with a mosaic of other bottom types such as mud, are largely mirrored in the underwater environment. While the ocean environment in northern and southern Massachusetts share many characteristics and habitats, the differences in geologic framework and species assemblages influence the type and function of marine habitat supported in each region. Tyrrell (2005) and Massachusetts Office of Coastal Zone Management (2004-2005) provide a summary of physical and biogenic habitats and ecological relationships found in Massachusetts.

Habitat Management

Coastal and fishery resource managers are frequently tasked with making decisions about uses of the coastal zone and ocean environment without sufficient knowledge of the habitat types that may be impacted by proposed projects. Massachusetts faces strong development pressures in the coastal zone from existing and proposed projects such as aquaculture, wind farms, pipeline and cable installations, deepwater ports, construction of docks and piers and sewage outfalls. Pollutants, such as excessive nutrients and heavy metals, also enter coastal and ocean waters from a variety of sources (e.g., atmospheric deposition, groundwater, stormwater, etc.). The combination of anthropogenic influences and natural disturbances potentially disrupt and degrade habitat functions and values (see Wilbur and Pentony 1998 for review of human-induced impacts to marine habitat). Without comprehensive maps of the ocean environment and standardized classification of habitats, resource management is hindered and the assessment of the relative abundance of various habitat types is impossible.

The advent of technology to map seafloor topography and surficial geology is, however, providing a fundamental information base for the ocean environment in Massachusetts. Acoustic – or sonar – mapping (e.g., sidescan, multibeam and seismic reflection) in combination with underwater imagery and benthic sampling provides accurate views of the seafloor landscape and supports efforts to classify benthic environments. By acquiring these types of data and being better able to identify and classify habitats in a standardized way, resource managers can enhance their ability to protect particularly sensitive or productive habitat types (Tyrrell 2004).

Many steps go into mapping a habitat, including collecting and analyzing physical, chemical and biological data, applying a classification system to identify and classify habitat types and analyzing data to depict habitat boundaries. Terminology to describe habitat management activities is often confusing. The following key terms are defined to provide a basis for the remainder of this study (Valentine et al. 2005):

- ***Habitat characterization*** produces narrative and illustrative descriptions of habitats based on geological, biological, chemical and oceanographic observations and sampling.

- ***Habitat classification*** is the process of identifying habitat types based on a set of standard terms.

- ***Habitat mapping*** is the spatial representation of described and classified habitat units.

Many different data types are used to characterize, classify and map ocean habitats. Data applied to habitat studies range from previously published seafloor geologic, biologic and bathymetric maps to newly collected remote sensing images (e.g., multibeam bathymetry, sidescan sonar and LIDAR – Light Detection And Ranging) and in situ observation such as video, still photographs, benthic grabs and trawls (Greene et al. 2005). Figure 2 shows imagery and a map illustrating habitat classes in southeast Alaska (Greene et al. In Press). In general, there are various approaches to study the seafloor, ranging from broad geologic framework research to species behavior and habitat requirements observations. The result of the variety of seafloor-related studies is a more comprehensive understanding of the types, distribution, abundance and ecological function of habitats in the estuarine and ocean environment. Furthermore, increasing the scientific knowledge of the marine environment guides the development of appropriate habitat classification frameworks.

According to the "Strategic Plan for Mapping Massachusetts' Benthic Marine Habitats," the first phase for a mapping program in Massachusetts should involve high-resolution acoustic or spectral sensor mapping of surficial geology (Tyrrell 2004). The second phase should integrate biological data gathered by groundtruth sampling or other biological sampling (e.g., stock assessment and benthic community monitoring) into the geological maps or targeted studies to produce seafloor habitat maps. However, "one of the biggest obstacles to conducting large-scale benthic habitat mapping may be the lack of a commonly accepted marine habitat classification system" (Tyrrell 2004). Therefore, closely coupled with the second phase is the need to identify and choose a habitat classification scheme so that mapping efforts begin using standardized terminology and methods to classify habitat types.

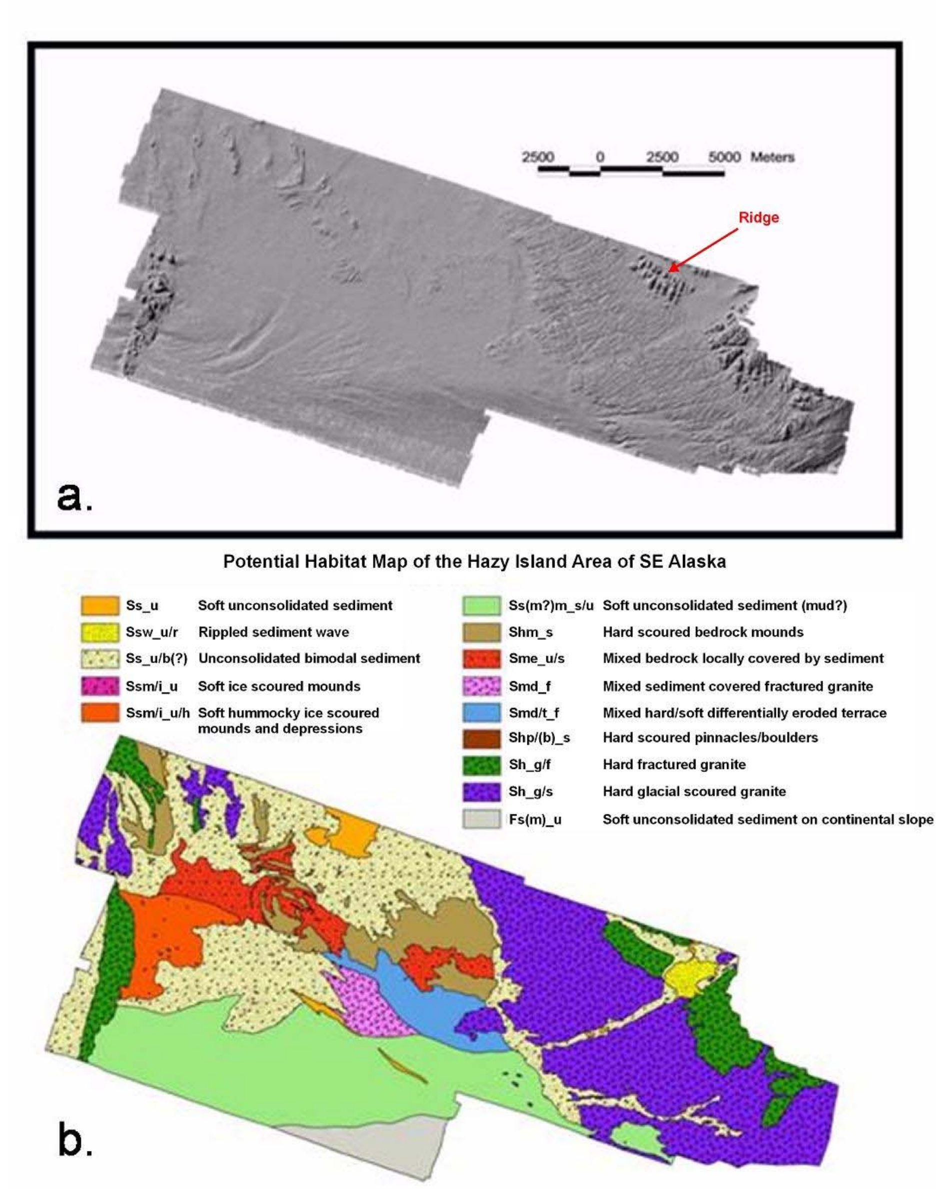

Figure 2. Example of multibeam bathymetry (a.) and seafloor habitat interpretation (b.) from southeast Alaska. Habitat codes follow the benthic habitat classification scheme of Greene et al. (1999; In Press). Images reproduced from Greene et al. (In Press).

Habitat Classification

Habitat classification schemes generally assess similar abiotic and biotic variables and assign names to a combination of habitat characteristics. For example, seafloor topography and surficial sediments are fundamental to appropriately classify a seafloor habitat in all classification schemes. The number of habitats that will be recognized and classified in a region depends on the physical and biological heterogeneity of the seabed, data availability and scale (Valentine et al. 2005).

An effective classification scheme is helpful to resource managers and scientists because it standardizes terminology, organizes data in a logical manner, allows habitat types to be coded for data management and facilitates communication among users. For example, a national agency seeking to identify and catalog all large estuaries in North America can restrict their analysis to the upper, coarse-scale levels of a classification hierarchy, while a local agency working within an estuary will use the lower, more detailed levels of a classification scheme. Using classification codes as a common standard, both agencies will be able to organize and compare results using a unified vocabulary within a common data framework. The differences in classification schemes reflect how designers choose to organize, understand and rank the structures and functions of natural systems (Valentine et al. 2005).

The most effective classification schemes are organized in a nested hierarchy, which allows data to be organized at the level of detail desired by the user and aids data analysis and mapping. A nested hierarchy is structured in such a way that the top level class is subdivided into second level classes and each second level class into third level classes and so on (Kurtz et al. 2006; Figure 3). Each lower level describes the habitat at a higher degree of detail and spatial precision.

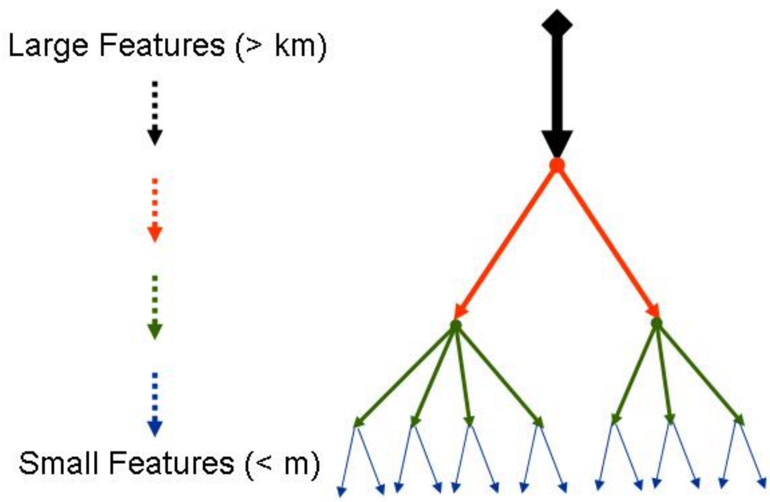

Figure 3. Schematic showing structure of nested hierarchy and generic difference in size of features among classes.

When classifying habitat types, the level of classification achieved depends on the scale of data gathered for a particular area. For example, a map showing classified data developed from remotely sensed images without ground validation will often only be valid for less-detailed, higher (broad) classification levels. This highlights the need for groundtruthing remote sensing data and gathering more detailed information (e.g., grain size and composition, biota and water column properties) to classify habitat to the lowest and most-detailed levels in a classification hierarchy (Madden et al. 2004b). Thus, a habitat can be mapped as narrowly or as broadly as the data and purpose permit, and this flexibility of scale influences the development of habitat classification schemes (Valentine et al. 2005).

Classified habitats require consistent names and coding systems to organize data to facilitate communication among the management, science and stakeholder communities. The coding or naming conventions typically include numeric or letter sequences (or both). Although habitat name codes can be cumbersome and require effort to decipher, they are necessary shorthand for communication in situations where long text descriptions are inappropriate and where the information needs to be incorporated into a database (Kutcher et al. 2005; Valentine et al. 2005). In geographic information system (GIS) and spreadsheet formats, a coding system also facilitates data organization and queries (Kutcher et al. 2005).

Of particular interest in Massachusetts is classifying benthic habitat. A standard approach to classifying marine benthic habitats is not established and endorsed by the scientific and management communities, even though several schemes exist or are evolving (e.g., Valentine et. al. 2005 and Greene et al. In Press). The lack of a generally accepted habitat classification scheme, encompassing benthic, water column and coastal environments, leads resource managers to either modify existing approaches for their study site or develop new schemes.

ROLE OF HABITAT CLASSIFICATION IN RESOURCE MANAGEMENT

Habitat management is emerging as an important consideration for regulating coastal and fisheries resources. While aspects of habitat management, such as wetlands protection and restoration, are well-founded in resource management, the improved understanding of the ocean environment coupled with continued anthropogenic impacts highlights the need for a comprehensive strategy to manage coastal and ocean resources. New approaches to manage ocean resources (e.g., ecosystem-based management) require a solid information base, which includes identification and delineation of estuarine and marine habitat.

Maps showing habitat characteristics, such as seafloor topography and surficial sediments, are expected to improve the efficiency of managing the ocean environment throughout Massachusetts (Tierney et al. 2004). Examples of processes that will improve as a result of habitat mapping include: resource managers referencing the maps when siting projects (e.g., docks and piers, mooring fields, dredged material disposal, cable and pipeline routes, aquaculture sites, no wake zones and other activities); scientists identifying monitoring locations based on specific habitat features; and GIS analysts quantifying the amount of different habitat types protected by various management options (Tyrrell 2004). In addition, habitat maps and classifications are important to the identification of essential fish habitat (EFH) and the facilitation of habitat-based fishery management. For example, a classification code created in the contiguous western U.S. for NOAA's National Marine Fisheries Service was adopted and modified to produce EFH maps (Greene et al. In Press).

Overall, coastal and fishery managers can benefit from adopting a classification scheme because it will: (1) provide a mechanism for identifying and mapping habitats in the ocean with standardized descriptions; (2) facilitate communication among scientists, managers and stakeholders; (3) help habitat mapping efforts by combining spatial information with a standardized coding system in GIS; and (4) better organize and communicate habitat information to help address a variety of management issues.

Coastal Zone Management Considerations

Since every classification approach is a tool to accomplish a given set of objectives (Kutcher 2006), CZM needs to identify objectives for classifying habitats. The following questions are important to consider while studying classification approaches:

- *What are the specific management questions CZM hopes to address with a classification approach?*

  Will a classification scheme be used to facilitate project review, organize habitat map products, help monitor habitat change through time, design restoration strategies and/or plan areas for zoning and conservation designation? The answer is most likely yes to all of these questions. Management needs should be clearly articulated to help define the type and level of classification required to achieve management objectives. Furthermore, identifying management objectives will assist in determining the resolution of data required to support a particular scheme and management strategy.

  Data requirements to support classification efforts intended to address management issues need *a-priori* decision-making. For example, preliminary planning efforts to site a submerged pipeline may use coarse resolution surveys (remote sensing technologies) to understand general sedimentary characteristics and distribution of seagrass, while fine-scale resolution of biological and physical characteristics are needed to assess potential environmental impacts and determine a final pipeline route.

  CZM would benefit from a scheme (or combination of schemes) that includes both detailed and broad habitat features. Nested hierarchal structures, beginning at the landscape level and succeeding into ecosystem function and habitats, lend utility to different needs of scale, data availability and management issues. Identifying key management questions will help ensure that the development and selection of a classification scheme will appropriately support management issues.

- *Does CZM want to adopt a system that has local, regional and/or national relevance?*

  Madden et al. (2005) was developed at the national level and is in the process of being sanctioned by NOAA as a national approach. Future funding and resources may become available from national funding sources for projects using this scheme. In addition, the value of using a classification system may be enhanced if the scheme were congruent with a nationally accepted marine and estuarine habitat classification approach so that eventually a regional synthesis can be made between states and perhaps even Canadian provinces. It may be useful to link habitat classification and mapping efforts in Massachusetts to the wider region so that environmental problems at local scales can benefit from the ability to link to regional scale data.

  Classification schemes with a particular geographic focus, such as northeastern North America (Valentine et al. 2005) or zone (e.g., deep-sea; Greene et al. 1999), are seemingly effective in classify habitats in the intended focus areas. These types of studies are adaptable (see Greene et al. In Press) to other geographic areas and habitats and may provide a more-effective means of describing fine-scale elements of habitat.

- *Does CZM want to include nearshore and even terrestrial habitats in coastal watersheds (coastal wetlands, tidal rivers, etc) in a classification approach?*

  Several schemes solely focus on the offshore, ocean environment, such as the Greene et al. (1999 and In Press), Brown (2002) and Valentine et al. (2005). For example, Brown (2002) includes a supratidal zone, but falls short of capturing the upland habitats or even habitats on the coastal plain influenced by the spray zone. Both Valentine et al. (2005) and Greene et al. (1999 and In Press) focus on seafloor habitats and do not detail the nearshore component.

  The National Estuarine Research Reserve System (NERRS; Kutcher et al. 2005) and CMECS (Madden et al. 2005) approaches incorporate nearshore and upland habitat components within their classifications. However, the NERRS approach may not include the level of detail CZM needs for offshore areas that Valentine et al. (2005) and Greene et al. (In Press) achieve.

  If classification of wetland, estuarine and intertidal resources is desired, then a combination of the deepwater approaches with nearshore and upland approaches may be appropriate. Or otherwise, Madden et al. (2005), which includes a general overview of upland to offshore habitats, may be sufficient. These types of decisions cannot be made until CZM defines the spatial area where the classification scheme will be applied (and this may be related to management questions).

These management questions are critical to answer before choosing a habitat classification scheme. This report better equips CZM to choose among classification approaches and will ultimately help future mapping and habitat-based management projects.

Geographic Information System Considerations

Classification studies typically use unique numerical and/or letter codes to organize data and classify habitats, which facilitate the use of a geographic information system (GIS). GIS also provides a consistent organizational tool for managing, analyzing and monitoring habitat mapping and classification products. For example, GIS is the primary tool used by the scientific community for the compilation, analysis and display of seafloor data and the creation of seafloor habitat maps (Greene et al. In Press).

GIS eases the incorporation of maps and geospatial data from a variety of sources into a database and facilitates the use of historical and contemporary data sources in unison. GIS is also effective for updating maps and can be used to quantify and track changes in habitat types. However, without standard definitions for classifying and quantifying habitats, informative comparisons between areas cannot be easily made (Kutcher et al. 2005). Marine benthic habitat maps created with a GIS, for example, must be properly attributed (Greene et al. 2005) to accurately analyze and describe spatial and trends in seafloor conditions.

Although GIS has increased the availability, and in certain circumstances the quality and quantity, of data, users are often unaware of data limitations. Data collection and interpretation protocols must be thoroughly described within robust metadata to facilitate appropriate use of data. Seafloor mapping technology is still in relatively early stages of development, so protocols must be established to clearly identify data type, quality and interpretive processes (Greene et al. 2005). Greene et al. (2005) describes how habitat classification map products have occasionally been misinterpreted and incorrectly used because the process and quality of the source data was not fully understood. See Greene et al. (2005) for a more thorough explanation of the advantages and disadvantages encountered and possible solutions in using GIS for mapping and classifying marine benthic habitats.

GIS is a valuable tool in science, data management and resource management. A habitat classification scheme will ultimately result in the creation of spatial data. GIS is an effective means to analyze and display spatial data and facilitates effective use of data by multiple users. Metadata is critical to facilitate appropriate application of GIS data to management strategies. GIS will be used to facilitate the identification of an appropriate method to classify habitats.

HABITAT CLASSIFICATION SCHEMES – REVIEWED BUT NOT RECOMMENDED

Many classification schemes have a particular geographic focus, may not include habitat types common in Massachusetts or may be outdated. The following classification schemes were developed with a national or international focus, or to meet local needs, and are often cited and reviewed in habitat classification literature. These schemes are briefly described, highlighting limitations for CZM's use.

Cowardin et al. (1979)

The national benchmark, "Classification of Wetlands and Deepwater Habitats of the United States," provides a geographically comprehensive, nested-hierarchical classification scheme for wetland and deepwater habitats. Cowardin et al. (1979) provides an intuitive, useful and logical classification that is based on ecological parameters. This scheme was designed by the U.S. Fish and Wildlife Service (USFWS) in the late 1970s with the goal of inventorying wetland and deepwater habitats at a national scale. It became a very successful tool and provided the basis for many subsequent studies (e.g., Dethier 1992; Greene et al. 1999; Allee et al. 2000; Kutcher et al. 2005; and Greene et al. In Press). Each of these later classifications modified the original approach to address shortcomings in marine and estuarine descriptions, deepwater habitats, high-energy environments and upland and cultural habitats. Although inclusive of deepwater habitats, the Cowardin et al. (1979) system is mostly derived from a wetland-centric perspective and heavily emphasizes wetland habitat types, particularly coastal marshes. While the concept of a universally applicable coastal habitat classification could be construed as being initially tested and validated by the Cowardin system, CZM should focus on later-derived schemes to address its shortcomings (e.g., lack of detail for subtidal environments).

Dethier (1992)

"The Marine and Estuarine Habitat Classification System for Washington State" is based on Cowardin et al. (1979). Dethier (1992) adds energy as a level, significantly enhancing the utility of the 1979 classification not only for Washington State but for use in high-energy coasts. The energy element incorporates concepts such as exposed, moderately exposed and sheltered designations for rocky substrates. This modification is an example of adapting a regional approach to reflect local features. Another example of modifying an existing scheme was the narrowing of the Dethier (1992) classification focus to marine and estuarine systems, eliminating rivers and lakes. Dethier (personal communication) indicated that the 1992 scheme would not be as appropriate for Massachusetts because of its focus on Pacific Northwest environments.

Brown (1993)

“A Classification System of Marine and Estuarine Habitats in Maine: An Ecosystem Approach to Habitats” describes a preliminary hierarchical classification system organized by substratum, depth, energy level and salinity. This study included a review of classification systems (however, since this report is relatively old, the study did not include recent classification schemes that were reviewed as part of the CMECS approach [Madden et al. 2005]). Ultimately, the scheme for Maine builds primarily on those developed by Cowardin et al. (1979) and Dethier (1992). Hierarchical levels of the classification include: system (biome types), subsystem (tidal regimes), class (substrata), subclass (energy levels), modifiers (as needed), diagnostic species and common species.

This study contains good descriptions of habitat types and associated species and provides examples of applications of the classification approach. Habitat types identified for Maine closely relate to those found in northern Massachusetts, making this study a potential model for presenting information for specifically classified areas. However, the document does not include classification for pelagic areas and lacks a numeric or letter coding system that is important for developing a GIS.

Allee et al. (2000)

The “Marine and Estuarine Ecosystem and Habitat Classification” scheme was developed to be comprehensive for coastal and marine systems, encompassing the entire U.S. coastal margin from the landward extent of tidal influence to the outer edge of the continental shelf. Allee et al. (2000) was the first national classification since Cowardin et al. (1979) and presents several enhancements, including (1) focus on universal applicability across a variety of target regions; (2) stronger focus on marine and estuarine landscapes; and (3) linkages between geologic framework, energy and biology.

The NERRS reviewed Allee et al. (2000) and found the scheme difficult to use because of departure from traditional language in Cowardin et al. (1979), its complex format and the detail necessary to classify at lower levels (NERRS 2000). In addition, NERRS reviewers characterized the scheme at its lowest levels of habitat descriptions to be “open-ended” with choices being subjective and dependent on user knowledge and discretion rather that having standardized categories, which made it harder to compare across sites. In addition, marine and estuarine categories are classified together, which resulted in NERRS sites with the same classification for freshwater and brackish habitats, despite having completely different species composition due to the salinity gradient. These categories should be distinct and split early in the hierarchy (NERRS 2000). Another concern identified in the NERRS review was that Allee et al. (2000) does not follow a hierarchy, which makes it less user-friendly.

Brown (2002)

“Our Living Oceans Benthic Habitat Classification System” was developed to describe and define critical habitats for federally managed fishery species and consists of five major habitat types (Freshwater, Estuarine, Nearshore, Offshore and Oceanic Islands and Banks). This hierarchical scheme was also reviewed by the NERRS (NERRS 2000). The scheme does not provide protocol for dealing with habitat disturbances or habitat gradients. Brown (personal communication) recommended using Madden et al. (2005), which, “although it's still in the developmental phase, is a much more mature product. The framework I had been working on has pretty much dropped by the wayside.”

Madley (2002)

The "Florida System for Classification of Habitats in Estuarine and Marine Environments (SCHEME)" focuses on estuarine and marine environments that are relevant to coastal resource managers in Florida. Habitats of particular focus include nearshore and neritic areas inhabited by corals, hardbottom and seagrass communities. The boundary of the classification scheme is from the high tide line to the edge of the continental shelf. This approach lacks provision for descriptions of geologic structure, coastal complexity or hydrodynamic features – apparently more reflective of the calm coastal environment of the Florida Gulf coast. The scheme is data driven with Light Detection and Ranging (LIDAR), single beam sonar and aerial photography. While the hierarchy itself may not be useful to CZM for reasons above, the mapping methodology and the approach to determine how to use certain data sources to create the maps for each kind of habitat may still be relevant.

European Classification Studies

Since the mid-1990s, a European movement to map and classify coastal and marine habitats produced several notable projects, including BIOMAR (Marine Habitat Classification for Britain and Ireland) and EUNIS (European Nature Information System). These international efforts are described below because they contain overlapping ideas and useful approaches:

- The "Marine Habitat Classification for Britain and Ireland" developed in the late 1990s and revised in 2004 (Connor et al. 2004) is often referred to as the BIOMAR project. While the BIOMAR system has several useful components that CZM may want to consider (e.g., web-based), it only covers marine habitats from high tide seaward (excluding salt marshes) and does not extend to the deep ocean beyond 80m. Connor et al. (2004) focused on marine areas closely associated with the coastline, with little attention to estuarine systems and their connection to upstream watersheds. Important components of the BIOMAR scheme are incorporated in the CMECS classification (i.e., Madden et al. 2005).

  It is worth noting that the BIOMAR system is designed to be easy to use and is largely web-based (http://www.jncc.gov.uk/MarineHabitatClassification). Five levels of classification are identified on the website including: Level 1 – Marine Environment; Level 2 – Broad Habitats; Level 3 – Main Habitats; Level 4 – Biotope Complexes; Level 5 – Biotopes. The website contains a full listing of habitat types within these levels, a detailed description of each type, distribution maps and color photographs along with a glossary of terms. The web-based approach should be considered as a model for future data presentation.

- The EUNIS (European Union Nature Information System) classification incorporates major themes of BIOMAR. EUNIS is a broader study that was developed for aquatic and terrestrial habitats for most of Europe. In addition to having a terrestrial focus, the EUNIS classification is also different from the BIOMAR because it includes deeper water column habitats. It also has a web application http://eunis.eea.europa.eu/index.jsp, which contains the full classification hierarchy with keys for identification of all habitat types along with a glossary of terms and background information on the classification's rationale. While the online EUNIS classification leads users through a useful series of logical questions to help identify classification levels (i.e., permanently water-covered? shelf? substrate type? characterized by macroalgae?), the marine and coastal component is only a small focus of the overall classification scheme that has eight other main levels devoted to terrestrial habitats. In addition, the habitat types represented range from Northeast Atlantic (England

and Ireland) to the Mediterranean and Black Sea marine habitats (Davies et al. 2004). This approach is more complex and covers a much wider range of habitats than CZM needs.

RECOMMENDED HABITAT CLASSIFICATION SCHEMES

Four habitat classification schemes are recommended for CZM's consideration. Ultimately, resource management questions previously identified in this report will help CZM determine the most suitable classification scheme(s). It is important to note that the following descriptions of the four recommended classifications may be confusing, especially examples of the coding approaches, without referencing Appendix 1. Appendix 1 shows details of each hierarchy and classification code.

Madden et al. (2005), "Coastal and Marine Systems of North America – Framework for an Ecological Classification Standard: Version II"

The Coastal and Marine Ecological Classification Standard (CMECS), developed by NatureServe, NOAA and other national partners, is a classification approach for estuaries, coasts and oceans of North America (Madden et al. 2005). The study intended to create a national standard for classifying habitats to ensure data collected by different parties is consistent with regional, national and international standards. Development of standards for a U.S. marine and coastal classification system also supports federally mandated marine protected area and essential fish habitat efforts. Finally, NOAA viewed development of this scheme as a way to assist integration of federal, local, state and regional efforts to develop ecosystem-oriented resource management plans (Madden et al. 2005).

NOAA Fisheries (National Marine Fisheries Service) and NOAA's Coastal Services Center (CSC) established a partnership with NatureServe, previously the scientific arm of The Nature Conservancy, in 2002 to build upon previous NOAA studies (e.g., Allee et al. 2000) and several existing national and international frameworks. Madden et al. (2004a and 2005) conducted a thorough review of existing classification studies (e.g., Cowardin et al 1979; Dethier 1992; Greene et al. 1999; Allee et al. 2000; Madley et al. 2002; Zacharias et al. 2000; and Connor 1997 and 2004) and described elements of each study and approach to incorporate into the CMECS. Madden et al. (2005) attempted to combine the best elements of previous schemes to establish a single national marine and estuarine classification standard with broad, regional and local applicability.

Geographic Focus

The CMECS extends from the head-of-tides in the coastal zone to the deep ocean. This area encompasses estuaries, wetlands, rivers, shorelines, islands, intertidal and benthic zones and the entire water column from the shore to the deep ocean at scales of <1m to >10^6m (Madden et al. 2005).

Hierarchical Organization

The CMECS is organized into a nested hierarchy with the following six levels (Madden et al. 2005):

- **Regime** (Level 1) – is differentiated by a combination of salinity, geomorphology and depth organized in five categories: estuarine, fresh water-influenced marine, nearshore marine, neritic and oceanic (10km^2 to > 1000km^2).
- **Formation** (Level 2) – is relatively large physical structures formed by water (currents) or substrate (islands) (10,000m^2 to 100km^2).
- **Zone** (Level 3) – distinguishes between water column, littoral or sea bottom (100m^2 to 10,000km^2).
- **Macrohabitat** (Level 4) – is large physically complex structures that typically contain several habitats, such as a rocky shore (100m^2 to 1,000m^2).
- **Habitat** (Level 5) – is a specific combination of physical (i.e., grain size) and energy characteristics that create a suitable place for colonization or use by biota (1 m^2 to 100m^2).
- **Biotope** (Level 6) – is identified by characteristic biology associated with a specific habitat (1 m^2 to 100m^2).

A key feature of the CMECS is the capacity to handle water column data in three dimensions with the use of the category *Zone* (water column, littoral, bottom). While users may see this complexity as a drawback if a simpler approach for mapping purposes is desired (Kutcher 2006), others see this classification level as a decision point on the focus area (i.e., water column, littoral, bottom) before continuing to lower levels of the hierarchy (Wright personal communication 2006).

Classification Coding System

Madden et al. (2005) developed a coding system based on a sequence of numbers and letters. Regime is represented by a capitol letter (**X**); Formation follows to two decimal points (X**.00**); Zone is represented by bottom (B), littoral (L) or water column (W) – X.00.**B/L/W**; Macrohabitat is distinguished by a lower case letter (X.00.B/L/Z**.x**); and Habitat is a series of numbers to two decimal points (X.00.B/L/Z.x**.00**). It is uncertain how Biotope is coded in this classification system. This classification scheme is evolving, and the coding system may change (Allee personal communication).

Example:

A	Estuarine Regime
A.02	Estuarine embayment Formation
A.02.B	Estuarine embayment bottom Zone
A.02.B.c	Estuarine embayment softbottom Macrohabitat
A.02.B.c.09	Estuarine embayment subtidal vegetated mud and mixed-fine sediments Habitat

See also http://www.natureserve.org/getData/CMECS/app/classification/tree/pivot/browse and http://www.natureserve.org/getData/CMECS/ for more examples.

Data Sources and Scale

The CMECS sets uniform classification rules that function at multiple scales across a diversity of environments. The hierarchy is conceptually divided into two parts based on data required for applying the classification. The upper levels (Regime through Zone) can be identified from maps, bathymetry, remote imagery and historical data. Lower levels (Macrohabitat through Biotope) are distinguished at local spatial scales and data are collected through direct observation and measurement. The lower, more-detailed four levels require the most work and are valuable for applying the classification for purposes of habitat conservation and management (Madden et al. 2004a).

Data availability will – in most cases – prevent classification to the full (most-detailed) extent. Allee (personal communication), a primary contributor to CMECS, indicated that the Macrohabitat or Habitat levels are the most realistic levels to classify habitats because of data availability (not enough information exists to get at many Habitat or Biotope levels for regional assessments). The CMECS was, however, designed to partially identify classes at lower levels even if comprehensive data are not available. In other words, a user can skip levels where data are lacking, and as additional data in the area are gathered, the entire hierarchy will continue to grow and strengthen the understanding of the whole system (Madden et al. 2004a).

Comments and Updates

The CMECS is a collaborative and ongoing process, with NOAA, USFWS, Census of Marine Life, The Nature Conservancy, several universities and NatureServe contributing to the development of the classification framework. Development of the scheme included a national workshop in 2003, numerous interviews with scientists and managers that map and study habitat and pilot testing (Madden et al. 2005). The most recent 2005 version is now available through the NatureServe website www.natureserve.org/getData/CMECS. This product is a revision of Madden et al. (2004a). NOAA's Coastal Service Center and partners are updating CMECS and actively advocating its use as a national standard.

Numerous habitats are included in the CMECS, encompassing intertidal environments through oceanic areas. The online catalog, however, does not include a comprehensive list of all coastal and marine types. CMECS is not well developed for certain areas (e.g., nearshore non-estuarine benthic habitats). The upper three levels (Regime, System, and Zone) are fairly complete, while lower three levels are less complete. CZM should review the CMECS to make sure the scheme includes habitats in Massachusetts.

An important stage in the development of the CMECS was piloting the classification. Pilot projects were undertaken in Florida, the south Atlantic Bight and the Columbia River to help make the classification more robust and populated with information from different ecological systems. The purpose of the Florida Keys project was to map shallow water seagrass and coral reef habitat; the purpose of the south Atlantic Bight project was to locate and map marine hardbottom habitat; a large-scale test of the classification in the Columbia River estuary was to examine suitability for mapping salmon habitat (Madden et al. 2004b).

The pilot studies included examining data sources, scale, procedure, analysis and lessons learned along with tables and figures. The Columbia River study particularly provided insight to the strengths and challenges of CMECS as a national marine data structure. This 24 month pilot project implemented the scheme from Level 1 (Regime) through Level 3 (Zone) with limited use information at Level 4 (Macrohabitat). A manuscript is in development that outlines challenges, benefits and considerations of CMECS (Wright In Press). Nan Wright is the author of this study and expressed interest in providing training on the use of CMECS for those interested in applying it to their local waters. CZM should consider this opportunity since she has experience from piloting the CMECS.

NatureServe is the primary developer of CMECS, with Chris Madden as principal investigator and major guidance and funding from NOAA. CMECS continues to evolve and NOAA's CSC is interested in testing CMECS in Massachusetts (Allee personal communication). NOAA intends to go on the road with the latest scheme for introduction to coastal managers and explain how it was developed and how it can be used (Wright personal communication). This local training could be an opportunity for CZM to gain an understanding of CMECS and applications in Massachusetts. As CZM proceeds with examining, developing and adopting a habitat classification framework for Massachusetts, NOAA's CSC should be actively engaged to ensure mutual objectives of CZM and CSC can be achieved while maintaining local research and management initiatives.

Kutcher et al. (2005), "A Recommendation for a Comprehensive Habitat and Land Use Classification System for the National Estuarine Research Reserve System"

The National Estuarine Research Reserve System (NERRS) is investigating the development of a habitat classification scheme to facilitate measuring the magnitude and extent of habitat change in estuarine systems and linking observed changes to watershed land-use practices (Kutcher et al. 2005). The NERRS habitat classification scheme is an ecologically based, nested hierarchy intended to encompass ongoing classification efforts within the NERRS, allow effective use of existing data and comprehensively inventory and classify all land-cover types. The classification scheme is GIS-based to allow integration of varying scales of data and facilitate use of data with scientists and non-scientists (Kutcher 2006).

The NERRS scheme is largely based on Cowardin et al. (1979), with classes directly adopted or slightly modified from Cowardin et al. (1979) and expanded to include upland and cultural habitats (Kutcher et al. 2005). Cowardin et al. (1979) provided the foundation for the collection and classification of wetland data through the National Wetlands Inventory (NWI), and NWI data were available for most sites. Incorporating NWI, with expanded classes and descriptions for site-specific features, allowed historical analyses within the NERRS (Kutcher personal communication). NOAA's CSC Coastal Change Analysis Program (C-CAP; Dobson et al. 1995) approach also informed the NERRS scheme. The C-CAP was referenced for coarse level mapping of watershed habitats and land uses. Anderson et al. (1976) informs cultural land use classes.

Geographic Focus

Boundaries of NERRS typically include coastal watersheds and estuaries without an offshore, ocean environment component. This classification scheme was designed to facilitate objectives related to geospatial inventory and land cover change analyses of coastal uplands, wetlands and nearshore habitats.

Hierarchical Organization

The NERRS scheme is organized in a five-level, nested hierarchy. The following hierarchy begins with a broad level and progresses to finer classes, designed to guide the user through progressively more detailed attributes:

- **System** (Level 1) – is based on predominant water source (e.g., marine, estuarine).
- **Sub-System** (Level 2) – is based on hydrologic influence such as intertidal.
- **Class** (Level 3) – is based on vegetation or physical attributes (surficial geology).
- **Subclass** (Level 4) – is based on attributes such as grain size.
- **Descriptors** (Level 5) – are based on published scientific literature and defines habitat based on features such as single plant species (eelgrass) or substrate traits (mudflat).
- **Modifiers** – are used to describe habitats with additional natural features (e.g., salinity regime) and anthropogenic influences such as diked or excavated.

Although recommended scale/units were not provided for each of the top four classification levels, Walker et al. (2005) suggests a mapping scale between 1:24,000 and 1:3,000 if the source data are based on aerial photography and using on-screen digitizing techniques, a consistent on-screen viewing scale (e.g., 1:3,000 to 1:5,000) and minimum mapping unit (e.g., 0.25 acre) are needed to ensure integrity.

Descriptor and Modifiers are not within the hierarchical structure and are meant to be added as fields (columns) in the GIS attribute table. Descriptors and Modifiers are used to further describe habitats with qualitative information. For example, Modifiers describe habitat polygons like "sandy ocean bottom" with information such as circulation and tidal regime, water chemistry (salinity), anthropogenic pressures affecting habitats or percent cover of invasive species. Descriptors are common names and definitions chosen to standardize a particular habitat type such as "New England Saltmarsh." These common names are important in helping local managers use the same terminology for a habitat type (Kutcher et al. 2005).

More background on descriptors, modifiers and how the Cowardin system was adapted to meet the needs of the NERRS is described in Kutcher et al. (2005).

Classification Coding System

Kutcher et al. (2005) use a numeric code that follows Anderson et al. (1976) and Cowardin et al. (1979), with the addition of Level 5 (Descriptors) and the option for a narrative description of detailed features (Modifiers). The coding system is arranged by eight Systems (1,000-8,000), followed by progressively more detailed classes (Sub-System, Class and Sub-Class). Descriptors (Level 5) are added to Sub-Class and represented by two decimal places (Kutcher et al. 2005).

Example:

NERR Code:	2261.01	
System:	Estuarine	(2000)
Subsystem:	Intertidal Haline	(2200)
Class:	Emergent Wetland	(2260)
Subclass:	Persistent	(2261)
Descriptor:	New England Low Salt Marsh	(2261.01)

Data Sources and Scale

The NERRS classification scheme requires data to be collected at two geographic scales: 1) broad-scale, low resolution data for characterizing entire watersheds; and 2) detailed, fine-scale, high resolution data for characterizing specific properties (Walker et al. 2005). Watershed-level data are used to measure habitat and land-use change in the area of interest, assess the sensitivity of habitats to changes in adjacent uplands and analyze the relationship between land use and water quality over time. Broad-scale data are primarily derived from 30m Landsat TM imagery and classification is automated. Reserve-level, finer scale data identify species-habitat associations and landscape ecology features and are mostly interpreted from high resolution imagery (e.g., aerial photography) or field observations.

The NERRS classification scheme provides the foundation to create a comprehensive GIS. The GIS data are capable of characterizing, organizing and displaying strictly defined land cover units (and associated attributes) that allow direct spatial analysis of all habitat and land-cover types. Each level or class represents a single column in an attribute data set, and each polygon is a single row in a GIS database. Point data (e.g., grab samples) can be assigned as Modifiers or Descriptors and organized in data columns, further characterizing each polygon with more information. Modifier or Descriptor data can also be organized as discrete GIS layers (Kutcher personal communication).

Comments and Updates

A modified version of the NERRS classification scheme was recently approved, and a Habitat Mapping and Change Technical Advisory Panel is determining how best to implement the approach (Kutcher personal communication). The NERRS classification approach will continue to adapt and improve.

The original CMECS scheme (derived from Allee et al. 2000) was piloted by several NERRS in 2000 and 2006. The major issue with the CMECS approach was that coastal uplands were not incorporated, which are crucial for analyzing processes that NERRS scientists wanted to consider (Kutcher personal communication). Kutcher et al. (2005) was developed with particular focus on estuarine and upland habitats and does not cover deeper subtidal benthic areas. The NERRS scheme contains codes for offshore areas and altered habitats but are largely untested, as most reserves do not contain deepwater (Kutcher personal communication). The use of descriptors and modifiers are not clear and should be explained in more detail, if CZM decides to use Kutcher et al. (2005).

Emergent (and most submerged) habitats were recently mapped to a species assemblage level in the Waquoit Bay National Estuarine Research Reserve (WBNERR; Annett personal communication). This mapping is more detailed than the NERRS classification system, but the NERRS approach allows flexibility in detail. WBNERR has not yet agreed to appropriate names to classify species assemblage polygons and has not populated the database for the mapped features. CZM could coordinate with WBNERR on these tasks and gain experience with the NERRS approach (Kutcher et al. 2005).

Greene et al. (In Press), "Construction of Digital Potential Marine Benthic Habitat Maps Using a Coded Classification Scheme and Their Application"

Efforts to classify seafloor habitats in California began in the late 1990s (Greene et al. 1999) and have continued to evolve, broaden and improve (Greene et al. In Press). Greene's original classification in 1999 was developed for coastal California deep seafloor habitats, with the goal of understanding and predicting spatial distribution of fish species. The Greene et al. (1999) approach developed during more than 15 years of mapping seafloor habitats and was adopted by several organizations, agencies and countries. Greene et al. (In Press) refined the 1999 study, with the goal of establishing a standard technique for making habitat designations and comparisons of deepwater marine benthic habitats worldwide. This scheme is GIS compatible and generally based on geomorphology, substrate type and textures produced by physical processes, and sessile biology (Greene et al. In Press).

Geographic Focus

Greene et al. (1999) was developed primarily for deepwater (greater than 30m), however the approach is easily applied to nearshore shallow coastal areas and estuaries (Greene personal communication). The classification scheme applies to seafloor habitat types throughout marine regions, from high (sub-arctic) to low (tropical) latitudes, and shallow, intertidal regions and estuaries to abyssal plains (Greene et al. In Press). While the scheme is flexible and can be modified to match habitat mapping objectives, the approach should not be altered to the extent that reproducibility of delineating habitat classes is lost (Greene personal communication).

Hierarchical Organization

Physiography, depth, seafloor induration (hardness of substrate), geomorphology, texture and biology are used to classify seafloor habitats (Greene et al. In Press). Seafloor mapping datasets (e.g., multibeam bathymetry, backscatter intensity and groundtruth imagery) and analogous optical data, such as LIDAR, provide the foundation for applying this scheme. The hierarchy is largely based on spatial scale – in terms of mapping scale. Examples of the large geologic features mapped at small-scale (e.g., 1:1,000,000) are the continental shelf, abyssal plain and submarine canyons. Small characteristics such as biogenic structure (fauna forming observable features on the seafloor) and grain size require large-scale of 1:50,000 or less. The following classes progress from small-scale features to the larger-scale attributes (Greene et al. 1999):

- **Megahabitat** – is a large feature (>kilometer) defined at a small scale (e.g., 1:1,000,000), such as abyssal plain.
- **Mesohabitat** – is a relatively large feature, such as submerged canyons and extensive bedrock outcrops, defined at scales of 1:250,000 or less.
- **Macrohabitat** – ranges in size from one to 10s of meters, consisting of attributes delineated at scales of 1:50,000 or less (e.g., large boulders, sediment waves, algal mats and kelp beds).
- **Microhabitat** – is a small feature (<m) such as grain size and biogenic structure (individual habitat forming fauna such as anemones).

Classification Coding System

The attribute code associated with this scheme is adapted from Greene et al. (1999) and consists of seven primary letter and number characters (Greene et al. In Press). Codes represent (1) physiography and depth (i.e., Megahabitat – one of nine) – capital letter; (2) substrate induration – lower case letter; (3) geomorphology (i.e., Meso- and Macrohabitat) – lower case letter; (4) modifiers for texture, lithology, bedform and biology – subscript letter preceded by an underline; (5) seafloor slope or inclination – represented by five slope categories (numbers 1 to 5), (6) seafloor complexity (e.g., rugosity, vertical relief) – represented by capital A to E as measure of rugosity, and (7) geologic units represented by standard geologic symbols (Greene et al. In Press). Codes for classes one to five are typically derived from high-resolution seafloor mapping data. Characters 5-7 are optional and included only when slope and complexity can be calculated and when the geology is known.

Additional attribute codes are available to distinguish habitat types, when underwater imagery (e.g., video and photographic data) exist, consisting of geologic or substrate attributes and biological features. Underwater imagery usually allows classification to Macrohabitat or Microhabitat features, with Macrohabitat and Microhabitat preceded by an asterisk (*) in the coding system. Geologic attributes are in parentheses and biological features are in brackets. When information is inferred, a question mark (?) denotes the area of uncertainty.

The code was written to easily distinguish each habitat type and to facilitate ease of use and queries in a GIS (e.g., ArcGIS). The code is intuitive with the use of unique (non-repeatable) letters and numbers for each category (Greene et al. In Press). See Greene et al. (In Press) for detailed codes for each category.

Example: Shpd1S(Q/R)*(m)[w]1C

Large-scale habitat type:

Continental shelf megahabitat (S); flat, highly complex hard (h) seafloor with pinnacles (p) differentially eroded.

Geologic unit:

Quaternary/Recent (Q/R).

*Small-scale habitat type:

Flat or nearly flat mud (100%) bottom (m) with worm tubes [w]; flat (1) and moderate rugosity (C).

Data Sources and Scale

This scheme was developed to use acoustic (e.g., multibeam bathymetry and sidescan sonar) and/or optical (e.g., LIDAR and hyperspectral) mapping data to classify the seafloor environment. The classification approach pays particular attention to scale and emphasizes the need to groundtruth interpretations made from remotely sensed data (Greene et al. In Press). Greene et al. (1999; In Press) refer to scale in terms of mapping scale. Small-scale refers to mapping large or coarse-resolution features (e.g., continental shelf) and large-scale indicates smaller or fine resolution attributes, such as grain size, species assemblages and habitat associations.

Megahabitat can often be delineated from existing, coarse-scale data (1:1,000,000 or greater), such as maps and satellite images. Classifying Mesohabitat (1:250,000 or less) and Macrohabitat (1:50,000 or less) require high frequency (e.g., 200 kHz) seafloor mapping systems. Imaging and classification of Microhabitat is best accomplished from in-situ observations, such as benthic grabs or underwater video (Greene et al. 2005). Classifying Microhabitats is generally more difficult and time consuming compared to the other habitat classes.

While this approach is tested in relatively deeper waters using seafloor mapping data, bathymetric LIDAR, hyperspectral systems and other technologies (e.g., digital photography) are being used in shallow-water environments and provide data to apply Green et al. (1999; In Press).

Comments and Updates

Although this scheme was based on earlier habitat classification studies by Cowardin et al. (1979) and Dethier (1992), it represents a departure from coastal habitat and moves into the relatively deep ocean. Greene et al. (1999; In Press) focus on geologic structure of the bottom, leaving the classification of estuarine and freshwater systems to existing classifications. Classifying habitats in the offshore environment is an important aspect of habitat classification in Massachusetts. However, estuarine and coastal habitats are also important to include in a singular classification framework for Massachusetts.

Greene et al. (1999; In Press) is peer reviewed and is adopted by many organizations. Pilot mapping and classification is complete in Alaska, Washington and California, and new efforts are starting in the Pacific island areas, the Baltic and elsewhere using this scheme (Greene personal communication). Thus, the approach is becoming established, is field tested and can be applied in areas with seafloor mapping data.

Valentine et al. (2005), "Classification of Marine Sublittoral Habitats, with Application to the Northeastern North America Region"

The goal of the Valentine et al. (2005) scheme is to develop a practical method to classify marine sublittoral (subtidal continental-shelf and shelf-basin) habitats in northeastern North America. The classification approach is based on topographical, geological, biological and oceanographical attributes and natural and anthropogenic processes. Valentine et al. (2005) reviews several other classifications (e.g., Cowardin et al. 1979; EUNIS 1999; Greene et al. 1999; Allee et al. 2000; and Conner et al. 2004), and uses concepts from these approaches, tailoring the classification to the region under study and basing classes on extensive seabed observations (Valentine et al. 2005).

Geographic Focus

The focus is on marine sublittoral environments, with particular focus on the seafloor, in the northwest Atlantic Ocean from the Gulf of Maine to the continental shelf off New Jersey. The classification includes subtidal areas of the continental shelf basins of the Gulf of Maine that reach depths of approximately 400m and submarine canyon heads that incise the continental shelf in depths of up to 800m (Valentine et al. 2005).

Classification Organization

The classification published by Valentine et al. (2005) is slightly different than the other schemes by being only partly hierarchical. Given this structure, classification levels do not always fit neatly into broad classes and fine classes. Each class has broad geographic application, except in instances where floral and faunal features are regional. Valentine et al.

(2005) emphasizes seabed substrate type, substrate dynamics and complexity of physical and biological features on the seabed in classifying seafloor habitats.

There are eight **Themes**, with an associated **Class**, **Subclass**, **Category** and **Attribute**. Themes are the highest level of classification and include: **One** (Topographical Setting), **Two** (Seabed Dynamics and Currents), **Three** (Seabed Texture, Hardness and Layering), **Four** (Grain Size Analysis), **Five** (Seabed Roughness), **Six** (Fauna and Flora features), **Seven** (Faunal Association, Human Use and State of Disturbance), and **Eight** (understanding of Habitat Recovery). Classes are identified by seabed features (e.g., grain size, texture and roughness), flora and fauna, and natural and anthropogenic processes that affect habitat characteristics. Subclass, Category and Attribute include more-detailed habitat characteristics that are fundamental for recognizing and analyzing habitats (Valentine et al. 2005).

Examples of Classes include seabed dynamics and currents, texture and hardness and predominant grain size; Subclass includes features such as percent composition of grain size, mobility of sediments and bedforms; Category includes type of current (tidal or storm-induced) and biogenic features (burrows); and Attributes provide a semi-quantitative assessment of an area (e.g., percent cover of biogenic structure).

Classification Coding System

Valentine et al. (2005) developed descriptive habitat codes (and names) that incorporate information on seabed substrate type, seabed substrate dynamics and the degree of physical and biological complexity on the seabed. The least descriptive habitat name is based on seabed substrate type only (e.g., mud; M). The most descriptive habitat name has a seabed dynamics term, substrate type term and structural complexity term (e.g., Immobile - I; mud - M; physical structural complexity low - ps5-10L; biological structural complexity very, very low - bs<1VVL; I_M_ps5–10L_bs<1VVL). The following are examples from Valentine et al. (2005) of the application of this coding convention:

Example 1:

Habitat code based on seabed type: Mud (M)
Habitat code based on dynamic seabed type: Immobile; mud (I_M)
Habitat code based on dynamic seabed type with physical structure (ps) and biological structure (bs): Immobile; mud; physical structural complexity low; biological structural complexity very, very low (I_M_ps5-10L_bs<1VVL)

Explanation: Habitat name is based on seabed dynamics, seabed substrate type, and physical and biological structural complexity. The code is created as follows: Immobile (I); mud (M); physical structures cover 5-10% of the seabed (ps5-10), physical complexity is low (L); biological structures cover less than 1% of the seabed (bs<1), and biological complexity is very very low (VVL)

Example 2:

Habitat code based on seabed type: Sandy gravel (sG)
Habitat code based on dynamic seabed type: Intermixed mobile/immobile; sandy gravel (IMI_sG)
Habitat code based on dynamic seabed type with physical structure (ps) and biological structure (bs): Intermixed mobile/immobile; sandy gravel; physical structural complexity very high; biological structural complexity low (IMI_sG_ps>90VH_bs5-10L)

Explanation: Habitat name is based on seabed dynamics, on seabed substrate type, and on physical and biological structural complexity. Intermixed mobile/immobile (IMI); sandy gravel (sG); physical structures cover more than 90% of the seabed (ps>90), physical structure complexity is very high (VH); biological structures cover 5-10% of the seabed (bs5-10), and biological structural complexity is low (L).

Valentine et al. (2005) describes the coding and naming process in more detail.

Data Sources and Scale

Valentine et al. (2005) is based on seafloor observations using multibeam and sidescan sonar, video and photographic transects and sediment and biological sampling (i.e., benthic grabs). Geophysical surveys, such as multibeam and sidescan sonar, depict broad geological environments and provide a framework for identifying and classifying habitats. Although modern seafloor imagery is a solid foundation for the study of habitats, classification often requires additional biological information such as underwater imagery and benthic sampling.

Themes, Classes and Subclasses can generally be interpreted from seafloor mapping data. Identifying Categories and Attributes require underwater observations (e.g., video transects and/or benthic grabs). Since it is not always feasible to quantify the abundance of individual structures and organisms, this scheme allows for the inclusion of visual semi-quantitative estimates of habitat characteristics (Valentine et al. 2005).

Data and imagery availability dictate mapping scale of classified habitat. Observations needed to classify habitats at the higher levels (i.e., Theme and Class) range from tens of meters to >1 km and can be defined using maps and seafloor images at a scale of 1:250,000-1:1,000,000. Lower classification levels require maps in the range of 1:25,000-1:100,000 (Valentine et al. 2005). While the level of mapping and classification depends in a large part on the data and imagery available, the Valentine et al. (2005) approach is flexible, allowing classification of large geologic features and fine-resolution attributes such as grain size (mm-cm).

Comments and Updates

Valentine et al. (2005) focuses on subtidal seafloor habitats and does not does not cover near-coastal and estuarine benthic areas. Valentine (personal communication) believes most existing classification studies are weak on using geological attributes for characterizing habitats. This assertion is founded in the geologic-centric belief that habitats are "for the most part composites of geological and oceanographic attributes and process" (Valentine personal communication). Biological resources are also fundamental to habitat, since the attraction to an area (area described by physical or biological features) is based on the dispersal, behavior and/or life history requirements of a species.

Valentine described how much of the Massachusetts sublittoral environment can be classified to the level of Subclass vs. Category vs. Attributes using his scheme:

> "The goal should be to classify habitats to the "attribute" level, and this can be achieved with video imagery and sampling. The question is how much sampling (groundtruthing) is required, and that depends on an analysis of the sidescan and multibeam imagery and ultimately on the complexity of the seabed. Some areas will require more sampling than others. The attribute level quantifies a characteristic of the habitat (usually the

> percentage of some characteristic), and this kind of data can be estimated from video imagery."

Therefore, it seems the amount of groundtruthing (video imagery and sediment sampling) will dictate the ability of classifying habitat to the Attribute level. However, locating groundtruth samples during a seafloor mapping cruise is determined by geological features and not biological resources. Groundtruth data are not randomly collected and using groundtruth data to classify large areas of the seafloor without sufficient sampling coverage should be approached cautiously. Groundtruthing data certainly allow classification and characterization of fine-detailed seafloor habitats in areas with data, but because biological resources, such as the relative abundance of flora or fauna, are often patchy and unpredictable, sampling requires a statistically random design to describe biological patterns through space or time. Regardless of this uncertainty, groundtruthing data are often the best available data on benthic resources and should be used to classify seafloor habitat to fine-detail, as appropriate. Additional sampling of the seafloor environment may, however, be required to extrapolate between samples and classify larger areas of the seafloor.

The USGS is currently classifying habitats in the Stellwagen Bank region using Valentine et al. (2005). While this classification seems more complex with multiple choices in the Classes, Subclasses and Categories, it gets to a higher level of detail for sublittoral marine environments in New England than other schemes such as the NERRS or CMECS. Recent seafloor mapping and sampling in Massachusetts is generating detailed data and therefore, the more complex Valentine et al. (2005) approach may be appropriate. Valentine et al. (2005) is best described by reviewing the information and examples presented in Appendix 1-5 (in Valentine et al. 2005). Furthermore, results from Stellwagen Bank will help determine the detail and required data to implement the scheme. CZM should communicate with Valentine to ask about lessons learned.

Comparison of Greene et al. (1999; In Press) and Valentine et al. (2005)

Greene et al. (1999; In Press) and Valentine et al. (2005) approach habitat classification from a geologic-centric perspective and describe the use of seafloor mapping data to classify benthic habitat. Neither approach encompasses water column or intertidal environments. These studies are compared to better distinguish between the two similar approaches .

Valentine et al. (2005) compares closely to Greene et al. (1999; In Press) in that it was developed to characterize marine sublittoral (chiefly subtidal continental shelf and shelf basin) habitats predominately using seafloor mapping data. Valentine et al. (2005) is based on recent observations in northeast North America. Greene states that the Valentine et al. (2005) approach was concurrently developed with Greene et al. (1999; In Press), but Valentine et al. (2005) was specific to the East Coast and to glacial deposits where Greene et al. (1999; In Press) is more encompassing (e.g., can be used in the arctic as well as the tropics). Valentine (personal communication) describes the Greene et al. (1999; In Press) studies as using habitat as a major criterion, which the Valentine et al. (2005) does not. The Valentine et al. (2005) approach is based on describing habitats in terms of geology, oceanography, biology and related processes (e.g. sediment movement; current types; flora/fauna modifications of the seabed; etc.), designed with the idea that video imagery would be the basic data source for describing the seabed and flora/fauna (Valentine personal communication).

While this commentary helps elucidate differences between the two approaches, more clarity is needed to fully describe differences between the two. This clarity can be gained by either inviting both authors to a meeting at CZM (an action identified in the recommendations) to discuss and provide examples of their approach in more detail, or by CZM independently, evaluating the two schemes by choosing a pilot area and implementing these two classification approaches with existing data.

RECOMMENDATIONS

The review of existing classification studies in this report is a valuable first step in determining which approach or aspects of approaches are appropriate for classifying habitats in coastal and marine environments of Massachusetts. This report also raises questions to consider when testing or adopting classification studies and offers suggestions to consider as next steps. As with any technical project plan, certain resources must be secured before work can begin. In particular, personnel, technical knowledge and supporting infrastructure need to be appropriately allocated before applying and evaluating habitat classification frameworks.

The recommendations given below are organized by the stage of the project, as follows (1) before choosing a classification scheme, (2) identifying a pilot area and (3) after evaluating classification schemes. The following recommendations are based on this study and communications with habitat classification experts and are intended to inform next steps at CZM.

Before Choosing a Classification Scheme

- CZM should assemble a technical advisory group to provide input on the choice and implementation of a classification scheme. The advisory group should be composed of scientists and managers to ensure that the approach is valid and useful in a management context. Membership in this group should include a balance of expertise with knowledge of habitat ecology, fishery resources, natural resource management, mapping technology and GIS, including staff from DMF, USGS and USEPA, among others.

- CZM and potential collaborators should become familiar with the four classification schemes recommended in this study and determine which scheme or combination of schemes include habitats that are most important to classify. This step will include identifying habitat types needed in a classification framework.

- The classification scheme chosen should support a variety of data sources, since geospatial habitat data take many forms such as grab samples and sonar images.

- The geographic coverage of a classification framework needs to be determined to facilitate the identification of appropriate studies or combination of studies needed to achieve objectives. That is – should a classification system encompass the coastal watershed and ocean environment? For example, Greene et al. (1999; In Press) and Valentine et al. (2005) do not adequately cover nearshore or coastal habitats and would need to be combined with a classification that includes these habitats (e.g., Kutcher et al. 2005 or Madden et al. 2005), if such coverage is necessary.

- Experts involved in the creation and/or implementation of the four recommended classifications should be contacted and/or gathered to ask questions, discuss applicability, solicit advice on the selection of an appropriate scheme and possibly receive training on implementing an approach. Experts include: Nan Wright (University of Idaho), Becky Allee (NOAA's CSC), Mark Finkbeiner (NOAA's CSC) and Chris Madden (NatureServe) for CMECS (Madden et al. 2005); Tom Kutcher (Narragansett Bay NERR) and Brendan Annett (Waquoit Bay NERR) for NERRS (Kutcher et al. 2005); Gary Greene (Moss Landing Marine Laboratories) for Green et al. (1999; In Press); and Page Valentine (USGS, Woods Hole) and Kathryn Ford (DMF) for Valentine et al. (2005). This meeting should have clear objectives to facilitate the identification of next steps.

NOAA's CSC is intimately involved with CMECS (Madden et al. 2005), and CSC staff could provide assistance. Specifically, CSC can offer lessons learned from the Columbia River and other pilot projects, determine scales and data needed to populate different levels of the hierarchy, demonstrate the use of benthic data in the CMECS and train CZM and other staff on the use of the CMECS.

Evaluating a Pilot Area

- CZM should consider organizing a workshop with key partners to discuss existing habitat classification schemes, apply pre-selected classification scheme(s) to a pilot area and examine advantages and disadvantages of using one scheme over another in Massachusetts waters. Goals of this meeting could be to: 1) review existing classification schemes highlighted in this paper; 2) identify which scheme (or parts that need to be combined) best meets Massachusetts needs; 3) propose additional pilot areas to implement the classification scheme and discuss data requirements.

- The pilot area should have sufficient existing data to evaluate classification schemes. Data such as bathymetry and sediment characteristics are primary habitat attributes and important for determining the distribution and abundance of sessile invertebrates as well as motile species such as crustaceans and fish (Auster et al. 1998; Peter Auster, University of Connecticut, could advise classification efforts by CZM).

- The evaluation of habitat classification in Massachusetts should include a data gap analysis to determine data requirements to achieve specific levels of classification within each habitat classification framework.

After Evaluating Classification Schemes

- CZM should review "Recommended Guidelines for Adoption and Implementation of the NERRS Habitat and Land Use Classification System" (Walker et al. 2005) to provide a brief, practical set of guidelines for successful adoption and use of the chosen classification system. For example, Walker et al. (2005) describes the following steps: (1) identify and compile existing map resources and/or habitat description materials; (2) select appropriate scale for the habitat classification pilot; (3) design and document the GIS database structure; (4) develop a flow diagram for the implementation process; (5) document key "areas of interest" and habitats; (6) apply classification codes accordingly; and (7) generate metadata for the classification database.

- Resource management considerations should be identified (e.g., application of a classification system to address project review) and explicitly considered in choosing a classification scheme or modifying existing schemes.

- Incorporating biological and ecological characteristics into detailed, finer resolution habitat classes is not a strength in any of the four recommended classification schemes. Biotic characteristics such as the presence and relative abundance of epifaunal communities and macroalgae beds are temporally variable, as well as patchily distributed. Distributions of biological features are also greatly altered by human impacts, are a substantial part of the societal and resource value of habitats and are frequently the basis of regulatory strategies. More work is required to integrate biological data into a habitat classification framework, if resource management and/or scientific efforts require detailed, finer resolution habitat classification. The EUNIS approach to classifying biotopes (biological habitat class) may provide further guidance on incorporating biological resources into a habitat classification framework and could be reexamined while developing a classification system for Massachusetts.

- If a hybrid or modification of existing studies is selected, nomenclature must be exact and clearly constrain the meaning of terms. An official glossary of terms must be agreed upon and implemented by all users to maintain consistency in the database.

- CZM should designate one or more technical staff members to undertake future habitat classification exercises. Staff should familiarize themselves with classification schemes, mapping techniques, habitat structure and digital data management. Personnel consistency during database development is particularly important to develop and document approaches to classify habitat.

- Habitat classification scheme results should be incorporated into an existing, searchable data management system to store and disseminate data and habitat maps. CZM developed the Massachusetts Ocean Resources Information System (MORIS; a GIS database containing coastal and marine data layers), which could be used to store, view and disseminate habitat mapping products.

- CZM should consider hosting a workshop to evaluate and discuss the application of the recommended habitat classification frameworks to Massachusetts. Environmental managers, researchers, policy makers and other stakeholders involved with habitat characterization, classification and mapping should be invited to the workshop to guide identifying next steps needed to create a single habitat classification framework for Massachusetts. CZM should be mindful that revisions will most likely need to be made to the chosen classification system.

- Since habitat classification is an evolving research and management topic, a list of emerging pilot projects and studies should be maintained and coordination with overlapping activities and partners should be an ongoing process. USGS, DMF, US EPA, Massachusetts Bay National Estuary Program, Waquoit Bay and Narragansett Bay NERR and NOAA’s CSC are potential partners that could be involved in discussions about the choice, modification and implementation of a classification scheme in Massachusetts.

CONCLUSION

There are many benefits of incorporating a standardized habitat classification scheme into mapping and characterization projects. This report describes 12 approaches to classify habitat, with four studies (i.e., Madden et al. 2005; Kutcher et al. 2005; Greene et al. In Press; and Valentine et al. 2005) highlighted for consideration by CZM. No one, standard classification approach is currently endorsed by the scientific and management community. In order for an approach to be successful and useful on local, regional or national scales, users need to accept a disciplined, standardized terminology to classify and describe habitats at various scales.

The selection of a singular and flexible habitat classification framework for coastal and marine environments requires a clear identification of objectives for using a scheme and rigorous testing of chosen classification(s) with existing data in a pilot area. None of the four recommended schemes sufficiently classify habitats ranging from coastal areas to oceanic environments. Evaluating the application of the four recommended schemes in coastal and marine environments in Massachusetts will facilitate a process to augment or hybridize existing schemes to achieve management objectives in Massachusetts.

Managers will ultimately benefit from a classification scheme that provides geographic representation of habitats on a map, standardized terminology for different habitat types, guidelines for organizing data, facilitation of mapping efforts, incorporation of the classification results and associated ancillary data into a well-designed GIS and improved communication. To ensure the use of a habitat classification approach, CZM must engage potential partners, including government agencies – particularly NOAA’s CSC (a major partner in CMECS), academic institutions and other stakeholders.

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APPENDICES

APPENDIX 1: Classification hierarchy / organization of four recommended habitat classification studies.

A. Madden et al. (2005), “Coastal and Marine Systems of North America – Framework for an Ecological Classification Standard: Version II”

B. Kutcher et al. 2005, “A recommendation for a comprehensive habitat and land use classification system for the National Estuarine Research Reserve System”

C. Greene et. al (In Press), “Construction of digital potential marine benthic habitat maps using a coded classification scheme and their application”

D. Valentine et al. (2005), “Classification of Marine Sublittoral Habitats, with Application to the Northeastern North America Region”

A. Madden et al. (2005), "Coastal and Marine Systems of North America – Framework for an Ecological Classification Standard: Version II"

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Website: http://www.natureserve.org/getData/CMECS/

Level 1 Level 2 Level 3 Level 4 Level 5 (Habitat)

	Regime	Formation		Zone_Suffix		Macrohabitat_Suffix	Macrohab	Unit_id	Unit_Name_Suffix	Unit_Name
A	Estuarine	1 Lagoon	WU	Water Column upper layer	a	estuarine water column	A.01.WU.a	501	estuarine turbidity maximum	Estuarine Lagoon Upper water column Turbidity Maximum
A	Estuarine	1 Lagoon	WU	Water Column upper layer	a	estuarine water column	A.01.WU.a	502	pycnocline	Estuarine Lagoon Pycnocline
A	Estuarine	1 Lagoon	WU	Water Column upper layer	a	estuarine water column	A.01.WU.a	503	upper water column	Estuarine Lagoon surface foam
A	Estuarine	1 Lagoon	WU	Water Column upper layer	a	estuarine water column	A.01.WU.a	504	small fresh water lens	Estuarine Lagoon Freshwater Lens
A	Estuarine	1 Lagoon	WU	Water Column upper layer	a	estuarine water column	A.01.WU.a	505	hyperhaline estuarine water column	Estuarine Lagoon Hypersaline Water
A	Estuarine	1 Lagoon	WU	Water Column upper layer	a	estuarine water column	A.01.WU.a	506	phytoplankton bloom	Estuarine Lagoon Phytoplankton Bloom
A	Estuarine	1 Lagoon	WU	Water Column upper layer	a	estuarine water column	A.01.WU.a	507	epipelagic zone	Estuarine Lagoon Epipelagic Layer
A	Estuarine	1 Lagoon	WU	Water Column upper layer	a	estuarine water column	A.01.WU.a	508	floating vegetation mat	Estuarine Lagoon Floating Vegetation Mat
A	Estuarine	1 Lagoon	WU	Water Column upper layer	a	estuarine water column	A.01.WU.a	509	tributary discharge zone	Estuarine Lagoon Tributary Discharge
A	Estuarine	1 Lagoon	WU	Water Column upper layer	a	estuarine water column	A.01.WU.a	510	counter current	Estuarine Lagoon Counter Current Zone
A	Estuarine	1 Lagoon	WB	Water Column bottom layer	a	estuarine water column	A.01.WB.a	511	anoxic bottom water	Estuarine Lagoon Anoxic Bottom Water
A	Estuarine	1 Lagoon	WB	Water Column bottom layer	a	estuarine water column	A.01.WB.a	512	oxic bottom water	Estuarine Lagoon Oxic Bottom Water
A	Estuarine	1 Lagoon	WB	Water Column bottom layer	a	estuarine water column	A.01.WB.a	513	salt wedge	Estuarine Lagoon Salt Wedge
A	Estuarine	1 Lagoon	WB	Water Column bottom layer	a	estuarine water column	A.01.WB.a	514	groundwater seep	Estuarine Lagoon Groundwater Seep
A	Estuarine	1 Lagoon	WB	Water Column bottom layer	a	estuarine water column	A.01.WB.a	515	benthic boundary layer	Estuarine Lagoon Benthic Boundary Layer
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	A.01.LS.a	516	bare organic mud	Estuarine Lagoon Bare Organic Sediment
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	A.01.LS.a	517	bare carbonate sediment	Estuarine Lagoon Bare Carbonate Sediment
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	A.01.LS.a	518	bare carbonate mud	Estuarine Lagoon Bare Carbonate Mud
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	A.01.LS.a	519	bare carbonate sand	Estuarine Lagoon Bare Carbonate Sands
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	A.01.LS.a	520	bare mixed-coarse sediment softbottom	Estuarine Lagoon Bare Mixed-Coarse Sediment
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	A.01.LS.a	521	vegetated mineral sediments	Estuarine Lagoon Vegetated Mineral Sediments
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	A.01.LS.a	522	vegetated organic sediments	Estuarine Lagoon Vegetated Organic Sediments
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	b	rocky shore	A.01.LS.b	523	bedrock shore	Estuarine Lagoon Bedrock Shore
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	b	rocky shore	A.01.LS.b	524	hardpan shore	Estuarine Lagoon Hardpan Shore
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	b	rocky shore	A.01.LS.b	525	boulder shore	Estuarine Lagoon Boulder Shore
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	b	rocky shore	A.01.LS.b	526	cobble shore	Estuarine Lagoon Cobble Shore
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	b	rocky shore	A.01.LS.b	527	sand-bedrock shore	Estuarine Lagoon Sand-Bedrock Shore
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	c	dune system	A.01.LS.c	528	foredune	Estuarine Lagoon Foredune
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	c	dune system	A.01.LS.c	529	dune crest	Estuarine Lagoon Dune Crest

A	Estuarine	1 Lagoon	LS	Littoral Supratidal	c	dune system	A.01.LS.c	530	backdune	Estuarine Lagoon Backdune
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	d	cliff	A.01.LS.d	531	cliff notch	Estuarine Lagoon Cliff Notch
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	d	cliff	A.01.LS.d	532	cliff bioerosion notch	Estuarine Lagoon Bioeroded Cliff Notch
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	d	cliff	A.01.LS.d	533	cliff cave	Estuarine Lagoon Cliff Cave
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	d	cliff	A.01.LS.d	534	cliff fracture	Estuarine Lagoon Cliff Fracture
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	d	cliff	A.01.LS.d	535	cliff rubble zone	Estuarine Lagoon Cliff Rubble Zone
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	e	mangrove swamp	A.01.LS.e	536	prop root zone	Estuarine Lagoon Mangrove Prop Root Zone
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	e	mangrove swamp	A.01.LS.e	537	basin swamp	Estuarine Lagoon Mangrove Basin
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	e	mangrove swamp	A.01.LS.e	538	buttonwood ridge	Estuarine Lagoon Mangrove Buttonwood Ridge
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	e	mangrove swamp	A.01.LS.e	539	pneumatophore zone	Estuarine Lagoon Mangrove Pneumatophore Zone
A	Estuarine	1 Lagoon	LS	Littoral Supratidal	e	mangrove swamp	A.01.LS.e	540	swamp creek	Estuarine Lagoon Mangrove Swamp Creek
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	A.01.LI.a	541	bare organic mud softbottom	Estuarine Lagoon Intertidal Bare Organic Mud sediments
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	A.01.LI.a	542	bare carbonate sediment softbottom	Estuarine Lagoon Intertidal Bare Carbonate Sediment sediments
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	A.01.LI.a	543	bare carbonate mud softbottom	Estuarine Lagoon Intertidal Bare Carbonate Mud sediments
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	A.01.LI.a	544	bare carbonate sand softbottom	Estuarine Lagoon Intertidal Bare Carbonate Sand sediments
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	A.01.LI.a	545	bare mixed-coarse sediment softbottom	Estuarine Lagoon Intertidal Bare Mixed-coarse Sediment sediments
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	A.01.LI.a	546	vegetated softbottom- holdfast (macroalgae be	Estuarine Lagoon Intertidal Vegetated Softbottom- non-rooted
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	A.01.LI.a	547	vegetated softbottom- rooted (seagrass bed)	Estuarine Lagoon Intertidal Vegetated Softbottom- rooted
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	A.01.LI.a	548	vegetated organic softbottom	Estuarine Lagoon Intertidal Vegetated Organic Softbottom
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	b	mudflat	A.01.LI.b	549	fringing vegetated brackish mudflat	Estuarine Lagoon Intertidal Fringing Vegetated Brackish Mudflat
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	b	mudflat	A.01.LI.b	550	fringing vegetated saline mudflat	Estuarine Lagoon Intertidal Fringing Vegetated saline Mudflat
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	b	mudflat	A.01.LI.b	551	bare brackish mudflat	Estuarine Lagoon Intertidal Bare Brackish Mudflat
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	b	mudflat	A.01.LI.b	552	bare saline mudflat	Estuarine Lagoon Intertidal Bare Saline Mudflat
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.01.LI.c	553	saline fringing wetland tidal pass	Estuarine Lagoon Intertidal saline marsh tidal pass
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.01.LI.c	554	saline fringing wetland tidal creek	Estuarine Lagoon Intertidal saline marsh tidal creek
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.01.LI.c	555	saline fringing wetland tidal creek bank	Estuarine Lagoon Intertidal saline marsh tidal creek bank
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.01.LI.c	556	saline wetland hammock	Estuarine Lagoon Intertidal saline marsh hammock
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.01.LI.c	557	saline wetland inland basin marsh	Estuarine Lagoon Intertidal saline marsh basin
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.01.LI.c	558	saline wetland streamside marsh	Estuarine Lagoon Intertidal saline streamside marsh
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.01.LI.d	559	brackish fringing wetland tidal pass	Estuarine Lagoon Intertidal brakish marsh tidal pass
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.01.LI.d	560	brackish fringing wetland tidal creek	Estuarine Lagoon Intertidal brakish marsh tidal creek
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.01.LI.d	561	brackish fringing wetland tidal creek bank	Estuarine Lagoon Intertidal brakish marsh tidal creek bank
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.01.LI.d	562	brackish wetland hammock	Estuarine Lagoon Intertidal brakish marsh hammock
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.01.LI.d	563	brackish wetland inland basin marsh	Estuarine Lagoon Intertidal brakish marsh basin
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.01.LI.d	564	brackish wetland streamside marsh	Estuarine Lagoon Intertidal brakish streamside marsh
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	e	hardbottom	A.01.LI.e	565	bare gravel hardbottom	Estuarine Lagoon Intertidal bare gravel
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	e	hardbottom	A.01.LI.e	566	bare limestone pavement hardbottom	Estuarine Lagoon Intertidal bare limestone pavement
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	e	hardbottom	A.01.LI.e	567	bare bedrock hardbottom	Estuarine Lagoon Intertidal bare bedrock

A	Estuarine	1 Lagoon	LI	Littoral Intertidal	f	cliff	A.01.LI.f	568	notch	Estuarine Lagoon Intertidal cliff notch
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	f	cliff	A.01.LI.f	569	bioerosion notch	Estuarine Lagoon Intertidal Bioeroded cliff notch
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	f	cliff	A.01.LI.f	570	cave	Estuarine Lagoon Intertidal cliff cave
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	f	cliff	A.01.LI.f	571	fracture	Estuarine Lagoon Intertidal cliff fracture
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	f	cliff	A.01.LI.f	572	rubble zone	Estuarine Lagoon Intertidal cliff rubble zone
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	A.01.LI.g	573	prop root zone	Estuarine Lagoon Intertidal mangrove prop root zone
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	A.01.LI.g	574	basin swamp	Estuarine Lagoon Intertidal mangrove basin swamp
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	A.01.LI.g	575	buttonwood ridge	Estuarine Lagoon Intertidal mangrove buttonwood ridge
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	A.01.LI.g	576	pneumatophore zone	Estuarine Lagoon Intertidal mangrove pneumatophore zone
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	A.01.LI.g	577	swamp creek	Estuarine Lagoon Intertidal mangrove creek
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	A.01.LI.g	578	basin pond	Estuarine Lagoon Intertidal mangrove basin pond
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	h	coastal beach	A.01.LI.h	579	sand beach	Estuarine Lagoon Intertidal sand beach
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	h	coastal beach	A.01.LI.h	580	mixed-fine sediment beach	Estuarine Lagoon Intertidal mixed-fine sediment beach
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	h	coastal beach	A.01.LI.h	581	mixed-fine sand and mud beach	Estuarine Lagoon Intertidal mixed-fine sand and mud beach
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	h	coastal beach	A.01.LI.h	582	mud beach	Estuarine Lagoon Intertidal mud beach
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	h	coastal beach	A.01.LI.h	583	rock and boulder beach	Estuarine Lagoon Intertidal rock and boulder beach
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	h	coastal beach	A.01.LI.h	584	cobble beach	Estuarine Lagoon Intertidal cobble beach
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	h	coastal beach	A.01.LI.h	585	mixed-coarse sediment beach	Estuarine Lagoon Intertidal mixed-coarse sediment beach
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	h	coastal beach	A.01.LI.h	586	gravel beach	Estuarine Lagoon Intertidal gravel beach
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	i	rocky shore	A.01.LI.i	587	bedrock shore	Estuarine Lagoon Intertidal bedrock shore
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	i	rocky shore	A.01.LI.i	588	hardpan shore	Estuarine Lagoon Intertidal hardpan shore
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	i	rocky shore	A.01.LI.i	589	boulder shore	Estuarine Lagoon Intertidal boulder shore
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	i	rocky shore	A.01.LI.i	590	cobble shore	Estuarine Lagoon Intertidal cobble shore
A	Estuarine	1 Lagoon	LI	Littoral Intertidal	i	rocky shore	A.01.LI.i	591	sand-bedrock shore	Estuarine Lagoon Intertidal sand-bedrock shore
A	Estuarine	1 Lagoon	B	Bottom	a	oyster reef	A.01.B.a	592	live oyster reef	Estuarine Lagoon Subtidal oyster reef
A	Estuarine	1 Lagoon	B	Bottom	a	oyster reef	A.01.B.a	593	relict oyster reef	Estuarine Lagoon Subtidal relict oyster reef
A	Estuarine	1 Lagoon	B	Bottom	a	oyster reef	A.01.B.a	595	periodically emergent oyster reef	Estuarine Lagoon Intertidal oyster reef
A	Estuarine	1 Lagoon	B	Bottom	a	oyster reef	A.01.B.a	596	oyster shell midden	Estuarine Lagoon Subtidal oyster shell midden
A	Estuarine	1 Lagoon	B	Bottom	b	worm reef	A.01.B.b	597	live worm reef	Estuarine Lagoon Subtidal worm reef
A	Estuarine	1 Lagoon	B	Bottom	b	worm reef	A.01.B.b	598	relict worm reef	Estuarine Lagoon Subtidal relict worm reef
A	Estuarine	1 Lagoon	B	Bottom	b	worm reef	A.01.B.b	599	live mussel reef	Estuarine Lagoon Subtidal mussel reef
A	Estuarine	1 Lagoon	B	Bottom	b	worm reef	A.01.B.b	600	relict mussel reef	Estuarine Lagoon Subtidal relict mussel reef
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	601	bare sandy softbottom	Estuarine Lagoon Subtidal bare sandy sediments
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	602	bare mineral mud softbottom	Estuarine Lagoon Subtidal bare mineral mud sediments
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	603	bare organic mud softbottom	Estuarine Lagoon Subtidal bare organic mud sediments
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	604	bare carbonate mud-shell hash softbottom	Estuarine Lagoon Subtidal bare carbonate mud-shell hash sediments
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	605	bare carbonate mud softbottom	Estuarine Lagoon Subtidal bare carbonate mud sediments
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	606	bare carbonate sand softbottom	Estuarine Lagoon Subtidal bare carbonate sand sediments
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	607	bare mixed-coarse sediment softbottom	Estuarine Lagoon Subtidal bare mixed-coarse sediment sediments

A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	608	colonized mixed-fine softbottom	Estuarine Lagoon Subtidal colonized mixed-fine sediments
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	609	vegetated mud and mixed-fine softbottom	Estuarine Lagoon Subtidal vegetated mud and mixed-fine sediments
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	610	bare gravel softbottom	Estuarine Lagoon Subtidal bare gravel
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	611	vegetated softbottom	Estuarine Lagoon Subtidal vegetated softbottom
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	612	colonized softbottom	Estuarine Lagoon Subtidal colonized softbottom
A	Estuarine	1 Lagoon	B	Bottom	c	unconsolidated sediments	A.01.B.c	613	vegetated colonized softbottom	Estuarine Lagoon Subtidal vegetated colonized softbottom
A	Estuarine	1 Lagoon	B	Bottom	d	hardbottom	A.01.B.d	614	bare limestone pavement hardbottom	Estuarine Lagoon Subtidal bare limestone pavement
A	Estuarine	1 Lagoon	B	Bottom	d	hardbottom	A.01.B.d	615	vegetated rock and boulder hardbottom	Estuarine Lagoon Subtidal vegetated rock and boulder
A	Estuarine	1 Lagoon	B	Bottom	d	hardbottom	A.01.B.d	616	cobble hardbottom	Estuarine Lagoon Subtidal cobble
A	Estuarine	1 Lagoon	B	Bottom	d	hardbottom	A.01.B.d	617	gravel hardbottom	Estuarine Lagoon Subtidal gravel
A	Estuarine	1 Lagoon	B	Bottom	d	hardbottom	A.01.B.d	618	boulder hardbottom	Estuarine Lagoon Subtidal boulder
A	Estuarine	1 Lagoon	B	Bottom	d	hardbottom	A.01.B.d	619	bedrock hardbottom	Estuarine Lagoon Subtidal bedrock
A	Estuarine	1 Lagoon	B	Bottom	d	hardbottom	A.01.B.d	620	colonized tidal creek bottom	Estuarine Lagoon Subtidal colonized tidal creek bottom
A	Estuarine	2 Embayment	WU	Water Column (upper layer	a	estuarine water column	A.02.WU.a	621	estuarine turbidity maximum	Estuarine Embayment Turbidity Maximum
A	Estuarine	2 Embayment	WU	Water Column (upper layer	a	estuarine water column	A.02.WU.a	622	pycnocline	Estuarine Embayment Pycnocline
A	Estuarine	2 Embayment	WU	Water Column (upper layer	a	estuarine water column	A.02.WU.a	623	upper water column	Estuarine Embayment surface foam
A	Estuarine	2 Embayment	WU	Water Column (upper layer	a	estuarine water column	A.02.WU.a	624	small fresh water lens	Estuarine Embayment Freshwater Lens
A	Estuarine	2 Embayment	WU	Water Column (upper layer	a	estuarine water column	A.02.WU.a	625	hyperhaline estuarine water column	Estuarine Embayment Hypersaline Water
A	Estuarine	2 Embayment	WU	Water Column (upper layer	a	estuarine water column	A.02.WU.a	626	phytoplankton bloom	Estuarine Embayment Phytoplankton Bloom
A	Estuarine	2 Embayment	WU	Water Column (upper layer	a	estuarine water column	A.02.WU.a	627	epipelagic zone	Estuarine Embayment Epipelagic Layer
A	Estuarine	2 Embayment	WU	Water Column (upper layer	a	estuarine water column	A.02.WU.a	628	floating vegetation mat	Estuarine Embayment Floating Vegetation Mat
A	Estuarine	2 Embayment	WU	Water Column (upper layer	a	estuarine water column	A.02.WU.a	629	tributary discharge zone	Estuarine Embayment Tributary Discharge
A	Estuarine	2 Embayment	WB	Water Column (bottom laye	a	estuarine water column	A.02.WB.a	630	counter current	Estuarine Embayment Counter Current Zone
A	Estuarine	2 Embayment	WB	Water Column (bottom laye	a	estuarine water column	A.02.WB.a	631	anoxic bottom water	Estuarine Embayment Anoxic Bottom Water
A	Estuarine	2 Embayment	WB	Water Column (bottom laye	a	estuarine water column	A.02.WB.a	632	oxic bottom water	Estuarine Embayment Oxic Bottom Water
A	Estuarine	2 Embayment	WB	Water Column (bottom laye	a	estuarine water column	A.02.WB.a	633	salt wedge	Estuarine Embayment Salt Wedge
A	Estuarine	2 Embayment	WB	Water Column (bottom laye	a	estuarine water column	A.02.WB.a	634	groundwater seep	Estuarine Embayment Groundwater Seep
A	Estuarine	2 Embayment	WB	Water Column (bottom laye	a	estuarine water column	A.02.WB.a	635	benthic boundary layer	Estuarine Embayment Benthic Boundary Layer
A	Estuarine	2 Embayment	LS	Littoral Supratidal	a	unconsolidated sediments	A.02.LS.a	636	bare organic mud	Estuarine Embayment Bare Organic Sediment
A	Estuarine	2 Embayment	LS	Littoral Supratidal	a	unconsolidated sediments	A.02.LS.a	637	bare carbonate sediment	Estuarine Embayment Bare Carbonate Sediment
A	Estuarine	2 Embayment	LS	Littoral Supratidal	a	unconsolidated sediments	A.02.LS.a	638	bare carbonate mud	Estuarine Embayment Bare Carbonate Mud
A	Estuarine	2 Embayment	LS	Littoral Supratidal	a	unconsolidated sediments	A.02.LS.a	639	bare carbonate sand	Estuarine Embayment Bare Carbonate Sand
A	Estuarine	2 Embayment	LS	Littoral Supratidal	a	unconsolidated sediments	A.02.LS.a	640	bare mixed-coarse sediment softbottom	Estuarine Embayment Bare Mixed-Coarse Sediment
A	Estuarine	2 Embayment	LS	Littoral Supratidal	a	unconsolidated sediments	A.02.LS.a	641	vegetated mineral sediments	Estuarine Embayment Vegetated Mineral Sediments
A	Estuarine	2 Embayment	LS	Littoral Supratidal	a	unconsolidated sediments	A.02.LS.a	642	vegetated organic sediments	Estuarine Embayment Vegetated Organic Sediments
A	Estuarine	2 Embayment	LS	Littoral Supratidal	b	rocky shore	A.02.LS.b	643	bedrock shore	Estuarine Embayment Bedrock Shore
A	Estuarine	2 Embayment	LS	Littoral Supratidal	b	rocky shore	A.02.LS.b	644	hardpan shore	Estuarine Embayment Hardpan Shore
A	Estuarine	2 Embayment	LS	Littoral Supratidal	b	rocky shore	A.02.LS.b	645	boulder shore	Estuarine Embayment Boulder Shore

A	Estuarine	2 Embayment	LS	Littoral Supratidal	b	rocky shore	A.02.LS.b	646	cobble shore	Estuarine Embayment Cobble Shore
A	Estuarine	2 Embayment	LS	Littoral Supratidal	b	rocky shore	A.02.LS.b	647	sand-bedrock shore	Estuarine Embayment Sand-Bedrock Shore
A	Estuarine	2 Embayment	LS	Littoral Supratidal	c	dune system	A.02.LS.c	648	foredune	Estuarine Embayment Foredune
A	Estuarine	2 Embayment	LS	Littoral Supratidal	c	dune system	A.02.LS.c	649	dune crest	Estuarine Embayment Dune Crest
A	Estuarine	2 Embayment	LS	Littoral Supratidal	c	dune system	A.02.LS.c	650	backdune	Estuarine Embayment Backdune
A	Estuarine	2 Embayment	LS	Littoral Supratidal	d	cliff	A.02.LS.d	651	cliff notch	Estuarine Embayment Cliff Notch
A	Estuarine	2 Embayment	LS	Littoral Supratidal	d	cliff	A.02.LS.d	652	cliff bioerosion notch	Estuarine Embayment Bioeroded Cliff Notch
A	Estuarine	2 Embayment	LS	Littoral Supratidal	d	cliff	A.02.LS.d	653	cliff cave	Estuarine Embayment Cliff Cave
A	Estuarine	2 Embayment	LS	Littoral Supratidal	d	cliff	A.02.LS.d	654	cliff fracture	Estuarine Embayment Cliff Fracture
A	Estuarine	2 Embayment	LS	Littoral Supratidal	d	cliff	A.02.LS.d	655	cliff rubble zone	Estuarine Embayment Cliff Rubble Zone
A	Estuarine	2 Embayment	LS	Littoral Supratidal	e	mangrove swamp	A.02.LS.e	656	prop root zone	Estuarine Embayment Mangrove Prop Root Zone
A	Estuarine	2 Embayment	LS	Littoral Supratidal	e	mangrove swamp	A.02.LS.e	657	basin swamp	Estuarine Embayment Mangrove Basin
A	Estuarine	2 Embayment	LS	Littoral Supratidal	e	mangrove swamp	A.02.LS.e	658	buttonwood ridge	Estuarine Embayment Mangrove Buttonwood Ridge
A	Estuarine	2 Embayment	LS	Littoral Supratidal	e	mangrove swamp	A.02.LS.e	659	pneumatophore zone	Estuarine Embayment Mangrove Pneumatophore Zone
A	Estuarine	2 Embayment	LS	Littoral Supratidal	e	mangrove swamp	A.02.LS.e	660	swamp creek	Estuarine Embayment Mangrove Swamp Creek
A	Estuarine	2 Embayment	LI	Littoral Intertidal	a	unconsolidated sediments	A.02.LI.a	661	bare organic mud softbottom	Estuarine Embayment Intertidal Bare Organic Mud Sediments
A	Estuarine	2 Embayment	LI	Littoral Intertidal	a	unconsolidated sediments	A.02.LI.a	662	bare carbonate sediment softbottom	Estuarine Embayment Intertidal Bare Carbonate Sediments
A	Estuarine	2 Embayment	LI	Littoral Intertidal	a	unconsolidated sediments	A.02.LI.a	663	bare carbonate mud softbottom	Estuarine Embayment Intertidal Bare Carbonate Mud Sediments
A	Estuarine	2 Embayment	LI	Littoral Intertidal	a	unconsolidated sediments	A.02.LI.a	664	bare carbonate sand softbottom	Estuarine Embayment Intertidal Bare Carbonate Sand Sediments
A	Estuarine	2 Embayment	LI	Littoral Intertidal	a	unconsolidated sediments	A.02.LI.a	665	bare mixed-coarse sediment softbottom	Estuarine Embayment Intertidal Bare Mixed-coarse Sediments
A	Estuarine	2 Embayment	LI	Littoral Intertidal	a	unconsolidated sediments	A.02.LI.a	666	vegetated softbottom- holdfast (macroalgae be	Estuarine Embayment Intertidal Vegetated Softbottom- non-rooted
A	Estuarine	2 Embayment	LI	Littoral Intertidal	a	unconsolidated sediments	A.02.LI.a	667	vegetated softbottom- rooted (seagrass bed)	Estuarine Embayment Intertidal Vegetated Softbottom- rooted
A	Estuarine	2 Embayment	LI	Littoral Intertidal	a	unconsolidated sediments	A.02.LI.a	668	vegetated organic softbottom	Estuarine Embayment Intertidal Vegetated Organic Softbottom
A	Estuarine	2 Embayment	LI	Littoral Intertidal	b	mudflat	A.02.LI.b	669	fringing vegetated brackish mudflat	Estuarine Embayment Intertidal Fringing Vegetated Brackish Mudflat
A	Estuarine	2 Embayment	LI	Littoral Intertidal	b	mudflat	A.02.LI.b	670	fringing vegetated saline mudflat	Estuarine Embayment Intertidal Fringing Vegetated Saline Mudflat
A	Estuarine	2 Embayment	LI	Littoral Intertidal	b	mudflat	A.02.LI.b	671	bare brackish mudflat	Estuarine Embayment Intertidal Bare Brackish Mudflat
A	Estuarine	2 Embayment	LI	Littoral Intertidal	b	mudflat	A.02.LI.b	672	bare saline mudflat	Estuarine Embayment Intertidal Bare Saline Mudflat
A	Estuarine	2 Embayment	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.02.LI.c	673	saline fringing wetland tidal pass	Estuarine Embayment Intertidal saline marsh tidal pass
A	Estuarine	2 Embayment	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.02.LI.c	674	saline fringing wetland tidal creek	Estuarine Embayment Intertidal saline marsh tidal creek
A	Estuarine	2 Embayment	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.02.LI.c	675	saline fringing wetland tidal creek bank	Estuarine Embayment Intertidal saline marsh tidal creek bank
A	Estuarine	2 Embayment	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.02.LI.c	676	saline wetland hammock	Estuarine Embayment Intertidal saline marsh hammock
A	Estuarine	2 Embayment	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.02.LI.c	677	saline wetland inland basin marsh	Estuarine Embayment Intertidal saline marsh basin
A	Estuarine	2 Embayment	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	A.02.LI.c	678	saline wetland streamside marsh	Estuarine Embayment Intertidal saline streamside marsh
A	Estuarine	2 Embayment	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.02.LI.d	679	brackish fringing wetland tidal pass	Estuarine Embayment Intertidal brakish marsh tidal pass
A	Estuarine	2 Embayment	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.02.LI.d	680	brackish fringing wetland tidal creek	Estuarine Embayment Intertidal brakish marsh tidal creek
A	Estuarine	2 Embayment	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.02.LI.d	681	brackish fringing wetland tidal creek bank	Estuarine Embayment Intertidal brakish marsh tidal creek bank
A	Estuarine	2 Embayment	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.02.LI.d	682	brackish wetland hammock	Estuarine Embayment Intertidal brakish marsh hammock
A	Estuarine	2 Embayment	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.02.LI.d	683	brackish wetland inland basin marsh	Estuarine Embayment Intertidal brakish marsh basin

A	Estuarine	2	Embayment	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	A.02.LI.d	684	brackish wetland streamside marsh	Estuarine Embayment Intertidal brakish streamside marsh
A	Estuarine	2	Embayment	LI	Littoral Intertidal	e	hardbottom	A.02.LI.e	685	bare gravel hardbottom	Estuarine Embayment Intertidal bare gravel
A	Estuarine	2	Embayment	LI	Littoral Intertidal	e	hardbottom	A.02.LI.e	686	bare limestone pavement hardbottom	Estuarine Embayment Intertidal bare limestone pavement
A	Estuarine	2	Embayment	LI	Littoral Intertidal	e	hardbottom	A.02.LI.e	687	bare bedrock hardbottom	Estuarine Embayment Intertidal bare bedrock
A	Estuarine	2	Embayment	LI	Littoral Intertidal	f	cliff	A.02.LI.f	688	cliff notch	Estuarine Embayment Intertidal cliff notch
A	Estuarine	2	Embayment	LI	Littoral Intertidal	f	cliff	A.02.LI.f	689	cliff bioerosion notch	Estuarine Embayment Intertidal Bioeroded cliff notch
A	Estuarine	2	Embayment	LI	Littoral Intertidal	f	cliff	A.02.LI.f	690	cliff cave	Estuarine Embayment Intertidal cliff cave
A	Estuarine	2	Embayment	LI	Littoral Intertidal	f	cliff	A.02.LI.f	691	cliff fracture	Estuarine Embayment Intertidal cliff fracture
A	Estuarine	2	Embayment	LI	Littoral Intertidal	f	cliff	A.02.LI.f	692	cliff rubble zone	Estuarine Embayment Intertidal cliff rubble zone
A	Estuarine	2	Embayment	LI	Littoral Intertidal	g	mangrove swamp	A.02.LI.g	693	prop root zone	Estuarine Embayment Intertidal mangrove prop root zone
A	Estuarine	2	Embayment	LI	Littoral Intertidal	g	mangrove swamp	A.02.LI.g	694	basin swamp	Estuarine Embayment Intertidal mangrove basin swamp
A	Estuarine	2	Embayment	LI	Littoral Intertidal	g	mangrove swamp	A.02.LI.g	695	buttonwood ridge	Estuarine Embayment Intertidal mangrove buttonwood ridge
A	Estuarine	2	Embayment	LI	Littoral Intertidal	g	mangrove swamp	A.02.LI.g	696	pneumatophore zone	Estuarine Embayment Intertidal mangrove pneumatophore zone
A	Estuarine	2	Embayment	LI	Littoral Intertidal	g	mangrove swamp	A.02.LI.g	697	swamp creek	Estuarine Embayment Intertidal mangrove creek
A	Estuarine	2	Embayment	LI	Littoral Intertidal	g	mangrove swamp	A.02.LI.g	698	basin pond	Estuarine Embayment Intertidal mangrove basin pond
A	Estuarine	2	Embayment	LI	Littoral Intertidal	h	beach	A.02.LI.h	699	sand beach	Estuarine Embayment Intertidal sand beach
A	Estuarine	2	Embayment	LI	Littoral Intertidal	h	beach	A.02.LI.h	700	mixed-fine sediment beach	Estuarine Embayment Intertidal mixed-fine sediment beach
A	Estuarine	2	Embayment	LI	Littoral Intertidal	h	beach	A.02.LI.h	701	mixed-fine sand and mud beach	Estuarine Embayment Intertidal mixed-fine sand and mud beach
A	Estuarine	2	Embayment	LI	Littoral Intertidal	h	beach	A.02.LI.h	702	mud beach	Estuarine Embayment Intertidal mud beach
A	Estuarine	2	Embayment	LI	Littoral Intertidal	h	beach	A.02.LI.h	703	rock and boulder beach	Estuarine Embayment Intertidal rock and boulder beach
A	Estuarine	2	Embayment	LI	Littoral Intertidal	h	beach	A.02.LI.h	704	cobble beach	Estuarine Embayment Intertidal cobble beach
A	Estuarine	2	Embayment	LI	Littoral Intertidal	h	beach	A.02.LI.h	705	mixed-coarse sediment beach	Estuarine Embayment Intertidal mixed-coarse sediment beach
A	Estuarine	2	Embayment	LI	Littoral Intertidal	h	beach	A.02.LI.h	706	gravel beach	Estuarine Embayment Intertidal gravel beach
A	Estuarine	2	Embayment	LI	Littoral Intertidal	i	rocky shore	A.02.LI.i	707	bedrock shore	Estuarine Embayment Intertidal bedrock shore
A	Estuarine	2	Embayment	LI	Littoral Intertidal	i	rocky shore	A.02.LI.i	708	hardpan shore	Estuarine Embayment Intertidal hardpan shore
A	Estuarine	2	Embayment	LI	Littoral Intertidal	i	rocky shore	A.02.LI.i	709	boulder shore	Estuarine Embayment Intertidal boulder shore
A	Estuarine	2	Embayment	LI	Littoral Intertidal	i	rocky shore	A.02.LI.i	710	cobble shore	Estuarine Embayment Intertidal cobble shore
A	Estuarine	2	Embayment	LI	Littoral Intertidal	i	rocky shore	A.02.LI.i	711	sand-bedrock shore	Estuarine Embayment Intertidal sand-bedrock shore
A	Estuarine	2	Embayment	LI	Littoral Intertidal	j	dune system	A.02.LI.j	712	foredune	Estuarine Embayment Intertidal dune system foredune
A	Estuarine	2	Embayment	LI	Littoral Intertidal	j	dune system	A.02.LI.j	713	dune crest	Estuarine Embayment Intertidal dune system dune crest
A	Estuarine	2	Embayment	LI	Littoral Intertidal	j	dune system	A.02.LI.j	714	backdune	Estuarine Embayment Intertidal dune system backdune
A	Estuarine	2	Embayment	B	Bottom	a	oyster reef	A.02.B.a	715	live oyster reef	Estuarine Embayment Subtidal oyster reef
A	Estuarine	2	Embayment	B	Bottom	a	oyster reef	A.02.B.a	716	relict oyster reef	Estuarine Embayment Subtidal relict oyster reef
A	Estuarine	2	Embayment	B	Bottom	a	oyster reef	A.02.B.a	718	periodically emergent oyster reef	Estuarine Embayment Intertidal oyster reef
A	Estuarine	2	Embayment	B	Bottom	a	oyster reef	A.02.B.a	719	oyster shell midden	Estuarine Embayment Subtidal oyster shell midden
A	Estuarine	2	Embayment	B	Bottom	b	worm reef	A.02.B.b	720	live worm reef	Estuarine Embayment Subtidal worm reef
A	Estuarine	2	Embayment	B	Bottom	b	worm reef	A.02.B.b	721	relict worm reef	Estuarine Embayment Subtidal relict worm reef
A	Estuarine	2	Embayment	B	Bottom	b	worm reef	A.02.B.b	722	live mussel reef	Estuarine Embayment Subtidal mussel reef
A	Estuarine	2	Embayment	B	Bottom	b	worm reef	A.02.B.b	723	relict mussel reef	Estuarine Embayment Subtidal relict mussel reef

A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	724	bare sandy softbottom	Estuarine Embayment Subtidal bare sandy sediments
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	725	bare mineral mud softbottom	Estuarine Embayment Subtidal bare mineral mud sediments
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	726	bare organic mud softbottom	Estuarine Embayment Subtidal bare organic mud sediments
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	727	bare carbonate mud-shell hash softbottom	Estuarine Embayment Subtidal bare carbonate mud-shell hash sediments
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	728	bare carbonate mud softbottom	Estuarine Embayment Subtidal bare carbonate mud sediments
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	729	bare carbonate sand softbottom	Estuarine Embayment Subtidal bare carbonate sand sediments
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	730	bare mixed-coarse sediment softbottom	Estuarine Embayment Subtidal bare mixed-coarse sediment sediments
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	731	colonized mixed-fine softbottom	Estuarine Embayment Subtidal colonized mixed-fine sediments
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	732	vegetated mud and mixed-fine softbottom	Estuarine Embayment Subtidal vegetated mud and mixed-fine sediments
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	733	bare gravel softbottom	Estuarine Embayment Subtidal bare gravel
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	734	vegetated softbottom	Estuarine Embayment Subtidal vegetated softbottom
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	735	colonized softbottom	Estuarine Embayment Subtidal colonized softbottom
A	Estuarine	2 Embayment	B	Bottom	c	unconsolidated sediments	A.02.B.c	736	vegetated colonized softbottom	Estuarine Embayment Subtidal vegetated colonized softbottom
A	Estuarine	2 Embayment	B	Bottom	d	hardbottom	A.02.B.d	737	bare limestone pavement hardbottom	Estuarine Embayment Subtidal bare limestone pavement
A	Estuarine	2 Embayment	B	Bottom	d	hardbottom	A.02.B.d	738	vegetated rock and boulder hardbottom	Estuarine Embayment Subtidal vegetated rock and boulder hardbottom
A	Estuarine	2 Embayment	B	Bottom	d	hardbottom	A.02.B.d	739	cobble hardbottom	Estuarine Embayment Subtidal cobble hardbottom
A	Estuarine	2 Embayment	B	Bottom	d	hardbottom	A.02.B.d	740	gravel hardbottom	Estuarine Embayment Subtidal gravel hardbottom
A	Estuarine	2 Embayment	B	Bottom	d	hardbottom	A.02.B.d	741	boulder hardbottom	Estuarine Embayment Subtidal boulder hardbottom
A	Estuarine	2 Embayment	B	Bottom	d	hardbottom	A.02.B.d	742	bedrock hardbottom	Estuarine Embayment Subtidal bedrock hardbottom
A	Estuarine	2 Embayment	B	Bottom	d	hardbottom	A.02.B.d	743	colonized tidal creek bottom	Estuarine Embayment Subtidal colonized tidal creek bottom
A	Estuarine	3 Open Shor	W	Water Column	a	estuarine water column	A.03.W.a	744	sea surface	Estuarine Open Shoreline sea surface
A	Estuarine	3 Open Shor	W	Water Column	a	estuarine water column	A.03.W.a	745	surf zone	Estuarine Open Shoreline surf zone
A	Estuarine	3 Open Shor	B	Bottom	c	reef	A.03.B.c	746	worm reef	
A	Estuarine	3 Open Shor	B	Bottom	c	reef	A.03.B.c	747	mussel reef	
A	Estuarine	4 Surface ch	W	Water Column	a	river current	A.04.W.a	748	turbid upper water column	
A	Estuarine	4 Surface ch	W	Water Column	a	river current	A.04.W.a	749	clear upper water column	
A	Estuarine	4 Surface ch	L	Littoral	a	riverbank	A.04.L.a	750	vegetated	
A	Estuarine	4 Surface ch	L	Littoral	a	riverbank	A.04.L.a	751	mud	
A	Estuarine	4 Surface ch	L	Littoral	a	riverbank	A.04.L.a	752	rocky	
A	Estuarine	4 Surface ch	B	Bottom	a	riverbed	A.04.B.a	753	softbottom	
A	Estuarine	4 Surface ch	B	Bottom	a	riverbed	A.04.B.a	754	hardbottom	
A	Estuarine	4 Surface ch	B	Bottom	a	riverbed	A.04.B.a	755	scour hole	
A	Estuarine	4 Surface ch	B	Bottom	a	riverbed	A.04.B.a	756	organic deposition zone	
A	Estuarine	5 Island	L	Littoral	c	reef	A.05.L.c	757	worm reef bed	
A	Estuarine	5 Island	L	Littoral	c	reef	A.05.L.c	758	mussel bed	
A	Estuarine	5 Island	L	Littoral	c	reef	A.05.L.c	759	coral head	
A	Estuarine	9 Wetland	W	Water Column	a	deeply flooded wetland water c	A.09.W.a	760	deeply flooded wetland water column	
A	Estuarine	11 Reef	B	Bottom	c	coral reef	A.11.B.c	765	relict coral	

A	Estuarine	19 River plum	W	Water Column	a	estuarine water column	A.19.W.a	766	phytoplankton bloom	
B	Freshwat	1 Estuarine p	WU	Water Column (upper layer	a	turbid estuarine water column	B.01.WU.a	761	phytoplankton bloom	
B	Freshwat	1 Estuarine p	WU	Water Column (upper layer	a	turbid estuarine water column	B.01.WU.a	762	floating mat	Freshwater plume upper water column floating mat
B	Freshwat	2 Fresh wat	WU	Water Column (upper layer	u	undefined	B.02.WU.u	763	phytoplankton bloom	Freshwater-influenced nearshore marine phytoplankton bloom
B	Freshwat	2 Fresh wat	WU	Water Column (upper layer	u	undefined	B.02.WU.u	764	floating mat	
C	Nearshore	1 Lagoon	WU	Water Column (upper layer	a	marine water column	C.01.WU.a	767	upper water column	Marine Lagoon upper surface foam
C	Nearshore	1 Lagoon	WU	Water Column (upper layer	a	marine water column	C.01.WU.a	768	pycnocline	Nearshore marine Lagoon pycnocline
C	Nearshore	1 Lagoon	WU	Water Column (upper layer	a	marine water column	C.01.WU.a	769	hyperhaline water column	Nearshore marine Lagoon hyperhaline water column
C	Nearshore	1 Lagoon	WU	Water Column (upper layer	a	marine water column	C.01.WU.a	770	phytoplankton bloom	Nearshore marine Lagoon phytoplankton bloom
C	Nearshore	1 Lagoon	WU	Water Column (upper layer	a	marine water column	C.01.WU.a	771	epipelagic zone	Nearshore marine Lagoon epipelagic zone
C	Nearshore	1 Lagoon	WU	Water Column (upper layer	a	marine water column	C.01.WU.a	772	floating vegetation mat	Nearshore marine Lagoon floating vegetation mat
C	Nearshore	1 Lagoon	WU	Water Column (upper layer	a	marine water column	C.01.WU.a	773	counter current	Nearshore marine Lagoon counter current
C	Nearshore	1 Lagoon	WU	Water Column (upper layer	a	marine water column	C.01.WU.a	774	surf zone	Nearshore marine Lagoon surf zone
C	Nearshore	1 Lagoon	WU	Water Column (upper layer	a	marine water column	C.01.WU.a	775	sea surface	Nearshore marine Lagoon sea surface
C	Nearshore	1 Lagoon	WB	Water Column (bottom laye	u	undefined	C.01.WB.u	776	anoxic bottom water	Nearshore marine Lagoon anoxic bottom water
C	Nearshore	1 Lagoon	WB	Water Column (bottom laye	u	undefined	C.01.WB.u	777	oxic bottom water	Nearshore marine Lagoon oxic bottom water
C	Nearshore	1 Lagoon	WB	Water Column (bottom laye	u	undefined	C.01.WB.u	778	salt wedge	Nearshore marine Lagoon salt wedge
C	Nearshore	1 Lagoon	WB	Water Column (bottom laye	u	undefined	C.01.WB.u	779	groundwater seep	Nearshore marine Lagoon groundwater seep
C	Nearshore	1 Lagoon	WB	Water Column (bottom laye	u	undefined	C.01.WB.u	780	benthic boundary layer	Nearshore marine Lagoon benthic boundary layer
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	C.01.LS.a	781	bare organic mud	Nearshore marine Lagoon bare organic mud
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	C.01.LS.a	782	bare carbonate sediment	Nearshore marine Lagoon bare carbonate sediment
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	C.01.LS.a	783	bare carbonate mud	Nearshore marine Lagoon bare carbonate mud
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	C.01.LS.a	784	bare carbonate sand	Nearshore marine Lagoon bare carbonate sand
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	C.01.LS.a	785	bare mixed-coarse sediment softbottom	Nearshore marine Lagoon bare mixed-coarse sediment softbottom
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	C.01.LS.a	786	vegetated mineral sediments	Nearshore marine Lagoon vegetated mineral sediments
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	a	unconsolidated sediments	C.01.LS.a	787	vegetated organic sediments	Nearshore marine Lagoon vegetated organic sediments
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	b	rocky shore	C.01.LS.b	788	bedrock shore	Nearshore marine Lagoon bedrock shore
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	b	rocky shore	C.01.LS.b	789	hardpan shore	Nearshore marine Lagoon hardpan shore
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	b	rocky shore	C.01.LS.b	790	boulder shore	Nearshore marine Lagoon boulder shore
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	b	rocky shore	C.01.LS.b	791	cobble shore	Nearshore marine Lagoon cobble shore
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	b	rocky shore	C.01.LS.b	792	sand-bedrock shore	Nearshore marine Lagoon sand-bedrock shore
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	c	dune system	C.01.LS.c	793	foredune	Nearshore marine Lagoon dune system foredune
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	c	dune system	C.01.LS.c	794	dune crest	Nearshore marine Lagoon dune system dune crest
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	c	dune system	C.01.LS.c	795	backdune	Nearshore marine Lagoon dune system backdune
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	d	cliff	C.01.LS.d	796	cliff notch	Nearshore marine Lagoon cliff cliff notch
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	d	cliff	C.01.LS.d	797	cliff bioerosion notch	Nearshore marine Lagoon cliff cliff bioerosion notch

C	Nearshore	1 Lagoon	LS	Littoral Supratidal	d	cliff	C.01.LS.d	798	cliff cave	Nearshore marine Lagoon cliff cliff cave
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	d	cliff	C.01.LS.d	799	cliff fracture	Nearshore marine Lagoon cliff cliff fracture
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	d	cliff	C.01.LS.d	800	cliff rubble zone	Nearshore marine Lagoon cliff cliff rubble zone
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	e	mangrove swamp	C.01.LS.e	801	prop root zone	Nearshore marine Lagoon mangrove swamp prop root zone
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	e	mangrove swamp	C.01.LS.e	802	basin swamp	Nearshore marine Lagoon mangrove swamp basin swamp
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	e	mangrove swamp	C.01.LS.e	803	buttonwood ridge	Nearshore marine Lagoon mangrove swamp buttonwood ridge
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	e	mangrove swamp	C.01.LS.e	804	pneumatophore zone	Nearshore marine Lagoon mangrove swamp pneumatophore zone
C	Nearshore	1 Lagoon	LS	Littoral Supratidal	e	mangrove swamp	C.01.LS.e	805	swamp creek	Nearshore marine Lagoon mangrove swamp swamp creek
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	C.01.LI.a	806	bare organic mud softbottom	Nearshore marine Lagoon Intertidal bare organic mud softbottom
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	C.01.LI.a	807	bare carbonate sediment softbottom	Nearshore marine Lagoon Intertidal bare carbonate sediment softbottom
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	C.01.LI.a	808	bare carbonate mud softbottom	Nearshore marine Lagoon Intertidal bare carbonate mud softbottom
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	C.01.LI.a	809	bare carbonate sand softbottom	Nearshore marine Lagoon Intertidal bare carbonate sand softbottom
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	C.01.LI.a	810	bare mixed-coarse sediment softbottom	Nearshore marine Lagoon Intertidal bare mixed-coarse sediment softbottom
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	C.01.LI.a	811	vegetated softbottom- holdfast (macroalgae be	Nearshore marine Lagoon Intertidal vegetated softbottom- non-rooted
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	C.01.LI.a	812	vegetated softbottom- rooted (seagrass bed)	Nearshore marine Lagoon Intertidal vegetated softbottom- rooted
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	a	unconsolidated sediments	C.01.LI.a	813	vegetated organic softbottom	Nearshore marine Lagoon Intertidal vegetated organic softbottom
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	b	mudflat	C.01.LI.b	814	fringing vegetated brackish mudflat	Nearshore marine Lagoon Intertidal fringing vegetated brackish mudflat
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	b	mudflat	C.01.LI.b	815	fringing vegetated saline mudflat	Nearshore marine Lagoon Intertidal fringing vegetated saline mudflat
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	b	mudflat	C.01.LI.b	816	bare brackish mudflat	Nearshore marine Lagoon Intertidal bare brackish mudflat
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	b	mudflat	C.01.LI.b	817	bare saline mudflat	Nearshore marine Lagoon Intertidal bare saline mudflat
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	C.01.LI.c	818	saline fringing wetland tidal pass	Nearshore marine Lagoon Intertidal saline fringing wetland tidal pass
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	C.01.LI.c	819	saline fringing wetland tidal creek	Nearshore marine Lagoon Intertidal saline fringing wetland tidal creek
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	C.01.LI.c	820	saline fringing wetland tidal creek bank	Nearshore marine Lagoon Intertidal saline fringing wetland tidal creek bank
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	C.01.LI.c	821	saline wetland hammock	Nearshore marine Lagoon Intertidal saline wetland hammock
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	C.01.LI.c	822	saline wetland inland basin marsh	Nearshore marine Lagoon Intertidal saline wetland inland basin marsh
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	c	saline fringing wetland (marsh)	C.01.LI.c	823	saline wetland streamside marsh	Nearshore marine Lagoon Intertidal saline wetland streamside marsh
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	C.01.LI.d	824	brackish fringing wetland tidal pass	Nearshore marine Lagoon Intertidal brackish fringing wetland tidal pass
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	C.01.LI.d	825	brackish fringing wetland tidal creek	Nearshore marine Lagoon Intertidal brackish fringing wetland tidal creek
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	C.01.LI.d	826	brackish fringing wetland tidal creek bank	Nearshore marine Lagoon Intertidal brackish fringing wetland tidal creek bank
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	C.01.LI.d	827	brackish wetland hammock	Nearshore marine Lagoon Intertidal brackish wetland hammock
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	C.01.LI.d	828	brackish wetland inland basin marsh	Nearshore marine Lagoon Intertidal brackish wetland inland basin marsh
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	d	brackish fringing wetland (marsh	C.01.LI.d	829	brackish wetland streamside marsh	Nearshore marine Lagoon Intertidal brackish wetland streamside marsh
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	e	hardbottom	C.01.LI.e	830	bare gravel hardbottom	Nearshore marine Lagoon Intertidal hardbottom bare gravel hardbottom
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	e	hardbottom	C.01.LI.e	831	bare limestone pavement hardbottom	Nearshore marine Lagoon Intertidal hardbottom bare limestone pavement hardbottom
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	e	hardbottom	C.01.LI.e	832	bare bedrock hardbottom	Nearshore marine Lagoon Intertidal hardbottom bare bedrock hardbottom
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	f	cliff	C.01.LI.f	833	notch	Nearshore marine Lagoon Intertidal cliff notch
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	f	cliff	C.01.LI.f	834	bioerosion notch	Nearshore marine Lagoon Intertidal cliff bioerosion notch
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	f	cliff	C.01.LI.f	835	cave	Nearshore marine Lagoon Intertidal cliff cave

C	Nearshore	1 Lagoon	LI	Littoral Intertidal	f	cliff	C.01.LI.f	836	fracture	Nearshore marine Lagoon Intertidal cliff fracture
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	f	cliff	C.01.LI.f	837	rubble zone	Nearshore marine Lagoon Intertidal cliff rubble zone
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	C.01.LI.g	838	prop root zone	Nearshore marine Lagoon Intertidal mangrove swamp prop root zone
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	C.01.LI.g	839	basin swamp	Nearshore marine Lagoon Intertidal mangrove swamp basin swamp
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	C.01.LI.g	840	buttonwood ridge	Nearshore marine Lagoon Intertidal mangrove swamp buttonwood ridge
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	C.01.LI.g	841	pneumatophore zone	Nearshore marine Lagoon Intertidal mangrove swamp pneumatophore zone
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	C.01.LI.g	842	swamp creek	Nearshore marine Lagoon Intertidal mangrove swamp swamp creek
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	g	mangrove swamp	C.01.LI.g	843	basin pond	Nearshore marine Lagoon Intertidal mangrove swamp basin pond
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	h	beach	C.01.LI.h	844	sand beach	Nearshore marine Lagoon Intertidal sand beach
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	h	beach	C.01.LI.h	845	mixed-fine sediment beach	Nearshore marine Lagoon Intertidal mixed-fine sediment beach
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	h	beach	C.01.LI.h	846	mixed-fine sand and mud beach	Nearshore marine Lagoon Intertidal mixed-fine sand and mud beach
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	h	beach	C.01.LI.h	847	mud beach	Nearshore marine Lagoon Intertidal mud beach
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	h	beach	C.01.LI.h	848	rock and boulder beach	Nearshore marine Lagoon Intertidal rock and boulder beach
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	h	beach	C.01.LI.h	849	cobble beach	Nearshore marine Lagoon Intertidal cobble beach
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	h	beach	C.01.LI.h	850	mixed-coarse sediment beach	Nearshore marine Lagoon Intertidal mixed-coarse sediment beach
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	h	beach	C.01.LI.h	851	gravel beach	Nearshore marine Lagoon Intertidal gravel beach
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	i	rocky shore	C.01.LI.i	852	bedrock shore	Nearshore marine Lagoon Intertidal bedrock shore
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	i	rocky shore	C.01.LI.i	853	hardpan shore	Nearshore marine Lagoon Intertidal hardpan shore
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	i	rocky shore	C.01.LI.i	854	boulder shore	Nearshore marine Lagoon Intertidal boulder shore
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	i	rocky shore	C.01.LI.i	855	cobble shore	Nearshore marine Lagoon Intertidal cobble shore
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	i	rocky shore	C.01.LI.i	856	sand-bedrock shore	Nearshore marine Lagoon Intertidal sand-bedrock shore
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	j	oyster reef	C.01.LI.j	857	live oyster reef	Nearshore marine Lagoon Intertidal live oyster reef
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	j	oyster reef	C.01.LI.j	858	relict oyster reef	Nearshore marine Lagoon Intertidal relict oyster reef
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	j	oyster reef	C.01.LI.j	859	submerged oyster reef	Nearshore marine Lagoon Intertidal submerged oyster reef
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	j	oyster reef	C.01.LI.j	860	periodically emergent oyster reef	Nearshore marine Lagoon Intertidal periodically emergent oyster reef
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	j	oyster reef	C.01.LI.j	861	oyster shell midden	Nearshore marine Lagoon Intertidal oyster shell midden
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	k	mussel reef	C.01.LI.k	862	live mussel reef	Nearshore marine Lagoon Intertidal live mussel reef
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	k	mussel reef	C.01.LI.k	863	relict mussel reef	Nearshore marine Lagoon Intertidal relict mussel reef
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	l	coral reef	C.01.LI.l	864	relict coral reef	Nearshore marine Lagoon Intertidal relict coral reef
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	k	worm reef	C.01.LI.k	865	live worm reef	Nearshore marine Lagoon Intertidal live worm reef
C	Nearshore	1 Lagoon	LI	Littoral Intertidal	k	worm reef	C.01.LI.k	866	relict worm reef	Nearshore marine Lagoon Intertidal relict worm reef
C	Nearshore	2 Embayment	WU	Water Column (upper layer	a	marine water column	C.02.WU.a	867	upper water column	Nearshore marine Embayment upper water column
C	Nearshore	2 Embayment	WU	Water Column (upper layer	a	marine water column	C.02.WU.a	868	pycnocline	Nearshore marine Embayment pycnocline
C	Nearshore	2 Embayment	WU	Water Column (upper layer	a	marine water column	C.02.WU.a	869	hyperhaline water column	Nearshore marine Embayment hyperhaline water column
C	Nearshore	2 Embayment	WU	Water Column (upper layer	a	marine water column	C.02.WU.a	870	phytoplankton bloom	Nearshore marine Embayment phytoplankton bloom
C	Nearshore	2 Embayment	WU	Water Column (upper layer	a	marine water column	C.02.WU.a	871	epipelagic zone	Nearshore marine Embayment epipelagic zone
C	Nearshore	2 Embayment	WU	Water Column (upper layer	a	marine water column	C.02.WU.a	872	floating vegetation mat	Nearshore marine Embayment floating vegetation mat
C	Nearshore	2 Embayment	WU	Water Column (upper layer	a	marine water column	C.02.WU.a	873	counter current	Nearshore marine Embayment counter current

C	Nearshore	2 Embayment	WB	Water Column (bottom laye	u	undefined	C.02.WB.u	874	anoxic bottom water	Nearshore marine Embayment anoxic bottom water
C	Nearshore	2 Embayment	WB	Water Column (bottom laye	u	undefined	C.02.WB.u	875	oxic bottom water	Nearshore marine Embayment oxic bottom water
C	Nearshore	2 Embayment	WB	Water Column (bottom laye	u	undefined	C.02.WB.u	876	salt wedge	Nearshore marine Embayment salt wedge
C	Nearshore	2 Embayment	WB	Water Column (bottom laye	u	undefined	C.02.WB.u	877	groundwater seep	Nearshore marine Embayment groundwater seep
C	Nearshore	2 Embayment	WB	Water Column (bottom laye	u	undefined	C.02.WB.u	878	benthic boundary layer	Nearshore marine Embayment benthic boundary layer
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	879	forereef	Nearshore marine coral forereef
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	880	backreef	Nearshore marine coral backreef
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	881	spur and groove	Nearshore marine spur and groove reef
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	882	reef halo	Nearshore marine reef halo
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	883	reef remnant	Nearshore marine reef remnant
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	884	sand channel	Nearshore marine reef sand channel
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	885	patch reef	Nearshore marine patch reef
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	886	aggregated patch reefs	Nearshore marine aggregated patch reefs
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	887	pinnacle	Nearshore marine pinnacle
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	888	fringe reef	Nearshore marine fringe reef
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	889	linear reef	Nearshore marine linear reef
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	890	platform	Nearshore marine platform
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	891	individual coral head	Nearshore marine individual coral head
C	Nearshore	11 Reef	B	Bottom	b	coral reef	C.11.B.b	892	reef rubble	Nearshore marine reef rubble
D	Neritic	2 Island arc	WU	Water Column (upper layer	a	inter-island pass	D.02.WU.a	893	clear water column	Neritic Island arc Water Column (upper layer) inter-island pass clear water column
D	Neritic	2 Island arc	LI	Littoral Intertidal	a	inter-island pass	D.02.LI.a	894	turbid water column	Neritic Island arc Littoral Intertidal inter-island pass turbid water column
D	Neritic	3 Atoll	WU	Water Column (upper layer	a	interior lagoon	D.03.WU.a	895	clear water column	Neritic Atoll Water Column (upper layer) interior lagoon clear water column
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	896	bare carbonate sand softbottom	Neritic Atoll coral reef bare carbonate sand softbottom
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	897	patch reef	Neritic Atoll coral reef patch reef
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	898	patch reef with halo	Neritic Atoll coral reef patch reef with halo
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	899	forereef	Neritic Atoll coral reef forereef
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	900	backreef	Neritic Atoll coral reef backreef
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	901	spur and groove	Neritic Atoll coral reef spur and groove
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	902	reef halo	Neritic Atoll coral reef reef halo
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	903	reef remnant	Neritic Atoll coral reef remnant
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	904	sand channel	Neritic Atoll coral reef sand channel
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	905	patch reef	Neritic Atoll coral reef patch reef
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	906	aggregated patch reefs	Neritic Atoll coral reef aggregated patch reefs
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	907	pinnacle	Neritic Atoll coral reef pinnacle
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	908	fringe reef	Neritic Atoll coral reef fringe reef
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	909	linear reef	Neritic Atoll coral reef linear reef
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	910	platform	Neritic Atoll coral reef platform

D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	911	individual coral head	Neritic Atoll solitary coral head
D	Neritic	3 Atoll	B	Bottom	b	coral reef	D.03.B.b	912	reef rubble	Neritic Atoll coral reef reef rubble
D	Neritic	3 Atoll	B	Bottom	c	hardbottom	D.03.B.c	913	bare limestone pavement hardbottom	Neritic Atoll bare limestone pavement
D	Neritic	3 Atoll	B	Bottom	d	unconsolidated sediments	D.03.B.d	914	carbonate sediments	Neritic Atoll carbonate sediments
D	Neritic	3 Atoll	B	Bottom	d	unconsolidated sediments	D.03.B.d	915	bare mineral mud softbottom	Neritic Atoll bare mineral mud softbottom
D	Neritic	3 Atoll	B	Bottom	d	unconsolidated sediments	D.03.B.d	916	bare organic mud softbottom	Neritic Atoll bare organic mud softbottom
D	Neritic	3 Atoll	B	Bottom	d	unconsolidated sediments	D.03.B.d	917	bare carbonate mud-shell hash softbottom	Neritic Atoll bare carbonate mud-shell hash softbottom
D	Neritic	3 Atoll	B	Bottom	d	unconsolidated sediments	D.03.B.d	918	bare carbonate mud softbottom	Neritic Atoll bare carbonate mud softbottom
D	Neritic	19 Plain	B	Bottom	a	lava field	D.19.B.a	919	compression ridge	Neritic Plain lava field compression ridge
D	Neritic	19 Plain	B	Bottom	a	lava field	D.19.B.a	920	lava tube	Neritic Plain lava field lava tube
D	Neritic	19 Plain	B	Bottom	a	lava field	D.19.B.a	921	crater	Neritic Plain lava field crater
D	Neritic	19 Plain	B	Bottom	a	lava field	D.19.B.a	922	lava flow	Neritic Plain lava field lava flow
D	Neritic	19 Plain	B	Bottom	b	sediment wave	D.19.B.b	923	organic debris	Neritic Plain sediment wave organic debris
D	Neritic	19 Plain	B	Bottom	b	sediment wave	D.19.B.b	924	mud	Neritic Plain sediment wave mud
D	Neritic	19 Plain	B	Bottom	b	sediment wave	D.19.B.b	925	sand	Neritic Plain sediment sand wave
D	Neritic	19 Plain	B	Bottom	c	bar	D.19.B.c	926	mud	Neritic Plain bar mud
D	Neritic	19 Plain	B	Bottom	c	bar	D.19.B.c	927	sand	Neritic Plain bar sand
D	Neritic	19 Plain	B	Bottom	c	bar	D.19.B.c	928	hardbottom	Neritic Plain bar hardbottom
D	Neritic	19 Plain	B	Bottom	d	moraine	D.19.B.d	929	gravel	Neritic Plain moraine gravel
D	Neritic	19 Plain	B	Bottom	d	moraine	D.19.B.d	930	pebble	Neritic Plain moraine pebble
D	Neritic	19 Plain	B	Bottom	d	moraine	D.19.B.d	931	cobble	Neritic Plain moraine cobble
D	Neritic	19 Plain	B	Bottom	d	moraine	D.19.B.d	932	boulder	Neritic Plain moraine boulder
D	Neritic	19 Plain	B	Bottom	d	moraine	D.19.B.d	933	mixed	Neritic Plain moraine mixed
D	Neritic	19 Plain	B	Bottom	d	moraine	D.19.B.d	934	bedrock	Neritic Plain moraine bedrock
D	Neritic	19 Plain	B	Bottom	e	cave	D.19.B.e	935	bedrock	Neritic Plain cave bedrock
D	Neritic	19 Plain	B	Bottom	e	cave	D.19.B.e	936	coral	Neritic Plain cave coral
D	Neritic	19 Plain	B	Bottom	e	cave	D.19.B.e	937	lava	Neritic Plain cave lava
D	Neritic	19 Plain	B	Bottom	f	crevice	D.19.B.f	938	bedrock	Neritic Plain crevice bedrock
D	Neritic	19 Plain	B	Bottom	f	crevice	D.19.B.f	939	coral	Neritic Plain crevice coral
D	Neritic	19 Plain	B	Bottom	f	crevice	D.19.B.f	940	lava	Neritic Plain crevice lava
D	Neritic	19 Plain	B	Bottom	g	sink	D.19.B.g	941	hardbottom	Neritic Plain sink hardbottom
D	Neritic	19 Plain	B	Bottom	h	debris field	D.19.B.h	942	gravel	Neritic Plain debris field gravel
D	Neritic	19 Plain	B	Bottom	h	debris field	D.19.B.h	943	pebble	Neritic Plain debris field pebble
D	Neritic	19 Plain	B	Bottom	h	debris field	D.19.B.h	944	cobble	Neritic Plain debris field cobble
D	Neritic	19 Plain	B	Bottom	h	debris field	D.19.B.h	945	boulder	Neritic Plain debris field boulder
D	Neritic	19 Plain	B	Bottom	h	debris field	D.19.B.h	946	mixed	Neritic Plain debris field mixed
D	Neritic	19 Plain	B	Bottom	h	debris field	D.19.B.h	947	bedrock	Neritic Plain debris field bedrock
D	Neritic	19 Plain	B	Bottom	i	groove	D.19.B.i	948	bedrock	Neritic Plain groove bedrock

D	Neritic	19 Plain	B	Bottom	i	groove	D.19.B.i	949	coral	Neritic Plain groove coral
D	Neritic	19 Plain	B	Bottom	j	channel	D.19.B.j	950	bedrock	Neritic Plain channel bedrock
D	Neritic	19 Plain	B	Bottom	j	channel	D.19.B.j	951	coral	Neritic Plain channel coral
D	Neritic	19 Plain	B	Bottom	k	ledge	D.19.B.k	952	bedrock	Neritic Plain ledge bedrock
D	Neritic	19 Plain	B	Bottom	k	ledge	D.19.B.k	953	coral	Neritic Plain ledge coral
D	Neritic	19 Plain	B	Bottom	l	wall	D.19.B.l	954	bedrock	Neritic Plain wall bedrock
D	Neritic	19 Plain	B	Bottom	l	wall	D.19.B.l	955	coral	Neritic Plain wall coral
D	Neritic	19 Plain	B	Bottom	m	pinnacle	D.19.B.m	956	coral	Neritic Plain pinnacle coral
E	Oceanic	3 Atoll	W	Water Column	a	interior lagoon	E.03.W.a	957	clear water column	Oceanic Atoll Water Column interior lagoon clear water column
E	Oceanic	3 Atoll	B	Bottom	b	coral reef	E.03.B.b	958	bare carbonate sand softbottom	Oceanic Atoll coral reef bare carbonate sand softbottom
E	Oceanic	3 Atoll	B	Bottom	b	coral reef	E.03.B.b	959	patch reef	Oceanic Atoll coral reef patch reef
E	Oceanic	3 Atoll	B	Bottom	b	coral reef	E.03.B.b	960	patch reef with halo	Oceanic Atoll coral reef patch reef with halo
E	Oceanic	3 Atoll	B	Bottom	b	coral reef	E.03.B.b	961	bare limestone pavement hardbottom	Oceanic Atoll coral reef bare limestone pavement hardbottom
E	Oceanic	3 Atoll	B	Bottom	b	coral reef	E.03.B.b	962	carbonate sediments	Oceanic Atoll coral reef carbonate sediments
E	Oceanic	3 Atoll	B	Bottom	b	coral reef	E.03.B.b	963	bare mineral mud softbottom	Oceanic Atoll coral reef bare mineral mud softbottom
E	Oceanic	3 Atoll	B	Bottom	b	coral reef	E.03.B.b	964	bare organic mud softbottom	Oceanic Atoll coral reef bare organic mud softbottom
E	Oceanic	3 Atoll	B	Bottom	b	coral reef	E.03.B.b	965	bare carbonate mud-shell hash softbottom	Oceanic Atoll coral reef bare carbonate mud-shell hash softbottom
E	Oceanic	3 Atoll	B	Bottom	b	coral reef	E.03.B.b	966	bare carbonate mud softbottom	Oceanic Atoll coral reef bare carbonate mud softbottom
E	Oceanic	19 Plain	B	Bottom	a	lava field	E.19.B.a	967	compression ridge	Oceanic Plain lava field compression ridge
E	Oceanic	19 Plain	B	Bottom	a	lava field	E.19.B.a	968	lava tube	Oceanic Plain lava field lava tube
E	Oceanic	19 Plain	B	Bottom	a	lava field	E.19.B.a	969	crater	Oceanic Plain lava field crater
E	Oceanic	19 Plain	B	Bottom	a	lava field	E.19.B.a	970	lava flow	Oceanic Plain lava field lava flow
E	Oceanic	19 Plain	B	Bottom	b	sediment wave	E.19.B.b	971	organic debris	Oceanic Plain sediment wave organic debris
E	Oceanic	19 Plain	B	Bottom	b	sediment wave	E.19.B.b	972	mud	Oceanic Plain sediment wave
E	Oceanic	19 Plain	B	Bottom	b	sediment wave	E.19.B.b	973	sand	Oceanic Plain sand wave sand
E	Oceanic	19 Plain	B	Bottom	c	bar	E.19.B.c	974	mud	Oceanic Plain bar mud
E	Oceanic	19 Plain	B	Bottom	c	bar	E.19.B.c	975	sand	Oceanic Plain bar sand
E	Oceanic	19 Plain	B	Bottom	c	bar	E.19.B.c	976	hardbottom	Oceanic Plain bar hardbottom
E	Oceanic	19 Plain	B	Bottom	d	moraine	E.19.B.d	977	gravel	Oceanic Plain moraine gravel
E	Oceanic	19 Plain	B	Bottom	d	moraine	E.19.B.d	978	pebble	Oceanic Plain moraine pebble
E	Oceanic	19 Plain	B	Bottom	d	moraine	E.19.B.d	979	cobble	Oceanic Plain moraine cobble
E	Oceanic	19 Plain	B	Bottom	d	moraine	E.19.B.d	980	boulder	Oceanic Plain moraine boulder
E	Oceanic	19 Plain	B	Bottom	d	moraine	E.19.B.d	981	mixed	Oceanic Plain moraine mixed
E	Oceanic	19 Plain	B	Bottom	d	moraine	E.19.B.d	982	bedrock	Oceanic Plain moraine bedrock
E	Oceanic	19 Plain	B	Bottom	e	cave	E.19.B.e	983	bedrock	Oceanic Plain cave bedrock
E	Oceanic	19 Plain	B	Bottom	e	cave	E.19.B.e	984	coral	Oceanic Plain cave coral
E	Oceanic	19 Plain	B	Bottom	e	cave	E.19.B.e	985	lava	Oceanic Plain cave lava
E	Oceanic	19 Plain	B	Bottom	e	crevice	E.19.B.e	986	bedrock	Oceanic Plain crevice bedrock

E	Oceanic	19	Plain	B	Bottom	e	crevice	E.19.B.e	987	coral	Oceanic Plain crevice coral
E	Oceanic	19	Plain	B	Bottom	e	crevice	E.19.B.e	988	lava	Oceanic Plain crevice lava
E	Oceanic	19	Plain	B	Bottom	f	sink	E.19.B.f	989	hardbottom	Oceanic Plain sink hardbottom
E	Oceanic	19	Plain	B	Bottom	g	debris field	E.19.B.g	990	gravel	Oceanic Plain debris field gravel
E	Oceanic	19	Plain	B	Bottom	g	debris field	E.19.B.g	991	pebble	Oceanic Plain debris field pebble
E	Oceanic	19	Plain	B	Bottom	g	debris field	E.19.B.g	992	cobble	Oceanic Plain debris field cobble
E	Oceanic	19	Plain	B	Bottom	g	debris field	E.19.B.g	993	boulder	Oceanic Plain debris field boulder
E	Oceanic	19	Plain	B	Bottom	g	debris field	E.19.B.g	994	mixed	Oceanic Plain debris field mixed
E	Oceanic	19	Plain	B	Bottom	g	debris field	E.19.B.g	995	bedrock	Oceanic Plain debris field bedrock
E	Oceanic	19	Plain	B	Bottom	h	groove	E.19.B.h	996	bedrock	Oceanic Plain groove bedrock
E	Oceanic	19	Plain	B	Bottom	h	groove	E.19.B.h	997	coral	Oceanic Plain groove coral
E	Oceanic	19	Plain	B	Bottom	I	channel	E.19.B.I	998	bedrock	Oceanic Plain channel bedrock
E	Oceanic	19	Plain	B	Bottom	I	channel	E.19.B.I	999	coral	Oceanic Plain channel coral
E	Oceanic	19	Plain	B	Bottom	j	ledge	E.19.B.j	1000	bedrock	Oceanic Plain ledge bedrock
E	Oceanic	19	Plain	B	Bottom	j	ledge	E.19.B.j	1001	coral	Oceanic Plain ledge coral
E	Oceanic	19	Plain	B	Bottom	k	wall	E.19.B.k	1002	bedrock	Oceanic Plain wall bedrock
E	Oceanic	19	Plain	B	Bottom	k	wall	E.19.B.k	1003	coral	Oceanic Plain coral reef wall

B. Kutcher et al. 2005, "A recommendation for a comprehensive habitat and land use classification system for the National Estuarine Research Reserve System"

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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 Aquaculture
8325. Finfish Aquaculture
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

C. Greene et. al (In Press), "Construction of digital potential marine benthic habitat maps using a coded classification scheme and their application"

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This code is based on the deep-water habitat characterization scheme developed by Greene et al. (1999) and modified for use in mapping habitats offshore of California (Greene et al. 2004; In Press). The code is designed so that the first character in the code, a capital letter, indicates one of nine Megahabitat types. These general Megahabitat types with suggested depth ranges in parentheses (depth estimations and can be changed to fit depth ranges known to occur for the mapping project at hand) are as follows:

A = Aprons, continental rise, deep fans and bajadas (3000-4000m)
B = Basin floors, borderland types (floors at 1000-2500m)
E = Estuary, (0-100m)
F = Flanks, continental slope, basin/island flanks (200-3000m)
I = Inland seas, fiords, and narrow inlets or passages (0-200m)
P = Plains, abyssal (4000-6000+ m)
R = Ridges and seamounts (crests at 200-2500m)
S = Shelf, continental and island shelves (0-200m)
Z = Zone of fractures (3000-5000m) or fracture zones associated with spreading ridges

The second character in the code, a lower case letter, indicates bottom induration (hardness) and consists of the following:

h = hard bottom (e.g., rock outcrop or sediment pavement)
m = mixed hard and soft bottom (e.g., local sediment cover of bedrock)
s = soft bottom, sediment cover

Sediment types (for above indurations) - Use parentheses.
(b) = boulder
(c) = cobble
(p) = pebble
(g) = gravel
(s) = sand
(m) = mud, silt, clay
(h) = halimeda sediment, carbonate

When inferred, use question mark; i.e., (m?). This part of the code is not always used so is not considered as a character in the code.

The third character in the code, another lower case letter, not always used, indicates the Meso- or Macrohabitat type (based on scale). These types consist of the following:

a = atoll
b = beach, relic (submerged)
c = canyon
d = deformed, tilted and folded bedrock
e = exposure, bedrock
f = flats, floors
g = gully, channel
i = ice-formed feature or deposit, moraine, drop-stone depression
k = karst, solution pit, sink
l = landslide
m = mound, depression; includes linear ridges
n = enclosed waters, lagoon
o = overbank deposit (levee)
p = pinnacle, cone

(Note: Pinnacles are often difficult to distinguish from boulders. Therefore, these features may be used in conjunction [as (b)/p] to designate the meso/macrohabitat).

r = rill (subterranean winnowing of sediments forming linear depressions on surface
s = scarp, cliff, fault or slump scar
t = terrace
w = sediment waves (10 cm to <m amplitude) and dunes (10s of m in amplitude)
y = delta, fan
$z_{\#}$ = zooxanthellae hosting structure, carbonate reef
z_1 = barrier reef
z_2 = fringing reef

z_3 = head, bommie
z_4 = patch reef
z_5 = back reef
z_6 = reef flat
z_7 = reef crest
z_8 = forereef

The fourth character in the code, a subscript letter (in GIS preceded by an underline [i.e., _a], is a modifier that describes the texture, bedform, biology or rock type and consists of the following:

$_a$ = anthropogenic (artificial reef/breakwall/shipwreck/disturbances
(a-dd) = dredge disturbances
(a-dg) = dredge grooves or channels
(a-dp) = dredge potholes
(a-dm) = dredge mounds (disposal)
(a-td) = trawl disturbances
$_b$ = bimodal (conglomeratic, mixed [includes gravel, cobbles and pebbles])
$_c$ = consolidated sediment (includes claystone, mudstone, siltstone, sandstone, breccia, or conglomerate)
$_d$ = differentially eroded
$_f$ = fracture, joint; faulted
$_g$ = granite
$_h$ = hummocky, irregular relief
$_i$ = interface, lithologic contact
$_k$ = kelp
$_l$ = limestone or carbonate
$_m$ = massive sedimentary bedrock
$_o$ = outwash
$_p$ = pavement
$_r$ = ripples (>10 cm in amplitude)
$_s$ = scour (current or ice, direction noted)
$_u$ = unconsolidated sediment
$_v$ = volcanic rock

Seafloor Slope - Use category numbers, which is the fifth character in the code. Typically calculated for survey area from x-y-z multibeam data. Numbers in parentheses are suggestions only and can be tailored to meet objectives of the habitat mapping exercise at hand.

1	Flat (0-5º)
2	Sloping (5-30º)
3	Steeply Sloping (30-60º)
4	Vertical (60-90º)
5	Overhang (> 90º)

Seafloor Complexity - Use category letters (in caps), the sixth character in the code. Typically calculated for survey area from x-y-z multibeam slope data using neighborhood statistics and reported in standard deviation units. Numbers in parentheses are suggestions only and can be tailored to meet objectives of the habitat mapping exercise at hand.

A	Very Low Complexity (-1 to 0)
B	Low Complexity (0 to 1)
C	Moderate Complexity (1 to 2)
D	High Complexity (2 to 3)
E	Very High Complexity (3+)

An example of how this code for remotely sensed data can be used is given below:

Ssc_$_u$4 (Q, Qsp) = Canyon head indenting shelf with smooth, soft, gentle-sloping sedimentary walls locally crop out as steep (near vertical) scarps (10-100m).

Ssf_$_u$ (Q) = Flat to gently sloping shelf with soft, unconsolidated sediment (10-150m).

Fh_m (Tpr) = Continental slope with sedimentary (sandstone)
bedrock locally cropping out and smooth to moderately irregular relief (<1-3 m high): m means exposures often covered with sediment (200-2500m).

Geologic Unit – When possible, the associated geologic unit is identified for each habitat type and follows the habitat designation in parentheses. Examples given below:

Shp_d1D(Q/R) - Continental shelf megahabitat; flat, highly complex hard seafloor with pinnacles differentially eroded. Geologic unit = Quartenary/Recent.

Fhd_d2C (Tmm) - Continental slope megahabitat; sloping hard seafloor of deformed (tilted, faulted, folded), differentially eroded bedrock exposure forming overhangs and caves. Geologic unit = Tertiary Miocene Monterey Formation.

<u>Determined from video, still photos, or direct observation</u>. Macro/Microhabitat – Preceded by an asterisk. Use parentheses for geologic attributes, brackets for biologic attributes. Based on observed small-scale seafloor features.

<u>Geologic attributes (note percent grain sizes when possible)</u>

- (a) = anthropogenic (e.g., cables, pipelines, disturbances)
  - (a-t) = trawl trails or grooves
  - (a-d) = dredge tracks, pits or mounds
- (b) = boulder
  - (b-d) = dropstone (kelp or ice)
- (c) = cobble
- (d) = deformed, faulted, or folded
- (e) = exposure, bedrock (sedimentary, igneous, or metamorphic)
  - (e-s) = smooth bedrock surface
  - (e-r) = rough bedrock surface
- (f) = fans or aprons
- (g) = gravel
- (h) = halimeda sediment, carbonate slabes or mound
- (i) = interface
- (j) = joints, cracks, crevices, and overhang (differentially eroded)
- (k) = knob or ridge
- (l) = limestone, carbonate deposit
- (m) = mud, silt, or clay
- (n) = notch, groove
- (p) = pebble
- (q) = coquina (shell hash)
- (r) = rubble
- (s) = sand
- (t) = flat terrace-like seafloor including sedimentary pavements
- (u) = Undulating surface, hummocky
  - (u-r) = ripples
  - (u-s) = scours
  - (u-w) = sediment wave
- (w) = wall, scarp, or cliff

<u>Biologic attributes</u>

- [a] = algae
  - [a-b] = red algae
  - [a-g] = green algae
  - [a-r] = red algae
- [b] = bryozoans
- [c] = corals
- [d] = detritus, drift algae
- [e] = eelgrass
- [g] = gorgonians
- [h] = holothorians
- [k] = kelp
- [n] = anemones
- [o] = other sessile organisms
  - [o-c] = crinoids
- [s] = sponges
- [t] = tracks, trails, or trace fossils (bioturbation)
  - [t-b] = burrows
  - [t-m] = mounds
- [u] = unusual organisms, or chemosynthetic communities
- [w] = worm tubes
  - [w-s] = spoon worms

Examples: *(m)[w]1C - Flat or nearly flat mud (100%) bottom with worm tubes; moderate complexity.

*(s/c)1A - Sand bottom (>50%) with cobbles. Flat or nearly flat with very low complexity.

*(h)[c]1E - Coral reef on flat bottom with halimeda sediment. Very high complexity.

Shp_d1D(Q/R)*(m)[w]1C - *Large-scale habitat type:* Continental shelf megahabitat; flat, highly complex hard seafloor with pinnacles differentially eroded. Geologic unit = Quartenary/Recent. *Small-scale habitat type:* Flat or nearly flat mud (100%) bottom with worm tubes; moderate complexity.

D. Valentine et al. (2005), "Classification of Marine Sublittoral Habitats, with Application to the Northeastern North America Region"

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The classification includes classes, subclasses, categories, and attributes. It is designed as a template for a database. Class numbers are unique. Themes are the major subject elements of the classification and can include one to many classes. Themes are informal units and are not incorporated into the habitats database. Observations from Classes 2, 3, 11, and 24 are used to compile habitat names. Category and attribute terms in parentheses are not a complete list.

Theme 1, Topographical Setting

- Class 1: Topographical setting: major seabed features and industrial structures
    - Subclass 1: Shallow photic (presence of macrophyte algae)
    - Subclass 2: Deep aphotic (absence of macrophyte algae)
        - Categories: Seabed slope, major physiographic and biogenic features and industrial structures
        - Attributes: Angle of seabed slope, types of seabed features (e.g., basin, ridge, shelf edge reef), and industrial structures (e.g., cable, oil platform)

All categories and attributes apply to Subclasses 1 and 2.

Theme 2, Seabed Dynamics and Currents

- Class 2: Seabed dynamics and currents
    - Subclass 1: Mobile substrate
    - Subclass 2: Immobile substrate
    - Subclass 3: Intermixed mobile and immobile substrates
        - Categories: Types of currents (e.g., tidal, storm wave) and types of events (e.g., storms) causing sediment mobility
        - Attributes: Strength of currents and frequency of events (e.g., daily, monthly) causing sediment mobility

All categories and attributes apply to Subclasses 1–3.

Theme 3, Seabed Texture, Hardness, and Layering in the Upper 5–10 cm

- Class 3: Seabed texture, hardness, and layering in the upper 5–10 cm
    - Subclass 1: Fine-grained sediment: mud, very fine (4 phi) sand, and fine (3 phi) sand
    - Subclass 2: Coarse-grained sediment: medium (2 phi) sand, coarse (1 phi) sand, very coarse (0 phi) sand, and gravel (gravel is composed of granules > 1 mm and < 2 mm; pebbles < 64 mm; cobbles < 256 mm; and boulders > 256 mm).
    - Subclass 3: Mixed fine-grained and coarse-grained sediment: mud, sand, and gravel mixtures
    - Subclass 4: Rock or other hard seabed (with or without mud, sand, gravel)
        - Categories: Descriptive sediment and hard seabed types (e.g., mud veneer on clay, gravel pavement, cobbles in muddy sand, sand veneer on rock outcrop)
        - Attributes: Percentage of seabed covered by sediment and hard seabed types

Categories apply to appropriate subclasses; all attributes apply to Subclasses 1–4.

Theme 4, Seabed Grain-Size Analysis

- Class 4: Seabed grain sizes: general description
    - Subclass 1: General sediment description
        - Categories: Descriptive texture classification, sorting, grain size distribution, and particle shape
        - Attributes: Major descriptive texture classes (e.g., silty sand, gravelly mud), degree of sorting (e.g., well sorted), skewness (e.g., symmetrical), kurtosis (e.g., mesokurtic), and particle shape (e.g., rounded)
- Class 22: Seabed grain sizes - major Wentworth size-classes
    - Subclass 1: Major Wentworth grain size-classes, weight percent
        - Categories: Major Wentworth grain size-classes (e.g., sand, gravel, silt, clay, mud)
        - Attributes: Weight percent of major Wentworth grain size-classes
- Class 23: Seabed grain sizes - phi and all Wentworth size-classes
    - Subclass 1: Phi and all Wentworth grain size-classes, weight percent
        - Categories: Phi and all Wentworth size-classes (e.g., fine sand, coarse silt)
        - Attributes: Weight percent of phi and all Wentworth size-classes

Theme 5, Seabed Roughness

- Class 5: Seabed roughness - bedforms
    - Subclass 1: Bedforms (physical structures)

Categories: Bedform types (e.g., ripples, sand dunes)
Attributes: Percentage of seabed covered by bedform types

Class 6: Seabed roughness - shell materials
Subclass 1: Shell materials (physical structures)
Categories: Types of shell materials and deposits (e.g., shell fragments, shell deposits)
Attributes: Percentage of seabed covered by shell material and deposit types

Class 7: Seabed roughness - rough sediments and hard seabeds
Subclass 1: Rough sediments and hard seabeds (physical structures)
Categories: Associations of sediment particles, sediment type, seabed structures, and rock outcrops (e.g., cobbles in patches, piled boulders, pebbles in sand dune troughs, irregular rock outcrop)
Attributes: Percentage of seabed covered by rough sediment and hard seabed types

Class 8: Seabed roughness - biogenic structures
Subclass 1: Biogenic structures (physical structures)
Categories: Types of biogenic modifications of the seabed (e.g., crab depressions, fish burrows)
Attributes: Percentage of seabed covered by types of biogenic structures

Class 12: Seabed roughness - anthropogenic marks
Subclass 1: Anthropogenic marks (physical structures)
Categories: Types of marks made on the seabed by human activities (e.g., trawl marks, anchor marks)
Attributes: Percentage of seabed covered by types of anthropogenic marks

Class 13: Seabed roughness - anthropogenic structures
Subclass 1: Anthropogenic structures (physical structures)
Categories: Types of minor man-made structures and equipment on the seabed (e.g., types of fishing gear)
Attributes: Percentage of seabed covered by types of anthropogenic structures

Class 24: Seabed roughness - physical structures combined
Subclass 1: Extent of physical structures
Categories: Types of physical structures
Attributes: Percentage of seabed covered by physical structures by type and all combined

Class 24: summarizes observations for Classes 5–8, 12, and 13.

Class 9: Seabed roughness: attached epifauna
Subclass 1: Attached epifauna (biological structures)
Categories: Epifaunal groups attached to the seabed surface (e.g., erect sponges, tunicates, brachiopods)
Attributes: Percentage of seabed covered by types of attached epifauna

Class 10: Seabed roughness - emergent epifauna
Subclass 1: Emergent epifauna (biological structures)
Categories: Epifaunal groups emergent from below the seabed surface (e.g., burrowing anemones, sea pens)
Attributes: Percentage of seabed covered by types of emergent epifauna

Class 11: Seabed roughness - biological structures combined
Subclass 1: Extent of biological structures
Categories: Types of biological structures
Attributes: Percentage of seabed covered by biological structures by type and all combined

Class 11: Summarizes observations for Classes 9 and 10.

Theme 6, Fauna and Flora

Class 14: Faunal groups
Subclasses 1–6: Faunal groups (in several subclasses based on different methods of data collection; e.g., visual observations and/or specimens from various sampler types)
Categories: Faunal groups (e.g., erect sponges, burrowing anemones, sea stars, attached anemones)
Attributes: Presence/absence or percentage of seabed covered by individual faunal groups

All categories and attributes apply to Subclasses 1–6.

Class 15: Faunal species
Subclasses 1–6: Faunal species (in several subclasses based on different methods of data collection; e.g., visual observations and/or specimens from various sampler types)
Categories: Faunal species (e.g., Atlantic cod)
Attributes: Presence/absence or percentage of seabed covered by individual faunal species

All categories and attributes apply to Subclasses 1–6.

Class 16: Floral groups
Subclasses 1–6: Floral groups (in several subclasses based on different methods of data collection; e.g., visual observations and/or specimens from various sampler types)
Categories: Floral groups (e.g., calcareous algae, kelp)
Attributes: Presence/absence or percentage of seabed covered by individual floral groups

All categories and attributes apply to Subclasses 1–6.

Class 17: Floral species
Subclasses 1–6: Floral species (in several subclasses based on different methods of data collection; e.g., visual observations and/or specimens from various sampler types)

Categories: Floral species
Attributes: Presence/absence or percentage of seabed covered by individual floral species
All categories and attributes apply to Subclasses 1–6.

Theme 7, Habitat Association and Usage

Class 18: Fauna-habitat association: essential fish habitat (EFH)
Subclasses 1–6: Fauna-habitat association (in several subclasses based on different methods of data collection; e.g., visual observations and/or specimens from various sampler types)
Categories Faunal species (e.g., Atlantic cod, haddock, yellowtail flounder)
Attributes Types of fauna-habitat association by species (e.g. adult, spawning, juvenile habitat)
All categories and attributes apply to Subclasses 1–6.
Class 19: Human usage of habitat
Subclass 1: Human usage of habitat
Categories: Disturbed, undisturbed, or recovering habitat; kinds of disturbance (e.g., fishing, extraction)
Attributes: Types of disturbance activities (e.g., otter trawling, minerals mining)

Theme 8, Habitat Recovery from Disturbance

Class 20: Habitat recovery from fishing disturbance
Subclass 1: Fishing disturbance
Categories: Recovery of physical structures and biological structures (e.g., bedforms, attached epifauna)
Attributes: Time required for recovery (e.g., months, year, decades)
Class 21: Habitat recovery from natural disturbance
Subclass 1: Natural disturbance
Categories: Recovery of physical structures and biological structures (e.g., fish burrows, emergent epifauna)
Attributes: Time required for recovery (e.g., months, year, decades)

Note: Explanation of (1) habitat descriptions, (2) structural complexity of habitats, (3) three levels of descriptive habitat names, (4) probable marine sublittoral habitat types are found in Appendices 2-5 at http://woodshole.er.usgs.gov/project-pages/stellwagen**.**

APPENDIX 2: Contact information of habitat classification experts.

Contact	Organization	Email	Reasons for Collaboration
Allee, Becky	NOAA - CSC	becky.allee@noaa.gov	Technical advice and updates on CMECS
Annett, Brendan	Waquoit Bay NERR	brendan.annett@state.ma.us	Waquoit Bay implementation of the NERR classification scheme
Dethier, Megan	University of WA	mdethier@u.washington.edu	Experience with classification studies
Finkbeiner, Mark	NOAA - CSC	mark.finkbeiner@noaa.gov	Technical advice, particularly on CMECS Use of benthic data
Ford, Kathryn	MA DMF	kathryn.ford@state.ma.us	Project partner Piloting Valentine et al. (2005) scheme
Kutcher, Tom	Narragansett Bay NERR	tomk@nbnerr.org	Advice and updates on NERRS scheme
Madden, Chris	NatureServe	cmadden@sfwmd.gov	Technical advice and updates on CMECS
Smith, Jan	Mass Bays NEP	jan.smith@state.ma.us	US EPA/NEP efforts to use habitat classification
Valentine, Page	USGS	pvalentine@usgs.gov	Technical advice and updates on classification of Stellwagen Bank
Wilber, Pace	NOAA	pace.wilber@noaa.gov	Technical advice and updates on CMECS
Wright, Nan	University of Idaho	nwright@uidaho.edu	Technical advice and updates on CMECS Lead on Columbia River Estuary pilot project