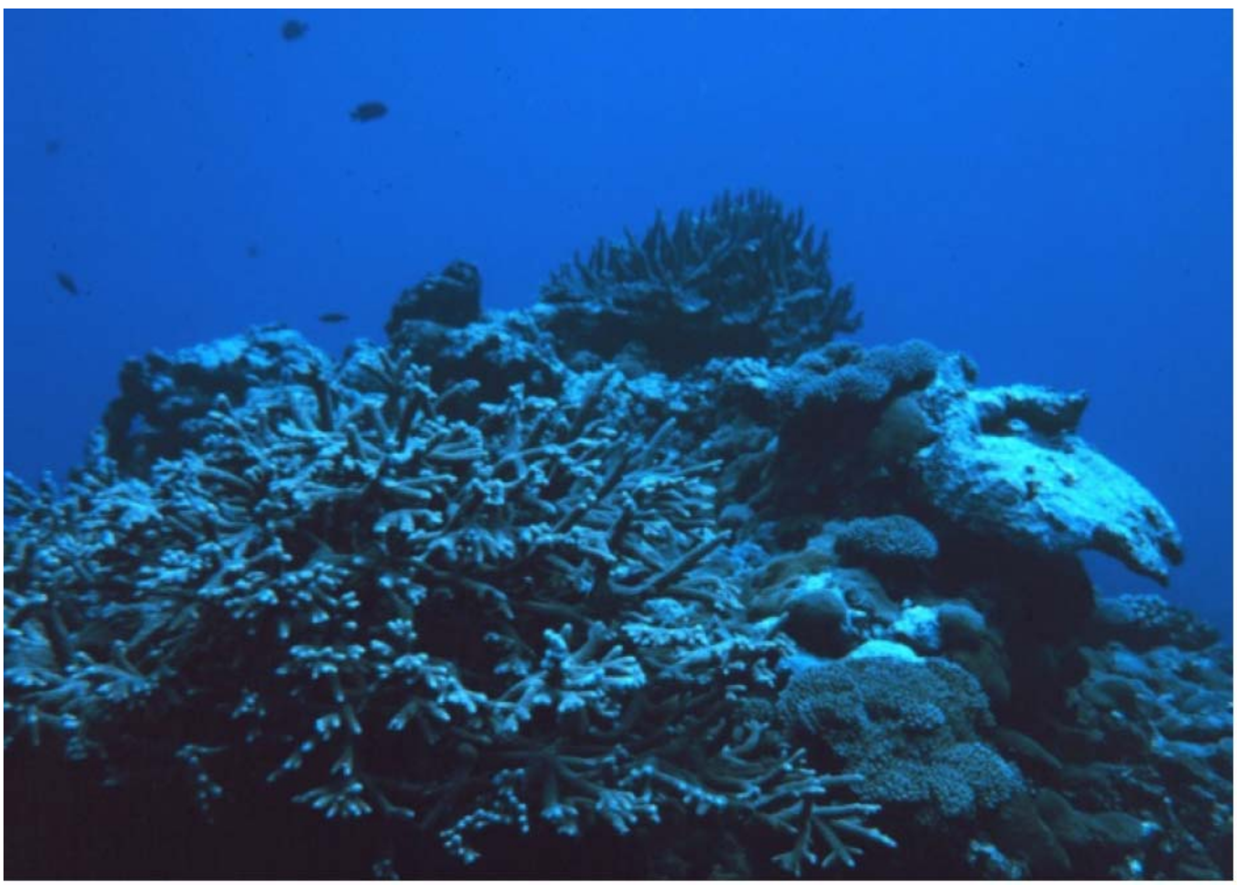
A Framework for a Coastal/Marine Ecological Classification Standard



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A FRAMEWORK FOR A COASTAL/MARINE ECOLOGICAL CLASSIFICATION STANDARD

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Executive Summary

Coastal and marine planners and managers are faced with a complex environment in which to make difficult decisions about habitat conservation and resource management. There is an urgent and increasing need for a habitat classification system that can be used to develop strategies for coastal and ocean resource management and for evaluating conservation priorities. In recent decades, a variety of coastal classifications have been developed that describe local or regional ecological systems and address local objectives. The conservation and resource management community has recognized a strong need for a single classification standard that is relevant to all U.S. coastal and marine environments and that can be applied on local, regional and continental scales. This need has prompted a NOAA initiative to develop a standard ecological classification system that is universally applicable for coastal and marine systems.

The framework for a Coastal/ Marine Ecological Classification Standard (CMECS) presented here was developed to meet this challenge. The classification is a framework for organizing knowledge about coasts and oceans and their living systems. It provides a structure for synthesizing data so that habitats can be characterized and reported in a standard way, and information can be aggregated and evaluated across the national landscape and seascape. Building on existing classification efforts and informed by a series of technical meetings and workshops, the CMECS framework integrates the current state of knowledge about ecological and habitat classification. The result is an ecosystem-oriented, science-based framework for the identification, inventory, and description of coastal and marine habitats and biodiversity.

A few of the many potential applications of the classification include:

- Development of a coastal marine biodiversity inventory for North America
- Delineation of regions for Marine Protected Areas and developing guidelines for their management
- Identification of important habitats and critical hotspots for conservation
- Identification of Essential Fish Habitat
- Forming a scientific basis for the development, implementation and monitoring of ecosystem-based management strategies for coastal systems

The CMECS framework is applicable on spatial scales of less than one square meter to thousands of square kilometers and can be used in littoral, benthic and pelagic zones of estuarine, coastal and open ocean systems. The hierarchical framework contains eight nested levels; each containing clearly defined classes and units. Linkages between levels of the hierarchy are defined by ecosystem processes and by spatial relationships. The classification articulates with existing national fresh water and terrestrial classification standards. It is based on simple sets of rules and is designed to be easy to use. The hierarchy extends from ecological regions at the largest spatial scale, to habitat and associated biotopes at the smallest, within the following structure:

Level 1- Ecological Region: large regions of the coasts and oceans defined by similar physical and/or biological characteristics
Level 2- Regime: areas defined by the presence or absence of fresh water
Level 3- System: areas that form estuaries, estuarine- influenced areas, or marine waters of shallow, deeper, or very deep water columns
Level 4- Hydroform/Geoform: large physical structures formed by either water or solid substrate within systems
Level 5- Zone: the water column, littoral or sea bottom
Level 6- Macrohabitat: large physical structures that contain multiple habitats
Level 7- Habitat: a specific combination of physical and energy characteristics that creates a suitable place for colonization or use by biota
Level 8- Biotope: the characteristic biology associated with a specific habitat

The CMECS is designed to provide a framework for developing a consistent and universally recognized inventory of all habitats of the North American coasts and oceans. The flexibility of this classification will support a variety of local and regional applications. Population of the classification framework with data from a variety of coastal and marine ecosystems, following a standardized, rigorous methodology, will lead to development of a robust national database of coastal and marine habitats and associated biology.

Introduction

The Need for a National Coastal and Marine Classification Standard

Coastal and marine planners and managers are faced with a complex environment in which to make difficult decisions about habitat conservation and resource management. There is an urgent and growing need for a habitat classification system that can aid in developing strategies for coastal and ocean resource management and in evaluating conservation priorities. A variety of coastal classifications have been developed that describe local or regional ecological systems and address local objectives. The conservation and resource management community has recognized a strong need for a classification standard that is relevant to all U.S. coastal and marine environments and that can be applied on a local, regional and continental scale. This need has prompted NOAA to support the development of an ecological classification standard that is universally applicable for coastal and marine systems.

The urgency of the need for an ecological classification standard for coastal and marine systems increases as threats to marine habitat and living resources grow, and as traditional means of assessing and managing marine systems prove progressively less effective. Single species management and the regulation of habitats in isolation, without reference to the ecosystem, results in ineffective resource stewardship. Such important processes as biological life cycles, energy flows, watershed linkages, migration patterns, food requirements and trophic dynamics must be considered as management plans are developed for estuarine, coastal and marine systems. A standardized approach is required to understand the interactions among all habitats, their biological associations, and the larger ecosystem context. The first step to gaining such an understanding is the systematic organization of key information about the system, its physical and biotic components, their relationships to internal and external forces and the scales of spatial and temporal interactions. The national-level classification framework described in this report is based on ecosystem principles that will enable integrated assessment and management of species, processes and whole systems.

This report describes a framework for a Coastal/Marine Ecological Classification Standard (CEMCS) that includes the estuaries, coasts and oceans of the United States. The product is the result of ongoing collaboration with scientific and management experts, and is based on recommendations from workshops conducted in Marathon, FL in 1999 (Allee et. al. 2000), and Charleston, SC, in March 2003 (Madden et al. 2003). The document describes the justification and need for the framework, details the structure of the classification, explains the logic of the hierarchy, identifies its levels and classes, defines classification units, and describes the relationship of classification elements to each other. As the framework is reviewed and used by end-users and applied in projects nationally and internationally, the classification will be further refined and expanded to improve its utility and universality.

It is important at this point to emphasize what this document is and what it is not. It is a conceptual model and a classification hierarchy for coastal and marine habitats. It includes a set of descriptions of coarser units at higher levels, a crosswalk of terms and concepts to other major classifications and a glossary of terms. It provides a standard for identifying and naming existing types. It provides a framework for identifying and naming new types. Although numerous habitat type descriptions are included in this report, it is not meant to provide a complete list of all coastal types and units at the finer classification levels. Similarly, it is not meant to be a complete translator for all existing data. The population of the classification hierarchy will be an important ongoing activity that will be enabled through the use of this classification framework. The majority of upper level types are described here, though additional classes will surely be identified as the classification is applied, particularly in new geographic areas. Approximately 30% of the finer level habitats are described in this document, with the remainder to be identified and classified through pilot projects and other applications of this framework.

The goal is that this classification be adopted as a universally accepted protocol. To accomplish this, the classification represents an effort to merge, to the extent possible, existing approaches for classifying different regions and habitats into an organized whole. In addition, there was a pragmatic focus to make it simple to understand and easy to apply using existing knowledge and available data. Acceptance by the conservation and management community will promote the use of the classification to effectively identify, monitor, protect and restore unique biotic assemblages, protected species, critical habitat, and important ecosystem components.

Classification Approach

Background

The increasing need for local conservation and resource management assessments has resulted in the development of numerous classifications that target specific coastal and marine systems. The growing need for regional level assessments have produced very few national and continental scale coastal/marine system classifications (e.g., Cowardin et al. 1979, Allee et al. 2000, EUNIS EEA 1999, Davies and Moss 1999). These comprehensive efforts have seen varied success in limited applications, but had limited success in meeting flexible objectives due to their inability to address systems at multiple scales, provide robust results with available data, or present a simple strategy for practical implementation.

The proliferation of classification systems underscores the regional/local nature of habitats, the special needs of agencies and organizations, and the variety of applications for which they are needed. It also provides insight into the operative scales of use for existing classifications, many of which tend to focus on spatial scales of tens to thousands of meters, the scale at which many state agencies monitor and manage resources. A focus on local and regional spatial scales of classification often results in the inability to correlate results across different systems and projects. A classification that is national in scope needs to capture the information provided by a locally designed classification, and provide the standardization that allows the aggregation and assessment of diverse systems on a continental scale.

The Process of Creating a National Coastal and Marine Ecological Classification Standard

The initial challenge in developing a national coastal/marine classification is to create a framework that can be used to classify all of the coastal and oceanic benthic/pelagic regimes in North America. Meeting that challenge requires a classification framework that functions across multiple scales and across the enormous diversity of environments and habitats. At the same time, it is imperative that the classification provides an umbrella that accommodates existing classification efforts, methodologies, and definitions to the maximum extent possible. The success of a national standard will depend on its ability to integrate both existing data and ongoing data collection efforts to ensure that existing data and knowledge are incorporated and reflected in the standard. Where appropriate, the national classification is constructed using concepts and units from prior work.

In order to accomplish effective conservation planning and resource management, the design of a comprehensive national framework is more challenging than simply merging various regional classifications. The framework must apply a uniform set of classification rules that serve coastal and marine systems across all climatic and geologic zones. The classification must also be easy to implement using existing data, and require few sophisticated tools to acquire new data. It must be capable of linking the biogeography at the continental scale to smaller features at local scales in an unbroken chain of logic.

The strategy for developing this classification is to build on the efforts of existing, tested systems, where possible. Allee et al. (2000) developed a synthesis (revised in Allee et al. 2002) that integrated across many classification schemes, and their work provided a strong base for the development of this standard. Allee added many levels and much information to the Cowardin standard, creating an expansive and comprehensive framework for classifying the nation's coasts. The CMEC standard that is presented here builds on Allee's work by creating a smaller number of comprehensive classification levels, focusing on practical application and existing data, elucidating the criteria needed for the classification of units, and defining the terms.

Several other classifications were used in the development of this CMECS framework (see Table 1). The Ecological Regionalization for North American Coasts and Oceans is the product of the Commission for Environmental Cooperation expert process (2004), incorporating the work of McGowan (1979), Hayden et al. (1984), Longhurst (1998) and the Large Marine Ecosystem concepts of Sherman (1991) and Sherman and Alexander (1986) and tropical biogeography of Sullivan-Sealey and Bustamante (1999). This regionalization forms Level 1 of the CMECS classification hierarchy. Deepwater benthic sections of the CMECS classification are a combination of the Greene et al. (1999) system for benthic ocean habitats and the system devised by Holthus and Maragos (1995) for tropical islands and waters, with inclusion of the Mumby and Harborne (1999) classification for Caribbean corals. Much of the shallow water and coastal sections of the CMECS classification and the energy modifiers are derived from the SCALE system by Schoch (1999), the Washington State system by Dethier (1990), and the Cowardin national system (1979). The list of shore type classes is derived from a combination of Dethier (1990), Schoch and Dethier (1996) and Schoch (1999), and the Shore-Zone mapping system of Howes et al. (1994, 2002), with refinements from the British Columbia Marine Ecosystem Classification (BCMEC) (Howes et al. 1994, 2002; Zacharias et al., 1998). The hierarchy of substrate elements and local geological formations for neritic and oceanic systems incorporates categories directly from the megahabitats and mesohabitats of the Greene et al (1999) deep seafloor habitat classification. Habitat units and local structures for the estuarine and nearshore marine systems are adopted or modified from Costello (2003), Wieland (1993), Allee et al. (2000), Cowardin (1979), Dethier (1990), Brown (2002), Connor (1997), and Madley et al. (2002). Coral and oceanic habitat units are modified from Maragos 1991, 1992 and Holthus and Maragos (1995). The concept of the biotope and terminology and criteria for the macrohabitat and habitat levels is derived from the work of Connor (1997) and Costello (2003). Seafloor habitat units and methologodies for mapping them were based on ideas presented in Greene et al. (1999) Valentine et al. (2002) and Schoch (1999).

Table 1. Major coastal/marine classification systems considered in development of the CMECS national classification standard.

Coverage	Source
Marine Biogeography	Ekman (1953)
Marine Biogeography	Briggs (1974)
U. S. Wetland & Deepwater Habitat	Cowardin et al. (1979)
Biogeography of World Oceans	Hayden, Ray and Dolen (1984)
Coastal WA Coastal Habitat	Dethier (1990)
MS Gulf of Mexico	Wieland (1993)
Large Marine Ecosystems	Sherman and Alexander (1986
Tropical Pacific Islands	Holthus and Maragos (1995)
UK Coast	Laffoley and Hiscock (1993)
British Columbia coast (BCMEC)	Zacharias et al. (1998)
European Coastal Habitats	EUNIS (1999)
CA Wildlife Habitat	Shaffer (2002)
NW U.S. Shores	Schoch (1999)
Deep Sea CA Benthic	Greene et al. (1999)
Caribbean Corals	Mumby and Harborne (1999)
Latin America, Bahamas Ecoregions	Sullivan Sealey and Bustamante (1999)
U.S. National Classification	Allee et al NOAA (2000)
CA Coastal Watersheds	Ferren et al. (1996)
Coastal U.S.	Brown et al. (2002)
FL Gulf of Mexico	Madley et al. (2002)
BIOMAR UK Coasts	Costello (2003)
Marine Ecosystems of North America	Wilkenson (in press)
Gulf of Maine Benthic Classification	Valentine et al. 2002

Guiding Principles

The following set of guiding principles emerged through the course of this project. These principles helped guide the development of this CMECS standard:

1. **Geographic and Ecological Bounds:** The classification is focused on North America, but is applicable over large areas and a wide diversity of types, ranging from the coastal landscape to the marine seascape. The classification is three-dimensional, taking into account surface, water column and benthic features. The classification extends from the head of tides and/or the most inland encroachment of ocean salinity in the coastal zone to the deep oceans and is applicable to all tidal and/or saline wetland, estuarine, coastal, nearshore marine, neritic and oceanic systems.

2. **Building on Existing Work:** The classification incorporates or articulates with existing coastal and marine classifications as appropriate. Where possible, the classification adopts concepts, units and definitions from other classification frameworks.

3. **Relation to Terrestrial and Fresh water Standards:** The classification has clear points of articulation with existing terrestrial and fresh water classification standards.

4. **Spatial Hierarchy:** The classification follows a progressive scale from large spatial units in the upper levels of the hierarchy to smaller units in the lower levels. The standard is hierarchical such that all of the elements mapped at one level spatially sum to the next-higher or enclosing level.

5. **Habitat / Biology Relationships:** Species and biological communities are associated with different levels of the hierarchy depending on their size, the spatial scale of their movements, and their use of the physical landscape.

6. **Physical-Ecological Relationships:** The classification must describe or account for how ecological relationships are shaped by physical factors.

7. **Measurable and Repeatable Units:** The classification units represent a measurable space and are repeating physical entities. Each classification unit describes a specific place in the marine realm within the defined geographic and ecological boundaries.

8. **Uniqueness of Classification Units:** Units in different parts of the hierarchy are unique; that is, if two similar units are found within two biogeographic regions, they represent two different and distinct types of coastal habitat.

9. **Nomenclature and Terminology:** The classification follows a rigorous nomenclature that is designed to constrain the meanings of classes and elements, to resolve ambiguous concepts and terms, and to firmly establish the exact definitions of terms and metrics. A glossary of terms representing the official nomenclature of the classification is an integral part of the classification standard (see Appendix 3). Universally recognizable and accepted standard terms for classification descriptors are used, and they replace or translate local vernacular or popular usage of terms.

10. **Accommodating Change and Growth:** The classification structure, unit catalog and definitions will grow and evolve with use of the classification and the development of new information. A formal mechanism will be established for submitting new terms, units, definitions, concepts or metric for review and acceptance into the classification.

Scope, Hierarchy and Scale

The scope of the classification framework extends from the head-of-tides in the coastal zone to the deep ocean. This encompasses the littoral zone that is influenced by the sea via tides and salinity, and therefore applies to wetlands and terrestrial coastal units that are affected by the ocean.

The hierarchical nature of the classification provides linkages between physical form in larger and smaller sized units, processes at different scales, and the underlying ecological relationships engendered by the physical environment. One end of the classification describes a broad level of ecological regions (Level 1), and all subsequent levels are increasingly oriented to describe finer level ecosystem processes and states. Levels 2 through 7 examine successively finer representations of the physical world, focusing on form and process. Level 8 characterizes the dominant biological communities associated with specific habitats.

The levels of the hierarchy relate to each other in clearly defined ways. The hierarchically nested levels form a chain of inter-relationships, where the lower level "fits into" the upper level, either spatially, by process, or by function. For example, all of the lower levels of the classification are cleanly nested within each ecological region. The elements (types and their spatial representation) within each daughter level add up to complete all types and polygons within the next highest level.

Elements within each level have a defined relationship to one another. By occupying the same level, they have spatial and energy relationships of equivalent magnitude. The large scale, comprehensive processes, such as climate, are characterized at the highest levels of the classification, and these drive processes such as water temperature and ice formation at levels further down the hierarchy. This arrangement of the framework documents and organizes the hierarchy of key forces that create each particular habitat.

Each classification level includes a finite set of identifiable types. In practice, a classification exercise can usefully proceed to partially identify types at lower levels even if a full set of data is not available at a higher level. For example, it is possible to classify the salinity and substrate environment of a *Ruppia maritima* seagrass bed without precise knowledge of the ecological region in which it resides. One does not need to know the salinity to inventory and classify a *Crassostrea virginica* oyster reef. In fact, the presence of the reef helps *establish* the salinity regime without requiring any measurement of salinity at all. Therefore the classification, while hierarchical, is not a strict key, meaning that it is not necessary to work down through each of the upper levels to identify types at the lower levels. Having data for each of the levels and classes provides more knowledge about the habitat, but is not always required to complete a classification.

In applying the classification, the user may skip levels where data are lacking. Due to limitations of current knowledge, it will be rare that all classification types in most areas can be immediately characterized fully. As additional data are gathered in an area, the entire hierarchy will continue to grow, thus strengthening the understanding of the entire system.

Spatial scale is an important criterion within this classification. In developing a classification standard and accompanying methodology, the spatial scales of elements to be measured and the scaling relationships between levels are identified and defined. The scale addressed by this classification ranges from <1m to 10^3 km linearly and 1 m^2 areally to 10^5 km^2 in area. The structure of the classification allows identification and classification at scales ranging from the ecological region to the habitat (and biotope). A range of spatial scales is reported for each level as a criterion for the identification and classification of types.

The classification is designed to be applicable to all estuarine and marine habitats, affording the flexibility to apply the methodology at different scales as needed to address different objectives.

For example, a federal management agency seeking to identify and catalog all large estuaries in North America can restrict their analysis to the upper three levels of the classification hierarchy. A local agency classifying habitats within a single estuary will want to use the bottom two or three levels of the classification. Yet, using this classification as a common standard, both agencies will be able to organize and compare results using a unified vocabulary within a common and interoperable data framework.

The Relationship between Habitats, Species and Biological Associations

Species and biological associations identified within the coastal marine classification can intersect with the physical structure of the environment in different ways. Two types of relationships are recognized within this classification framework that describe the linkage between the biology and physical structure. One physical-biological relationship is associated with attached or largely non-motile species and biological communities that themselves create a physical habitat. The term "biotope" (Costello 2003) is used for these communities; examples range from seagrass beds to coral reefs. A second physical-biological relationship is found between individual species and repeating biological associations that freely move through one or more physical habitats and environment on a daily to season basis. These species and associations can utilize physical habitats at different levels of the classification hierarchy. This report does not attempt to document the species associated with each habitat and biotope, although there are provisions for identifying them and numerous cases are described. As the database matures, the linkages of species and biological associations to different classification units at different levels will become better understood and characterized.

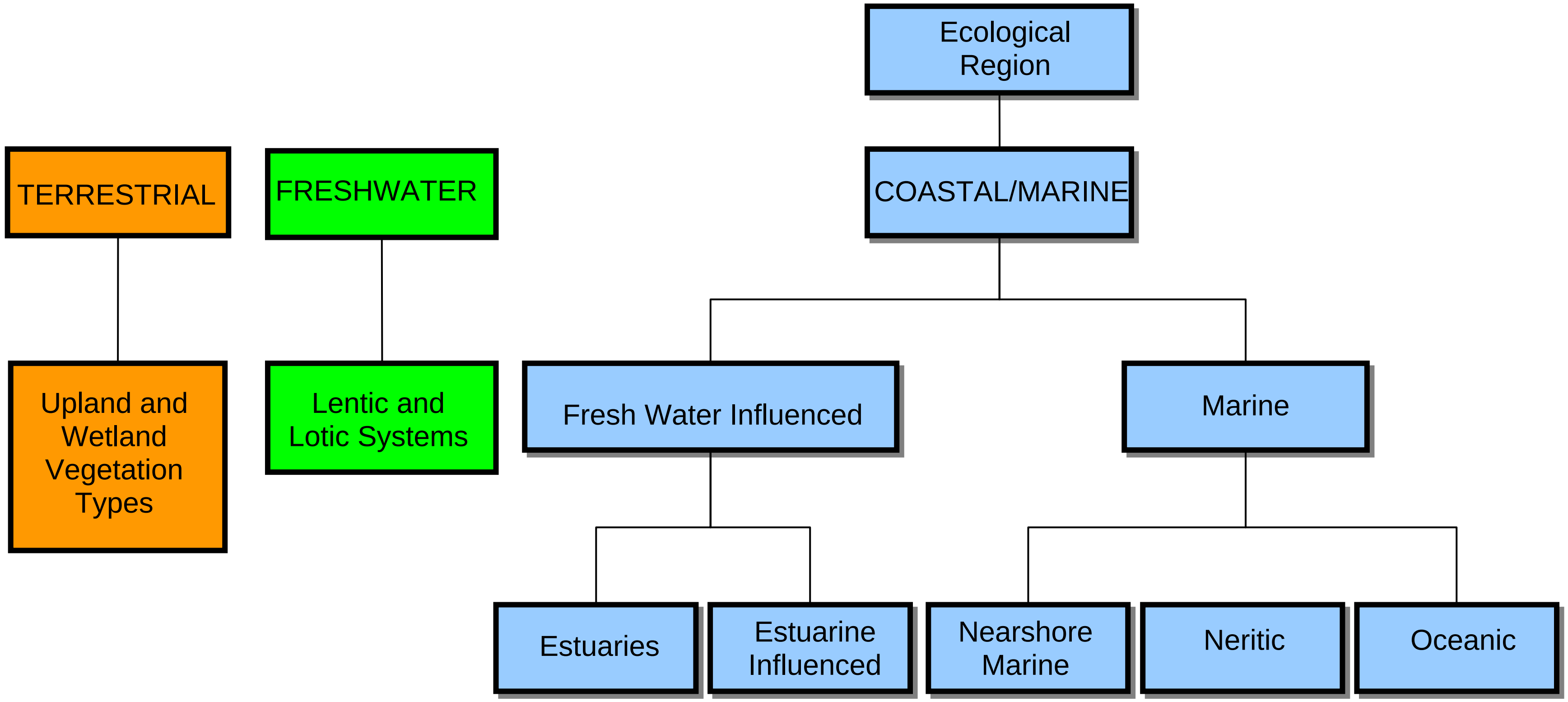
Articulation of the CMECS Classification with other Classifications

An associated goal for this classification framework is to create practical linkages between the estuarine and marine framework of the CMECS and the existing terrestrial vegetation (Grossman et al. 1998, FGDC 1997) and fresh water (Higgins et al. 1998, 1999; TNC 1996) classifications. This will provide a better basis for users to create maps and carry out analyses that depict the functional integration between these systems.

The coastal-marine division appears between Levels 1 and 2 of the CMECS and includes all of the physiognomic and habitat classes in the classification framework. It marks the point of articulation with the fresh water and terrestrial classification systems, where they join the coastal/marine classification as depicted in Figure 1. The terrestrial classification standard (Grossman et al. 1998) is a vegetation-based system that includes all emergent and floating vegetation that are found in fresh water and marine ecosystems. The CMECS and the terrestrial classification intersect in two areas: in the terrestrial Order "Vegetation not Dominant," there are several units at the Subclass and Group level that describe unvegetated geological structures (e.g. cliffs, sloping bedrock, cobble and gravel). These correspond directly to units in the CMECS structure. Secondly, in several tropical and temperate Groups in the terrestrial classification, multiple Formations that include floating or tidally flooded emergent vegetation are defined. These units are coincident with the wetland and submerged units of the CMECS. The two classifications differ in this aspect because the Terrestrial classification defines the classification unit in terms of the vegetation type, while the CMECS defines the equivalent unit in terms of substrate and hydrology at the Habitat level, and the colonizing vegetation at the next lower level, Biotope. At the points where the physical environment transitions from terrestrial and fresh water to marine, the three classification systems overlap, at wetlands, littoral vegetation, and rivers. When working at these points of overlap, the user may choose that appropriate classification that will most efficiently address their objectives.

The fresh water classification standard (The Nature Conservancy 1996; Higgins et al. 1998), following Frissell et al. (1986) is more similar to the coastal marine standard in describing physical processes and habitats that are secondarily correlated to species and biological communities. Figure 1 illustrates the spatial and ecological intersections between the terrestrial, fresh water and coastal marine classifications. The terrestrial and fresh water classifications articulate with the coastal marine classification in all fresh water influenced areas within the estuarine, nearshore and marine branches of the marine classification. This occurs via fresh water inputs to estuaries, in the palustrine wetland environments. It also occurs in the vegetated and non-vegetated descriptions of wetland, estuarine and marine types at the land-sea margin.

Figure 1. Relationship Among the Terrestrial, Freshwater and Coastal/Marine Classification Systems.



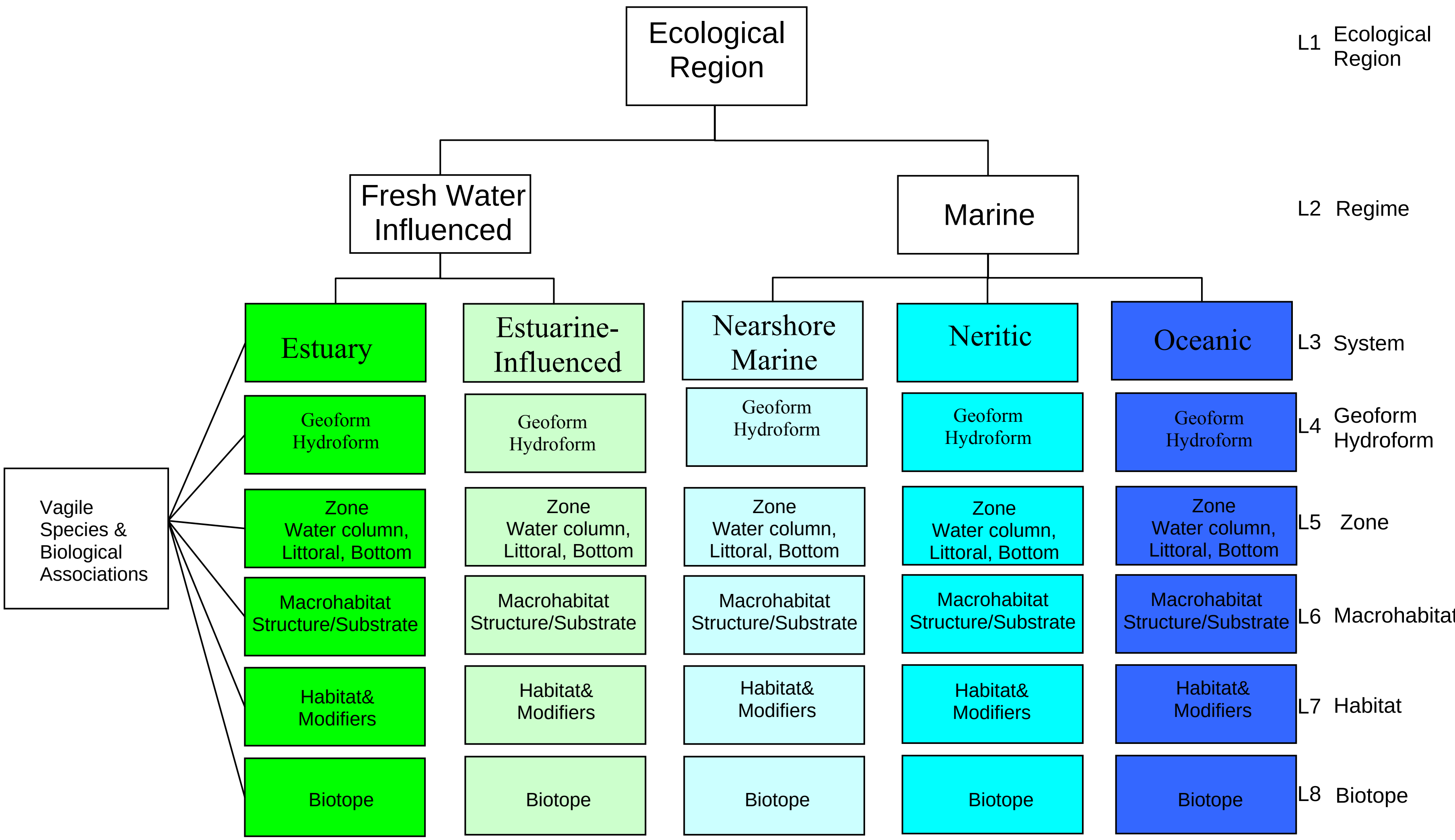
A Framework for a Coastal/Marine Classification Standard

Organization

The classification for coastal and marine habitats identifies and categorizes the physical environment at different spatial scales in estuarine, coastal and marine systems, and places the associated biology in the context of the physical habitat. The classification standard is organized into a branched hierarchy of 8 nested levels (Figure 2). The levels correspond to both a functional ecological flow and a progressively smaller map scale from the order of 1:1000000 (ecological region) to the order of 1:1 (habitat/biotope). In similar fashion to Hedgepeth (1957), Hayden et al. (1984), Longhurst (1998), and Allee et al. 2000, the coarsest level is an ecological regionalization of coastal North America. The regions are similar to those described by Cowardin (1979) and based on the ecoregions of the oceans of Bailey (1995) and the ecoregions and subregions of the US (Bailey et al. 1994). This regionalization creates a classification that is overarching and inclusive of all coastal/marine ecological types on the continent, distinguished on the basis of biogeography. From the ecological regions, the classification branches into two regimes: fresh water-influenced and marine. The regimes branch into five systems: estuarine, estuarine-influenced, nearshore marine, neritic and oceanic. Within each system, geoforms and hydroforms, which are large-scale physical structures, are elucidated. Each of these forms can be characterized according to its vertical structure: littoral, water column and bottom, each of which further splits into macrohabitat and then habitat. Finally, the biotope represents the quantum unit of the habitat, combining habitat and its commonly associated fixed biota. Modifiers are integral components of all levels of the classification, particularly the habitat and biotope levels.

A conceptual division within the hierarchy separates the kinds of data required for populating the classification. The division distinguishes the classification into upper levels, 1 though 4, which can be perceived from maps, remote imagery and existing historical data, as contrasted with the lower levels, 5 though 8, that exist at local spatial scales and where data collection is done through observation and direct measurement. It is at the bottom four levels (zone, macrohabitat, habitat and biotope), that most of the work will be done in testing, implementing, applying and expanding the classification for habitat conservation and biodiversity management.

Figure 2. Overview of the Hierarchy for the CMECS classification.



The Classification Hierarchy

Level 1: Ecological Region

Scale

100 km^2 to > 1,000 km^2

Brief Description

Level 1 in the Coastal/Marine Ecological Classification Standard is the ecological region. Ecological regions are defined as very large areas of the coasts and oceans that are relatively homogeneous with regard to physical and biological variables and reflect ecological boundaries determined by climate, water temperature and physical structures, such as major currents or ocean basins. Marine ecological regions are defined as large water masses and currents, enclosed seas, and regions of coherent sea surface temperature or ice cover. The spatial scales of units at this level are 100 to 1,000 km lengths and 100 to more than 1,000 km^2 areas. The domain of Level 1 extends from the continental coasts to the deep oceans. In practice, resource management policy can extend only to the jurisdictional limits of the U.S. Exclusive Economic Zone (EEZ), 200 mi offshore. However, the ecological regions extend beyond the EEZ so that management decisions can be informed by the full scope of available information.

The ecological region is based on biogeographical delineations determined by an expert panel and outlined in the report Ecological Regions of Coastal North America (Wilkenson in press). The Commission for Environmental Cooperation developed this report through several workshops on marine biogeography and in collaboration with the technical experts that developed the CMECS through a process similar to that for delineating terrestrial ecoregions (CEC 1997). The ecological regions for North America are listed in Table 2. Descriptions of the regions are included in Appendix 1. The more complete discussion regarding method and content is detailed in the CEC report.

Table 2. The Ecological Regions Of Coastal North America.

Region	Ecoregion Name
Region 1	Bering Sea
Region 2	Beaufort/Chukchi Seas
Region 3	Arctic Basin
Region 4	Central Arctic Archipelago
Region 5	Hudson Boothian Arctic
Region 6	Baffin/Labrador Arctic
Region 7	Acadian Atlantic
Region 8	Virginian Atlantic
Region 9	Northern Gulf Stream Transition
Region 10	Gulf Stream
Region 11	Carolinian Atlantic
Region 12	South Florida/Bahamian
Region 13	Northern Gulf of Mexico
Region 14	Southern Gulf of Mexico
Region 15	Caribbean Sea Region
Region 16	Middle American Pacific
Region 17	Mexican Pacific Transition
Region 18	Gulf of California
Region 19	Southern Californian Pacific
Region 20	Montereyan Pacific Transition
Region 21	Columbian Pacific
Region 22	Alaskan Fjordland Pacific
Region 23	Aleutian Archipelago
Region 24	Hawaiian Archipelago

Detailed Description and Rationale

The ecological regions encompass the environmental forces that determine the underlying characteristics and patterns of the coastal and marine biota. Temperature and physical structure are the primary determinants of biological distributions, migration patterns, rates of genetic exchange, patterns of biodiversity and endemism.

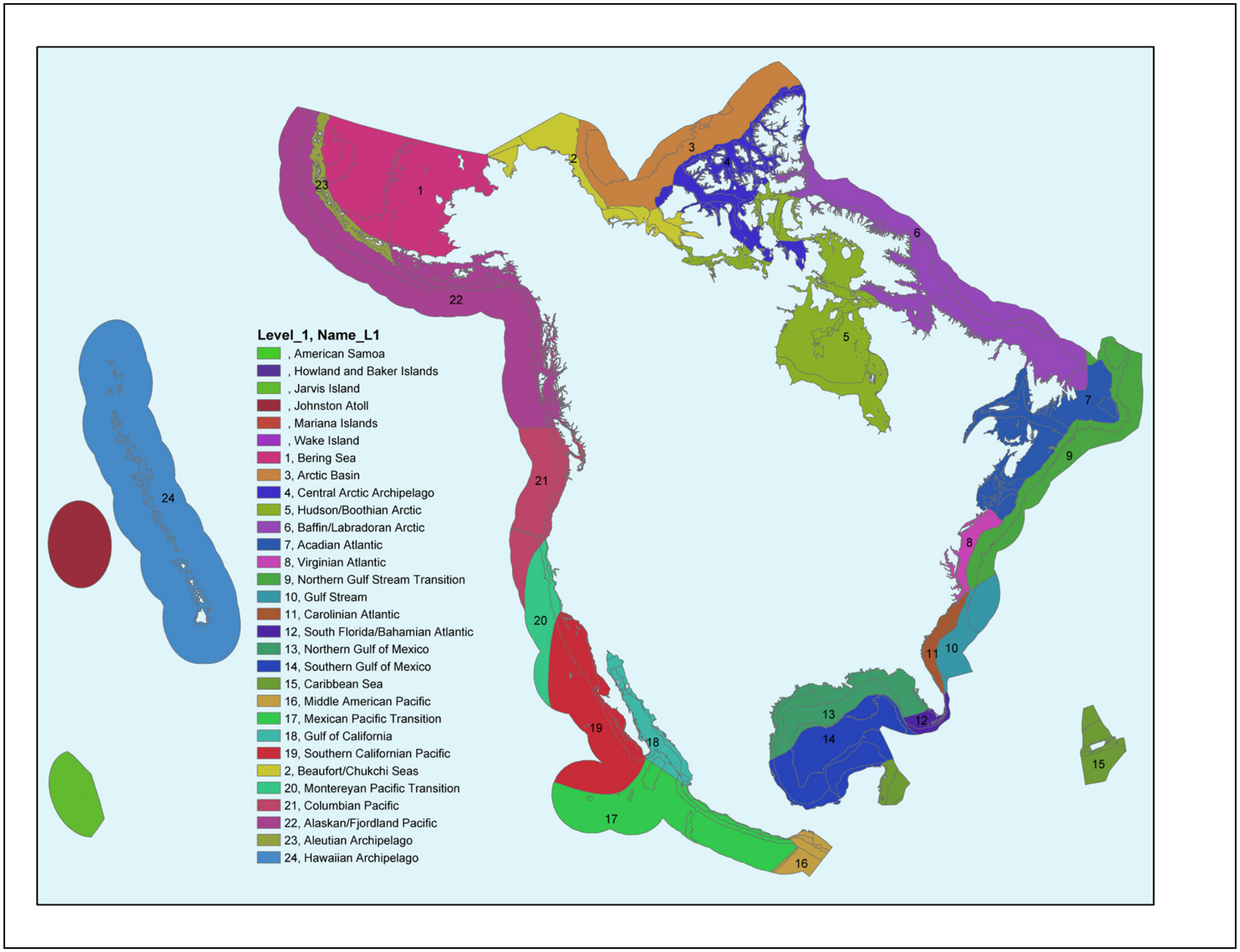
The physical components of the different water and land masses of these ecological regions can be remotely sensed and mapped. This classification level represents an aggregation of prior biogeographic classifications that supports the representation of ecological regions at smaller spatial scales. This approach enables the user of the classification to describe the subsurface environment expressed in the ecological regions in three dimensions and characterize the system at various depths, along with the littoral zone and the benthos.

Relationship to Other Ecoregionalizations

The ecological regions at Level 1 follow the work of many predecessors such as Udvardy (1969, 1975), Pielou (1979), Hayden et al. (1984), Longhurst (1998). The regionalization in this classification is particularly close to that of Cowardin (1979) who, in the report, "The Classification of Wetlands and Deepwater Habitats of the United States," produced the first comprehensive national habitat classification for the coastal U.S. The 24 biogeographical regions of North America (Appendix 1) adapted for this classification (Figure 3) also follow the logic of the life zones (Allee et al. 2000) for identification of large coherent areas of coasts and oceans. However, the ecological regions in this framework are more highly resolved and broken into a larger number of units than in Allee et al. (2000).

The ecological regions of the CMECS conform in large measure to the Large Marine Ecosystems (LMEs) described by Sherman and Alexander (1986), however there are important differences regarding both the conceptualization and the boundaries of the regions. The LME delineation uses fisheries data as a primary input, while the ecological regions in this classification are based on a broader suite of ecosystem factors that include the biology. This distinction has a particularly strong influence on the drawing of the land-sea margin boundaries.

Figure 3. Ecological Regions of North America
(Wilkenson in press).

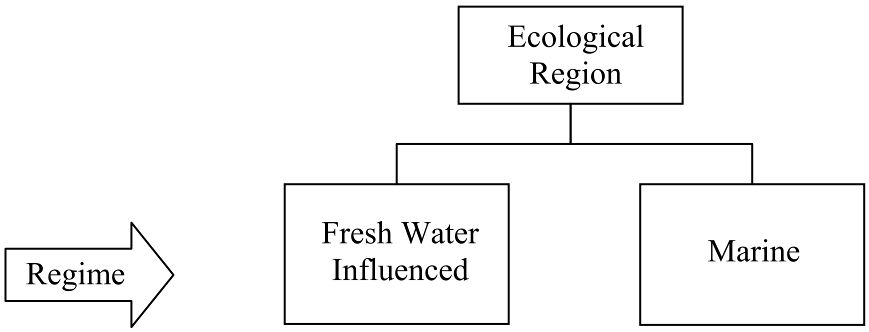


Level 2 Regime: Fresh Water-Influenced and Marine Waters

Scale

10 km^2 to > 1000 km^2

Figure 4. Level 2 – Regime



Brief Description

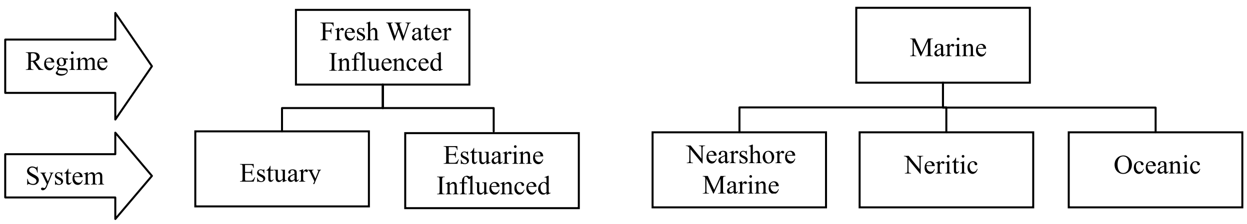
Level 2 differentiates the fresh water-influenced types from the truly marine waters in each ecological region (Figure 4). This fresh/salt distinction is made at a high level of this hierarchy to reflect the importance of fresh water and salinity in determining both habitat characteristics and their biological associations. The criterion that distinguishes between the two regimes is the presence of fresh water input from land (as opposed to direct precipitation) that reduces salinity to 30 psu (practical salinity units, similar to parts per thousand) or below during at least one month of the year. Waters that meet this criterion are classified as fresh water-influenced. Marine waters are defined as those waters that exhibit marine salinities of 30 psu or greater for more than 11 months of the year. There is no depth criterion for classifying fresh-influenced waters. On oceanic islands or coasts with narrow continental margins, fresh inputs may discharge directly into the deep ocean while on coasts with a wide continental platform, fresh water may discharge into shallow estuaries no more than a meter deep. Both of these examples would be classified as fresh water-influenced regimes.

Level 3: System

Scale

1 km^2 to > 1000 km^2

Figure 5. Level 3 – System



Brief Description

There are five Level 3 coastal and marine systems that nest under the regimes of Level 2 (Figure 5).

Nested within the fresh water-influenced regime are the estuarine systems (or estuaries) and the estuarine-influenced systems. Estuaries are identified by their semi-enclosed geomorphology and reduced salinities due to land-derived fresh water input; estuarine-influenced systems are waters that receive estuarine flow but are not found within an estuary. An example of an estuarine-influenced system is a fresh water plume from a river that extends out from the coast.

Nested within the marine regime are nearshore marine, neritic, and oceanic systems. These systems are distinguished from the two fresh water influenced systems by higher salinity and are distinguished from each other by depth. Nearshore marine systems are those marine waters that extend from the coast to the 30 m isobath. Neritic systems extend from 30 m to the continental shelf break, generally at approximately the 200 m isobath, although this boundary can vary by many meters in depth. Oceanic systems are waters beyond the shelf break, deeper than approximately 200 m.

The five systems are classified at this level of the hierarchy to reflect the importance of salinity, as well as depth, in distinguishing the major fresh water influenced and marine systems. This also emphasizes the functional interactions between shallow coastal margins and estuarine salinity conditions. The fresh water inflow from land into the shallow coastal margins results in high variations in salinity in these shallow, nearshore systems.

Detailed Description and Rationale

Fresh Water-Influenced Systems

Estuarine Systems

Estuarine systems are enclosed or semi-enclosed coastal water bodies that are influenced by fresh water input that reduces salinity to below 30 psu during at least one month of the year. Estuaries may exist on the margins of continentals and large islands. The geomorphology and hydrology determine the 'strength' of the physical enclosure, which in turn impacts the residence time for water within an estuary and the gradient of distinctiveness from open oceanic processes. The degree of geo-morphological enclosure defines the estuarine systems, and determines the level of temporal, chemical, biological and ecological distinctiveness from the ocean system. A river channeling directly into the ocean is very different than a well-developed coastal estuarine system that slowly discharges into the ocean.

Unlike marine systems, which are distinguished from each other strictly on the basis of depth, fresh water-influenced systems can occur in waters of any depth. Although they are coastal systems, many estuaries have water depths much greater than 30 m. In parts of the Puget Sound, Chesapeake Bay, and San Francisco Bay, the 30 m isobath is very close to shore, and yet within the enclosed area of the estuary. The depth of an estuarine water column can be significantly greater than 30 m and retain the characteristics of an estuary. Therefore, all areas within the enclosed space that generally defines the estuary, are classified as estuarine, regardless of depth.

Example of an Estuarine- nfluenced Marine System

The Mississippi River plume is an example of waters that are of estuarine-influenced marine character. The river discharges directly into the deep waters of the Gulf of Mexico and forms a thin layer (in some parts just a few cm thick) of turbid fresh water atop a deep water column. The plume extends for hundreds of km into the Gulf of Mexico, riding atop the saltier gulf waters, bathing islands in fresh water, depositing sediments, and introducing nutrients and organic matter to the water column. The impact on the immediate area of surface waters and deep into the waters below is profound. Although the water is the plume is estuarine, the Gulf of Mexico can hardly be considered an estuary. Its water column is overwhelmingly of marine character. Yet the fresh water lens that forms the plume has a marked influence on the light regime, the water chemistry and the biology of the impacted area. The branch of the classification that accommodates this condition is the Estuarine-Influenced Marine System. In these systems, the estuarine-influenced zone may be highly variable and mobile, responding to currents and winds, and may extend for hundreds of miles into the marine environment.

Estuarine-influenced Systems

Estuarine-influenced systems are waters that have no distinctly enclosing morphology, yet receive a significant amount of fresh water input from land during at least part of the year. In such cases, an unenclosed marine water column may be influenced by fresh water in the form of a river plume or an overlying fresh water lens or a ground water seep discharge (see box). As with the estuary, the estuarine-influenced system can occur in nearshore, neritic or oceanic depths, provided the region is influenced by fresh water input that reduces salinity to below 30 psu during at least one month of the year. These systems tend to be less well defined and variable, determined by wet season outflow from true estuaries. They often may have surface characteristics of estuaries, but deeper waters may be completely marine.

Marine Systems

The marine regime is subdivided into nearshore, neritic and oceanic systems that are distinguished based on water depths of 0-30 m, 30-200 m and >200 m. Many classifications merge the nearshore and neritic into one zone (usually called the neritic) that extends from the shoreline to the 30 m isobath. The CMECS breaks this zone into two zones, with the shallowest 30 m defined as the nearshore zone, including all coastal and shallow water processes and the deeper section defined as the neritic, which includes the remaining shelf. Ecological and biological decoupling of surface waters from the benthic regime increases with depth and the 30 m isobath has proven to represent a significant ecological and biological line between different systems.

Nearshore System

Nearshore marine systems are those coastal waters that are marine in character (> 30 psu throughout the year) which extend from the land margin to the 30 m depth contour. In the nearshore marine system, the benthic and above surface processes influence the ecology and biology throughout the water column. The photic zone, defined as the upper part of the water column where light exceeds 2% of surface light intensity during daylight, generally extends through the entire water column. This often supports the growth of vegetation on the bottom. The mixed layer generally distributes bottom nutrients and sediments throughout the water column.

Neritic System

The neritic system is the region of marine waters (> 30 psu year round) between the 30 m depth contour and the continental shelf break, which occurs at approximately at 200 m water depth. Depending on shelf morphology, waters at the 30 m isobath can be quite distant from the continent or they may lie quite close to land. The depth criterion is a more important ecological criteria than the distance from land. An example of a neritic system that begins far from the coast is found in the South Atlantic Bight offshore of South Carolina and Georgia, where the 30 m isobath is over 30 mi offshore in places. In comparison, the neritic system along the California coast can occur within a few meters of the coast.

Oceanic System

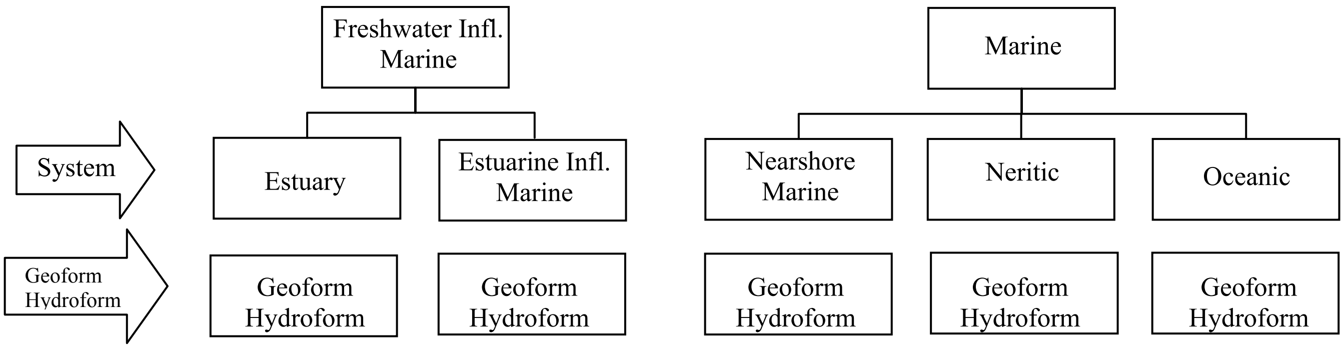
The oceanic system represents the marine realm beyond the continental shelf break, waters that are generally deeper than 200 m. The horizontal boundary created by the physical depth discontinuity of the shelf break establishes strong and identifiable constraints on the processes in the system and represents a logical breakpoint for the division of major marine systems. In the case of large islands where a shelf is absent, the oceanic system begins at the 200 m depth contour. The marine waters of the oceanic system are sufficiently distant from land and they receive little to no influences from fresh water, nutrient and sediment inputs. Due to the great water depths, there is little or no interaction of ocean bottom with the vast majority of the overlying water column. The sea bottom diminishes in importance in influencing pelagic processes. Light is greatly attenuated within the water column and does not reach the bottom. The upper water layer does not mix to the bottom and the mixing zone is separated from bottom waters by a density gradient or pycnocline generated by a temperature or salinity differential.

Level 4: Geoform and Hydroform

Scale

10,000 m^2 to 100 km^2

Figure 6. Level 4 – Geoform and Hydroform



Brief Description

Major geographic and hydrographic features of coastal-marine systems are represented at Level 4 (Figure 6). *Geoform* structures in this level are geological formations on the continent, islands or the seafloor on the order of 10,000 m^2 or larger in area. Examples include islands, lagoons and seamounts. *Hydroforms* are large physical features or boundaries created by water masses of 10,000 m^2 or larger in area. Examples include current systems, fronts, gyres and upwellings (see box).

The importance of these units is that they represent the geological and hydrological environments that both support and constrain the composition and dynamics of the biota.

Detailed Description and Rationale

At this level the shape and size of the physical features of the system play an important role in determining the nature of the ecological and biological processes. The morphology of these features controls such processes as water exchange rates and water turnover times, hydrologic and energy cycles,

Example of a coastal geoform

A river channel is a (seemingly) simple example of a geomorphologic unit that has predictable characteristics. The parallel banks of the river channel surface flow in a single direction toward the sea, sometimes creating a single or even double counter current of marine water beneath the surface flow. This forms a characteristic salt wedge estuary. Organisms such as white shrimp in the estuaries of south Louisiana use the saline bottom waters to ride up into the estuary, then migrate or ride vertical currents to maintain their optimal position in the estuary. Materials are often entrained in this bi-directional flow, and due to ionic field changes at low salinity, particulates precipitate out of solution, forming colloids and aggregations that create a typical turbidity maximum in the upper estuary. The uni-directional river flow carries sediments and nutrients into the generally clearer marine waters, fertilizing the nearshore zone. A center of high primary productivity often occurs where currents slow, sediments drop out of suspension, and the water column clears. This high primary productivity that typifies coastal zones, attracts the high secondary productivity for which estuaries are well-known.

shelter or exposure to energy inputs and migration and spawning patterns. Single features, such as an embayment, can encompass both land and water components, while others are either geomorphological (e.g. seamount) or hydromorphological (e.g. upwelling). Features in the geoform and hydroform category shape the seascape in repeatable and predictable ways by providing structure, channeling energy flows, regulating bioenergetics, and controlling transfer rates of energy, material and organisms.

One geoform or hydroform may incorporate another at the same level of the hierarchy, such as an island with a wetland or an atoll with a lagoon. This does not present a problem for the hierarchy, as a user will note the combination of geoforms and proceed with classification to lower levels. One consequence of this classification structure is to permit geoform features, such as wetlands, in the oceanic branch of the hierarchy. Oceanic islands are separated from the continent by a deep water column and therefore are functionally and ecologically different than their continental and nearshore island counterparts, even when the physical components are similar. Such islands possess large geoforms themselves, such as embayments, rivers and even estuaries, all of which are at the same hierarchical level of the classification, or at a higher level in the case of estuaries. This results from the fact that the physical scales of the classification levels overlap. If the particular user-application requires classification of an oceanic island geoform to finer levels, the methodology is to identify the included geoform feature on the island (such as wetland) and proceed to the estuarine or nearshore marine branches of the classification (as appropriate) to continue with the classification to finer levels. The procedure will produce a set of habitats that is similar to the analogous continental habitats in the estuarine and nearshore marine systems. The flagging of the wetland as being on an island leaves open the possibility for different biotopes to result, even within the same ecological region. Moving across branches of the hierarchy in this way provides flexibility within the conceptual model that is similar to the way that geoform features are organized in the real world. Despite this mobility within the conceptual framework, maps of these features will be appropriately nested because the units in the physical world are self-scaling- smaller geoform units will always nest within larger geoform units even if on the same hierarchical level.

<u>Geoforms and Hydroforms Common to all Systems</u>
Many geoforms are common to all branches of the classification, although not every type of geoform or hydroform can exist in every branch. The common geoforms are islands, embayments, lagoons, wetlands, river channels, banks, reefs, open coasts and seabeds. Some geoforms, such as wetlands, exist in neritic and oceanic systems only on islands. In shallower systems, these wetland can be found either on the continental land mass or on islands. The hydroforms common to all systems are current systems, upwellings, downwellings, currents, rivers, ice, and open waters.

<u>Neritic and Oceanic Geoforms</u>
Large geomorphic features or geoforms occur on the sea bottom or on islands and reefs in neritic and oceanic systems. These features are strongly based on the Greene et al. (1999) classification of deep-sea geological mega-habitat features. Examples of these include seamounts, trenches, canyons and faults.

Neritic and Oceanic Hydroforms
The neritic and oceanic water column extends from water of 30 m depth to the deep oceans beyond the shelf break (>~200 m). Certain hydrographic features are found only in these deeper waters, such as oceanic gyres, warm and cold core rings, and hydrothermal vents.

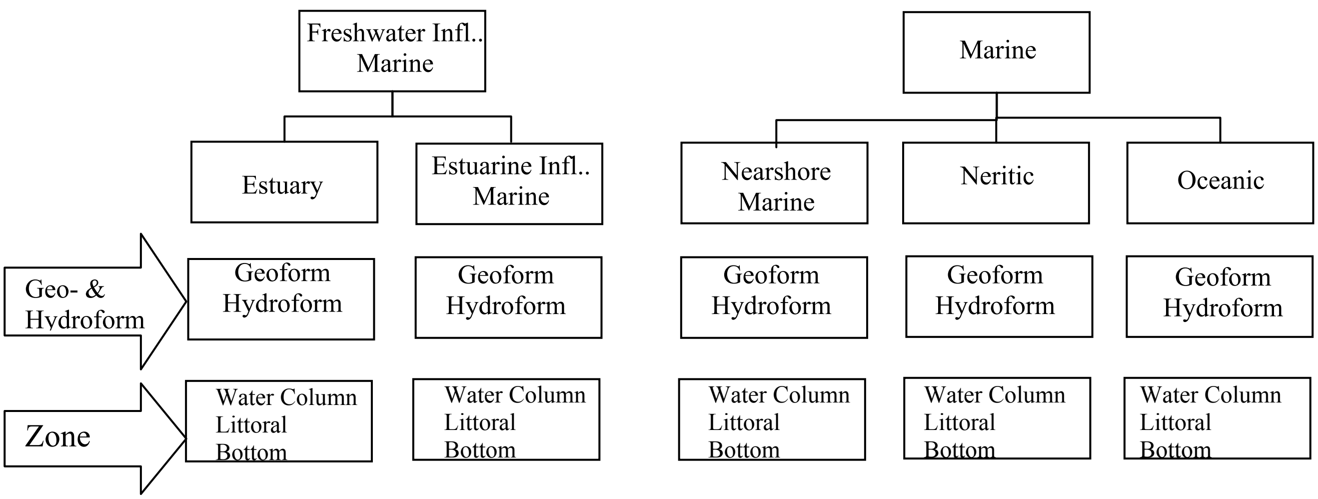
A listing of the hydroform and geoform units is found in Appendix 1.

Level 5: Zone

Scale

100 m^2 to 10,000 km^2

Figure 7. Level 5 – Zone



Brief Description

Zones of Coastal/Marine Systems

Level 5 characterizes the vertical zonation that exists in each of the coastal and marine systems. The vertical scope of this level extends from above the littoral in the supratidal area, to the deep ocean bottom and is comprised of three major zones: the littoral, the water column and the bottom (Figure 7). The Zone level integrates the vertical dimension into the classification hierarchy, creating relevant vertical ecological distinctions to the System Level and certain Level 4 geoforms and hydroforms. The three zones are defined as:

Littoral zone- the land-water interface at the margins of continents and islands. The littoral zone is the region between extreme lower low tide and the splash and aerosol zone that extends above extreme higher high spring tide. The land margin at the interface between coast and ocean includes subtidal substrate and water components that are subject to tidal and wave motion (infratidal) and to periodic wetting and drying (intertidal), as well as the land environment influenced by splash and sea spray and seafoam (supratidal).

Water column zone- all estuarine and marine waters in depths deeper than the intertidal. The water column extends from the sea surface to the ocean bottom. For this classification, the water column near the coasts begins where the depth is greater than 1 m. In the region between the 1 m depth and point where the waterline intersects with the coast, water motions are too active and variable to be considered separate and the water column and bottom together are considered to be a single entity forming part of the littoral zone.

Bottom zone- in the subtidal, the bottom part of the ocean formed by the sea floor that is completely and continuously covered by water.

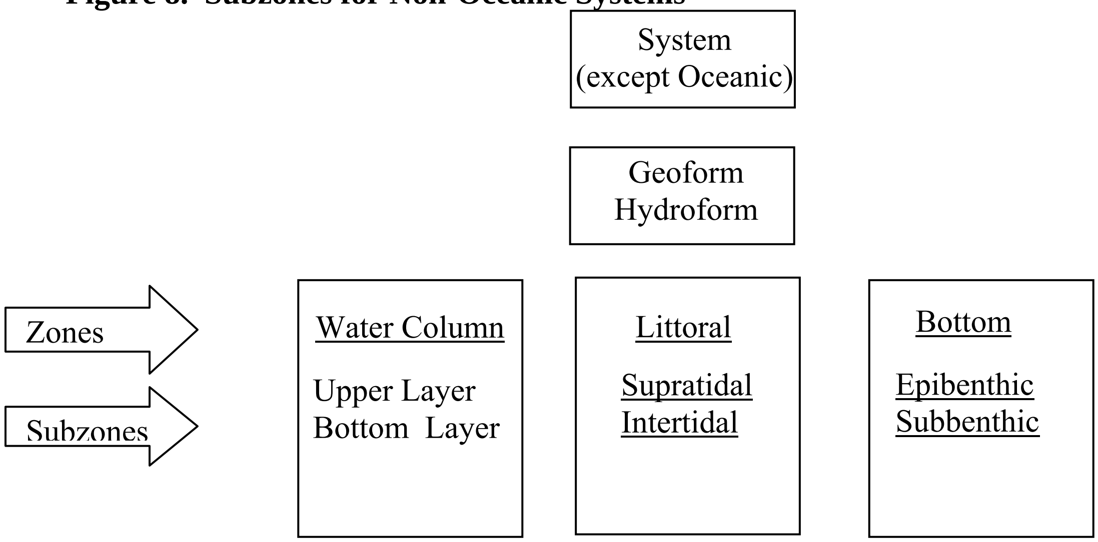
All geoforms incorporate at least one of the three vertical zones, and many of them (though not all) contain all three zones. For example, the geoform "lagoon" contains a water column, a benthic zone and a littoral zone. The hydroform "upwelling" in the neritic has only a water column zone. The geoform "seamount" in the oceanic system has only a benthic zone, yet if it is an emergent seamount (an island), it will also have a littoral zone. An atoll is an oceanic geoform, with a bottom and littoral zone. If it has an interior lagoon, it encloses a water column and therefore has all three vertical zones. In the cases of estuarine, estuarine-influenced and nearshore marine systems, the littoral zone may refer to a shoreline of a continent or large island or iceberg. In the cases of the neritic and oceanic systems, the littoral zone only refers to large islands and icebergs.

Detailed Description and Rationale

A littoral zone can exist in any of the five systems in the CMECS classification, including the deep Oceanic system. This zone covers the presence of emergent geoform structures above the water's surface in the deep ocean, such as islands and large icebergs. This feature of the classification has two consequences. It presents an opportunity to identify differences in littoral habitat function attributable solely to the system branch (e.g. oceanic island coast is different than a neritic island coast), and it allows mapping of surface features across all five systems in the landscape in an efficient manner. It also presents a decision point in the hierarchy- the oceanic system occurs in waters greater than 200 m, which precludes anything having a littoral zone. However, the presence of islands and icebergs, ice shelves, and floating mats creates littoral zones in the deepwater system, many of which are not associated with a shallow subtidal shelf or slope as in the nearshore zone. The littoral zone carries a number of features associated with the shallow water branches of the hierarchy. Rather than treat mid-ocean features as though they were on the continent, they are classified as part of the oceanic system; finer levels of those features are completed through the coastal branches. When applying the CMECS classification, the procedure for an oceanic island is to begin in the oceanic system branch, classify the geoform from the deepwater branch (e.g. island), classify the zone (e.g. littoral), then note any included features on the island (e.g. rocky shore, cave) at the macrohabitat and habitat levels from the shallow water branches. Thus, the finer levels of classification of those structures are appropriately accomplished from the estuarine or nearshore marine branches of the classification. The practical consequence of this classification structure is to acknowledge that non-continental branches (neritic or oceanic) have littoral zones and geoforms, yet enable finer classification of these forms without adding branches to the hierarchy to accommodate such structures.

Within each of the vertical zones, there are subzones that distinguish sections of the larger zone on the basis of finer vertical layers. The two subzones in each zone for all systems except the oceanic system are as shown in Figure 8. For the oceanic system, because the great depths require more highly resolved subdivisions to identify the greater diversity in vertical differences, a separate set of subzones was created and are described below in Figure 9.

Figure 8. Subzones for Non-Oceanic Systems



Subzones for All Systems (Except Oceanic)

Subzones of the Littoral
The littoral zone for fresh water-influenced systems, the nearshore marine and neritic systems is divided into two subzones. These apply to continental land margins and island land margins.

Supratidal - the area above the high tide line in the splash zone that is affected by spray, splash, aerosols and overwash. This interface is regularly exposed to the air by tidal movement. Aquatic organisms inhabiting these physically demanding habits are adapted to periods of exposure to the air and to wave action. Included in this subzone is the region of non-tidal wetlands and uplands that are saturated by coastal waters below the soil surface.

Intertidal - the area of littoral land at the land-sea interface that is periodically covered by water between extreme low and extreme high tide.

Subzones of the Water Column
With the exception of oceanic systems, an important functional distinction is created by temperature or salinity differences in the upper and bottom layers of the water column. When present, the upper layer is separated from the lower layer by a difference in density, which results

in little mixing between the layers. The two water layers define separate mixing zones and energy regimes, and create barriers to movement of materials and fauna. These layers may maintain this stratification for many months. Stratified water masses are usually highly stable, and separation is only broken down by wind or current energy input.

Upper water column- in a two-layer water column, the area above the sharp density gradient (pycnocline) which includes the air-water interface. Pycnoclines are generally formed by salinity or temperature differences between the upper and lower water layers and create effective barriers to transport across layers. The water layers remain largely distinct even having current regimes that flow in opposite directions in certain estuaries.

Lower water column- in a two-layer water column, the area below the pycnocline that includes the sediment-water interface.

Subzones of the Bottom

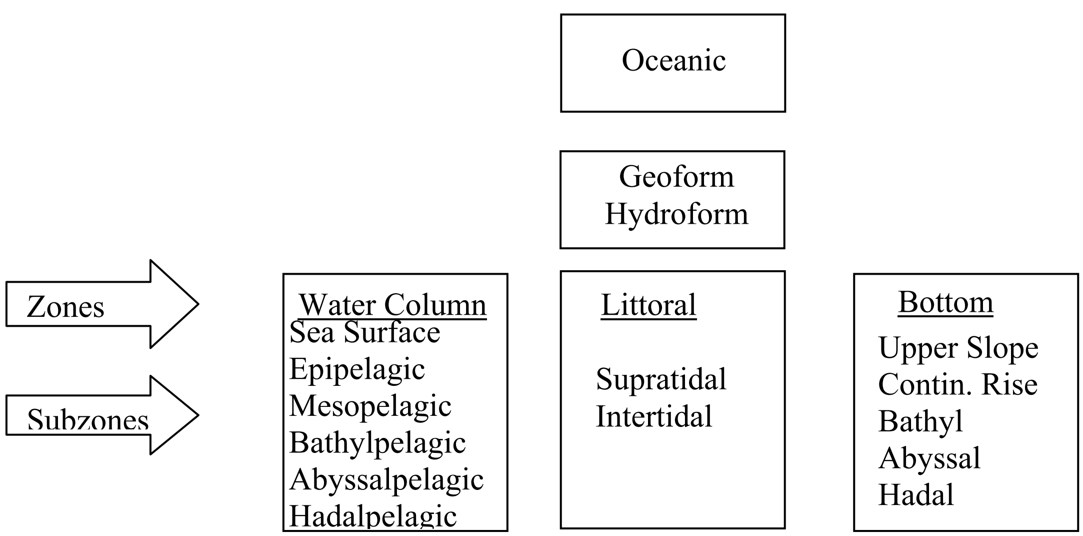
The bottom is resolved into two subzones.

Subtidal Epibenthic- the surface of the benthic zone, at the interface of the bottom of the water column and the seabed.

Subtidal Subbenthic- in soft unconsolidated sediments the substrata below the surface of the sediments. The subbenthic zone is often inhabited by burrowing organisms and other infauna, such as polychaetes, bivalves, and certain nekton. Bioturbation of the sediments by infauna is an important process for aeration and improves the transfer of sediment and nutrients from the benthos to the water column.

Subzones for Oceanic Systems

Figure 9. Subzones for Oceanic Systems



Subzones of the Oceanic Water Column

The oceanic system is distinguished by a proliferation of vertical subzones, each determined by water depth. Subzones for oceanic systems in the CMECS are shown in Figure 9, their depth characteristics are listed in Table 3.

Table 3. Subzones for the Water Column Zone in the Oceanic System (Holthus and Maragos 1995).

Subzone	**Depth**
Sea surface	0 m
Epipelagic	0-200 m
Mesopelagic	200-1000 m
Bathylpelagic	1000-4000 m
Abyssalpelagic	4000-7000 m
Hadalpelagic	>7000 m

Subzones of the Oceanic Littoral

The subzones of the littoral oceanic systems are the same as for other systems. These apply only to the littoral zones of islands, as there are no continental land margins abutting the oceanic water column.

Subzones of the Oceanic Bottom

On the oceanic bottom, vertical subzones of the benthos are also defined by depth ranges listed in Table 4.

Table 4. Subzones for Bottom Zone in the Oceanic System.

Subzone	**Depth**
Upper Slope	<200 m
Continental Rise	200-1000 m
Bathyl	1000-4000 m
Abyssal	4000-7000 m
Hadal	>7,000 m

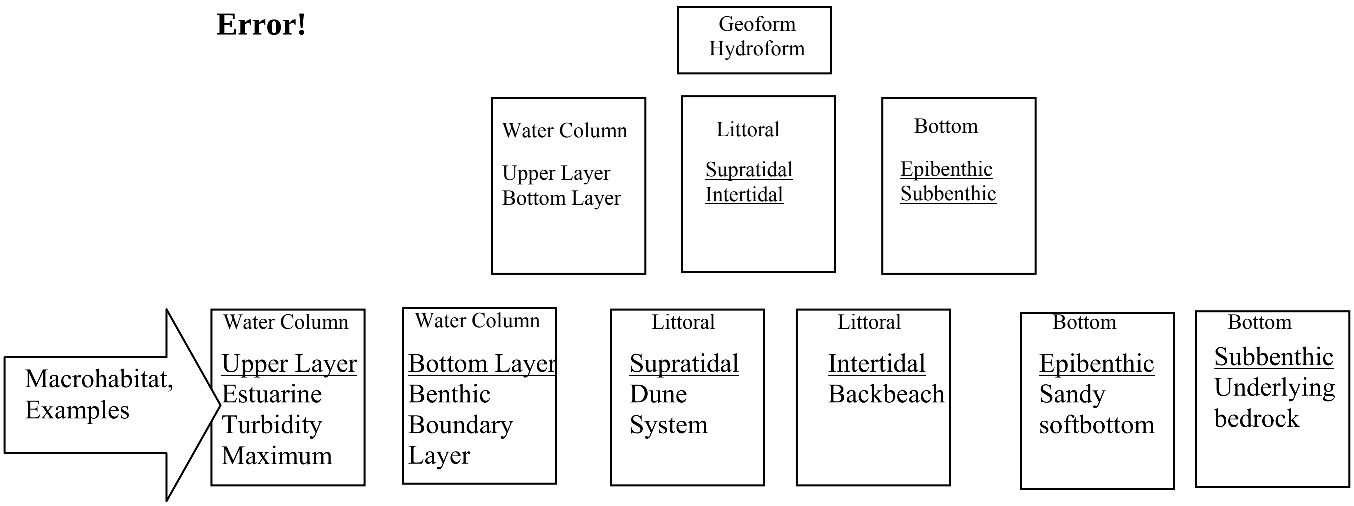
Level 6: Macrohabitat

Scale

100 m^2 to several 1000 m^2

Figure 10. Level 6 – Macrohabitat

Error!



Brief Description

Level 6 defines the macrohabitat, which is a geomorphic or hydromorphic structure of the coastal and marine environment that can be observed, measured and mapped using direct sampling (Figure 10). Macrohabitat units are specific, recognizable, repeatable structural units of the physical environment at a landscape-scale that are relatively homogeneous in terms of local climate, hydrology and chemistry. They are subunits of larger geoforms or hydroforms (Level 4), divided into smaller units on the basis of physical gradients, discontinuities, and/or vertical zone position (Level 5). Macrohabitats are physically complex entities that contain multiple habitats and structure the distribution of communities within an ecological region. A defining aspect of the macrohabitat is the physical inter-dependence of the habitat units.

Detailed Description and Rationale

Conceptually, large geoforms can be compartmentalized into macrohabitats by considering that any physical feature in the environment possesses a complexity imparted by its three dimensional geometry. Generally these forms possess a distinguishable upper surface, flanks, and a base which tend to be structurally different from each other. This is true whether the large feature is geomorphological (a seamount) or hydromorphological (the Gulf Stream current). Additionally a geoform feature may have several bands or zones based on further structural complexity (interior vs. exterior of a warm core ring), on depth, or on the presence of some resource such as light or energy that differentially interacts with the structure along its geometry. All of these factors create different zones of structure and/or energy interaction with the biota and these subdivisions are the basis of macrohabitat units. The rocky shore macrohabitat is the littoral intertidal component of an island geoform. The lava field macrohabitat is a benthic component of the seamount geoform. The turbidity maximum macrohabitat is an upper water column component of the river hydroform.

Each level of the classification hierarchy represents a progressive reduction in spatial scale. The distinction between the Level 4 geoform/hydroform and the Level 6 macrohabitat derives from macrohabitat units being of a size scale that more closely matches the biology utilizing the structure. Macrohabitats represent an intermediate scale between the geoform/hydroform and the habitat levels. Subcomponents of the geoforms and hydroforms create the macrohabitats. Each macrohabitat type represents a different physical setting that supports one or more distinct biological communities.

The habitat units within the macrohabitat are interconnected by physical or ecological processes. For example, the hydrology and geology of a sandy beach littoral macrohabitat incorporates the tidepool, beach face, and surf zone habitats. The subunits within a macrohabitat and the biology associated with them may interact with each other or may be isolated and distinct from each other, while still being physically part of the whole. The coral reef crown habitat generally does not interact with the sheer wall habitat of the same reef, but one element could not exist without the other, reflecting the cohesion of these component parts of the reef macrohabitat.

The macrohabitat generally occupies a single vertical zone (Level 5) of the geo/hydroform unit. For example, an oyster reef macrohabitat in a coastal plain estuary could be strictly intertidal. This vertical partitioning occurs because of the overriding structuring action of the processes forming the zone (tide, water depth, exposure to air). A rocky hardbottom macrohabitat is different from the rocky intertidal macrohabitat. In rare cases, a macrohabitat unit may be so cohesive that it can cross multiple vertical zones. For example, the interior lagoon in an oceanic land-ringed atoll is so unique and distinct that it is classified as one macrohabitat that encompasses both the littoral and benthic zones. Such distinctions are made sparingly on a case-by-case basis, following rules established for applying the classification.

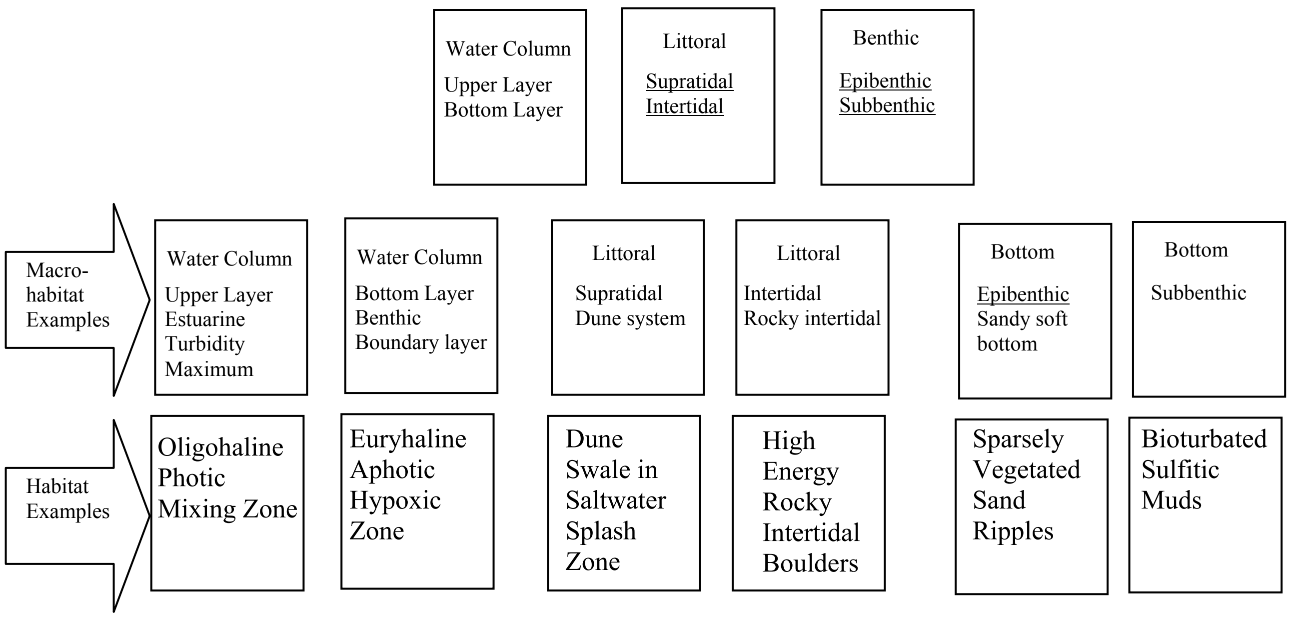
A distinction has been made within the CMECS as to where the biota become integrated into the classification hierarchy. Biological associations are introduced at the finest level of the hierarchy, the biotope, in order to keep a clear distinction between the habitat and its biology. In certain special cases, biological growth forms actually create physical structures that are recognized and classified at the level of macrohabitat. The distinguishing criterion is the stability and degree of structural complexity that the biota introduces to the physical environment. Two examples of biotic created macrohabitats are the mangrove forest and the biogenic reef. Both are examples of large structures that have components and sub-structures analogous to geologic structures in their complexity, persistence, durability and heterogeneity. Unlike more ephemeral and homogeneous biological structures such as aquatic vegetation beds, the reef and mangrove forest persist inter-annually and consist of a complex structure that can be subdivided into habitat units.

Level 7: Habitat

Scale

1 m^2 to 100 m^2

Figure 11. Level 7 – Habitat



Brief Description

The habitat is the physical unit of the environment that is recognized and directly used by the biota for food and/or refuge (Figure 11). The habitat unit is described as a geomorphological or hydromorphological type and includes specific substrate, energy, chemical, biological and anthropogenic modifiers. Habitat units can be classified and mapped by direct observation of the relationship between biota to the habitat. The size range for the habitats is determined by the spatial range of the biology that uses the habitat. The organisms considered to recognize these habitat units range from 1 mm to tens of meters, and the corresponding habitats range from tens of millimeters to thousands of square meters. Due to the technological constraints of detecting habitats, a lower unit spatial bound of 1 m^2 was established.

Detailed Description and Rationale

Habitat units are defined as the biotic and abiotic, physical features of the environment that are critical sites for biological and ecosystem health and function on a local scale. The habitat has a geomorphologic or hydromorphologic basis that is modified by at least one and usually several environmental variables (e.g. local geology, wave exposure, substrate composition, trophic status, impoundment). The local geo/hydromorphology of the habitat unit occurs at a much smaller spatial scale than the large geoforms and hydroforms of Level 4, and at a scale similar to or smaller than the macrohabitat of Level 6. Level 4 units (Geoforms/Hydroforms) can encompass entire ecosystems, and Level 6 (Macrohabitats) can be relatively large landscape scale features many thousands of square meters in area. Whether a particular unit is considered to be at the level of a macrohabitat or a habitat is based on its complexity, the spatial extent of the feature, whether it is composed of smaller distinct parts (habitats) and the size scale of those parts. While the macrohabitat is a complex unit that usually contains multiple habitat subunits, the habitat is a self-contained and distinct physical feature that relates directly to biota on a one-to-one basis. If a feature is not differentiable into multiple distinct physical components each of which has a unique interaction with biota, the unit is considered a habitat unit.

Observation and knowledge of biology at the habitat level is important in defining habitat units. Units at the habitat level are constrained to the size scale of the biological processes of a particular species or association that are in routine and intimate contact with the physical unit. These include areas directly suited for spawning, for refuge, for photosynthesis or for feeding. Many biological processes of a single organism are conducted in different parts of the physical environment, either simultaneously or in sequential life stages, and so several different habitats may be critical to the health and survival of specific species. The habitat types that populate this classification will be developed with input from regional and local experts knowledgeable about the species and ecology of the local environment.

It is important to define physical habitat as a means to evaluate both faunal and floristic distributions and associations. For example, the biological difference between a salt flat and a salt marsh is the colonization of the latter by emergent halophyte vascular vegetation. Both habitats are classified as intertidal unconsolidated sediments, one unvegetated and the other vegetated by emergent macrophytes (and defined as marsh). The type of vegetation (salt marsh- e.g. *Spartina alterniflora*), would introduced at the biotope level. This physically-based approach to habitat classification, similar to the Dethier (1990) and BCMEC (Zacharias et al. 1998) classifications, enables systematic assessment of the factors responsible for differences in (or the absence of) distributions of vegetation as well as of fauna in response to physical attributes of the environment.

The presence of exceptional structural units built by biogenic processes that were noted for macrohabitats at Level 6 holds true for Level 7 habitats. The mangrove swamp forests and coral reefs were classified as macrohabitats due to their function as persistent structuring agents in the environment. These living structures are similarly recognized as containing smaller structural habitat units such as the prop root zone, basin forest, reef halo and reef crown that warrant special consideration as habitat units.

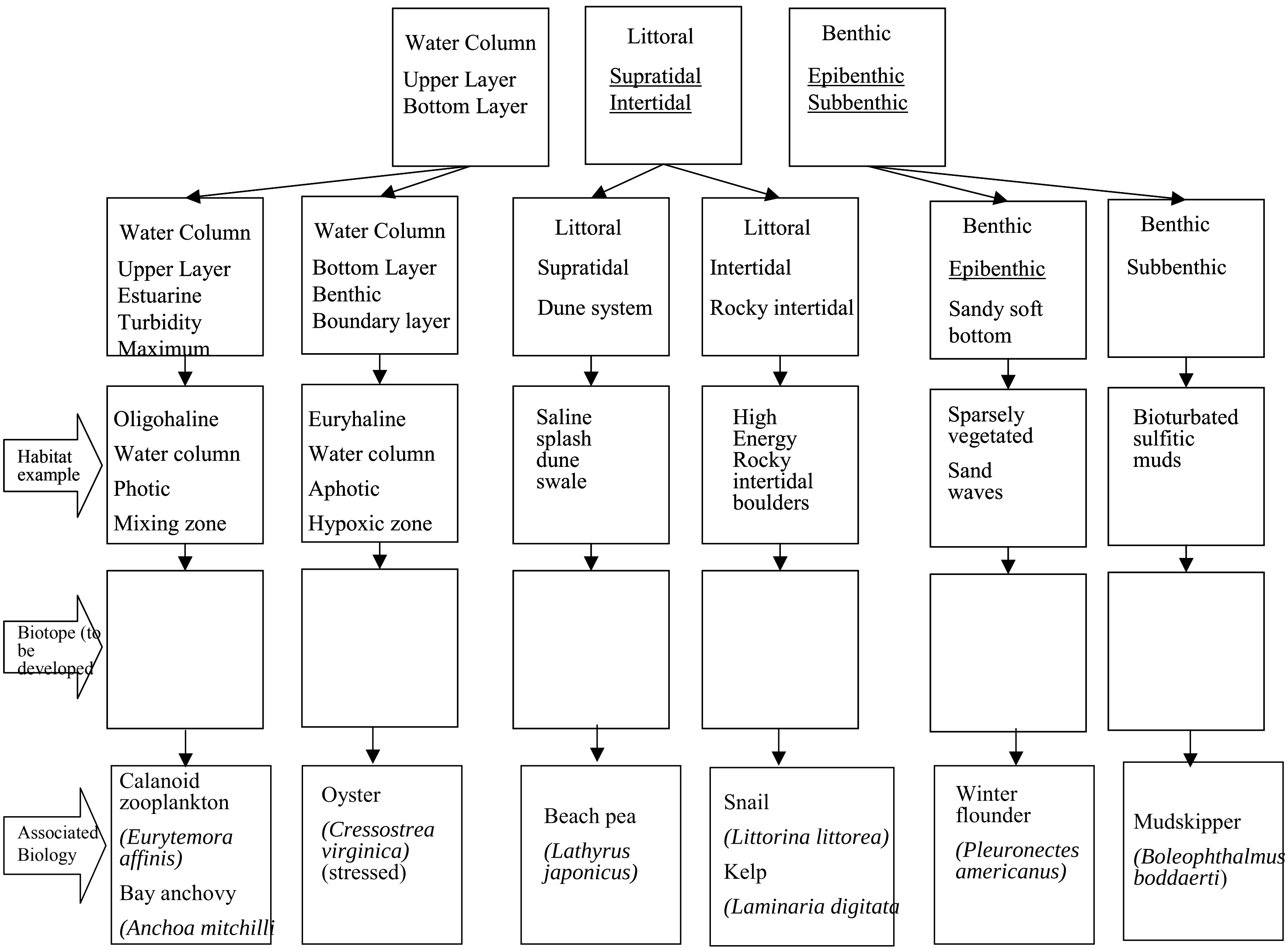
Additional information that defines the habitat is conveyed through modifiers. Although some modifiers can be applied at any level of the hierarchy, they are essential in determining habitat units. Modifiers for the habitat level include classes for characterizing variables like salinity, depth, temperature, oxygen, trophic status and turbidity (see Appendix 2).

Level 8: Biotope

Scale

1 m^2 to 100 m^2

Figure 12. Level 8 – Biotope



Brief Description

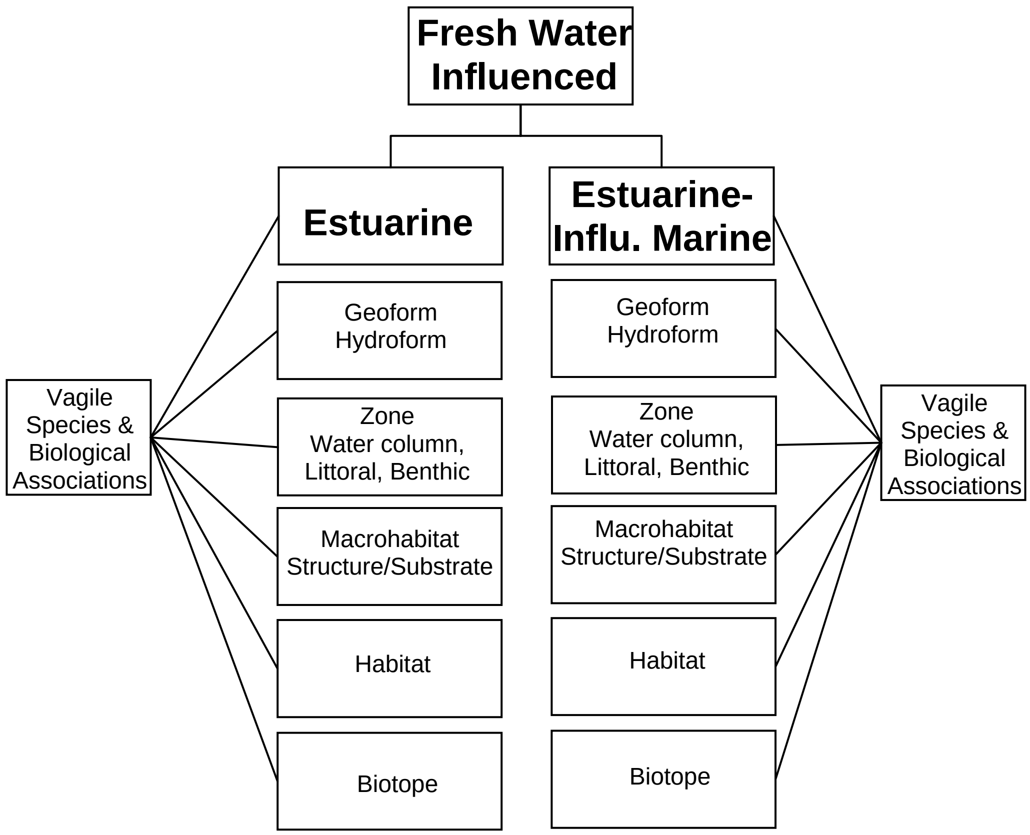
The finest lowest level of the classification is the biotope. A biotope is environmentally uniform in structure, environment, and biota. The biotope is a habitat in association with a dominant set of persistent species. The primary characteristic of the biotope is the relationship between the physical habitat and a strongly associated or fixed "high fidelity" plant and animal species. The biotope then refers to a specific area of a habitat that includes recurring, predictable biological associations, which are plants along with attached sessile and unattached but relatively non-motile fauna and bacterial colonies. "Fixed" is defined as an individual organism that cannot move beyond the frame of reference of the habitat boundary within 1 day. Epibenthic organisms like anemones, sponges, hydroids, and benthic infauna such as polychaetes would be considered part of a biotope complex.

While much of the sedentary or fixed biota defines a particular biotope, other organisms demonstrate less fidelity to any specific biotope. More vagile organisms can be associated with multiple biotopes or interact with the physical structure of the environment at any number of classification levels and spatial scales. Larger animals, such as blue whales, may interact with elements defined in the classification at a level of geoform features, such as the shelf break or submarine canyon. Smaller animals interact with macrohabitats, habitats or biotopes (Figure 13)

Detailed Description and Rationale

In general, physical characteristics determine the habitat unit, while biology plus habitat determine the biotope unit. The biotope concept has been employed for several years in Europe and is defined as the "physical habitat… and its community of animals and plants (Costello; 2003)." This refers to the dominant biological inhabitant(s) of a specific habitat, whether the species are

Figure 13. Relationship of Vagile Species to the Hierarchy at Multiple Scales.



"diagnostic," as in the terminology of Cowardin (1979) and Dethier (1990), or if they are "commonly associated." A species is considered to be part of a biotope if it is conspicuous, dominant, and physically linked to the habitat. The concept and nomenclature for the biotope follow the BioMar system (Costello, 2003; Connor, 1997), which has been integrated into the EUNIS classification for European habitats (Davies and Moss 1999) and into this classification, although some of the terminology has been changed here.

Vegetation units such as aquatic beds of algal and rooted plants, salt marsh meadows and other ephemeral vegetation are recognized at the biotope level. These biota are recognized as being associated with a particular habitat, rather than defining the habitat. This is an important departure from several widely used classifications such as Cowardin (1979), Ferren et al. (1996) and Madley et al. (2002) but follows the same logic as the Dethier (1990) and the Costello (2003) classifications. Figures 14 a-e illustrate the entire hierarchy for each of the five systems and include examples of habitat units and biotopes that are defined within each.

Figure 14a. Classification Hierarchy: Estuarine

L1	Ecological Region	**Biogeography- Regions 1-24 of North American and U.S. Waters**		
L2	Regime	**Fresh Water-Influenced**		
L3	System	**Estuarine** **(from supratidal with no maximum depth; semi-enclosed margins of continents or large islands with connection to sea and land; has freshwater input for part of the year)**		
L4	Geoform Hydroform	Up/Downwelling, River, Current System, Wave Zone, Ice, Open Water, Island, Embayment, Lagoon, Delta, Wetland, Channel, Bank, Open Coast, Reef, Seabed		
L5	Zone	**Water Column** Upper Water Column Lower Water Column	**Littoral** Littoral Supratidal Littoral Intertidal	**Bottom** Subtidal Epibenthic Subtidal Subbenthic
L6	Macrohabitat examples	River Current, Stratified Layer, Groundwater Seep, Turbidity Maximum, Benthic Boundary Layer, Wave Zone, Eddy	Rocky Shore, Flat, Beach, Creek, Flooded soil, Bottomland, Slough, Oyster Reef, Tidal Channel, Dune Overwash, Small Island	Softbottom, Hardbottom, Sandbottom, Oyster Reef, Unconsol. Sediments, Bar, Bank, Moraine, Lava Field, Mud Slump, Bench, Wall, Ledge, Sink, Midden
L7	Habitat examples	Estuarine Mesohaline Upper Water Column	Mudflat, Tidal Creek, Tide Pool, Intertidal Salt Marsh	Tidal Channel Scour Hole
L8	Biotope examples	Bay Anchovy *(Anchoa mitchilli)*	Saltmarsh cordgrass *(Spartina alterniflora)*	Rockfish *(Morone saxatilis)*

Figure 14b. Classification Hierarchy: Estuarine-Influenced

L1	Ecological Region	**Biogeography- Regions 1-24 of North American and U.S. Waters**		
L2	Regime	**Fresh Water-Influenced**		
L3	System	**Estuarine-Influenced** **(from supratidal with no maximum depth, adjacent to continent or large islands; unenclosed area with connection to sea and land; has some freshwater input)**		
L4	Geoform Hydroform	Upwelling, Downwelling, River, Current System, Wave Zone, Ice, Open Water, Island, Embayment, Lagoon, Wetland, Channel, Bank, Open Coast, Reef, Seabed		
L5	Zone	**Water Column** Upper Water Column Lower Water Column	**Littoral** Littoral Supratidal Littoral Intertidal	**Bottom** Subtidal Epibenthic Subtidal Subbenthic
L6	Macrohabitat examples	**Surf Zone, Eddy, Sea Surface, River Current, Stratified Layer, Groundwater Seep, Turbidity Maximum, Anoxic Zone, Benthic Boundary Layer**	**Rocky Shore, Flat, Beach, Creek, Flooded soil, Bottomland, Slough, Oyster Reef, Tidal Channel, Dune Overwash, Small Island**	**Softbottom, Hardbottom, Sandbottom, Mollusk Reef, Unconsol. Sediments, Bar, Bank, Moraine, Lava Field, Mud Slump, Bench, Wall, Ledge, Sink**
L7	Habitat examples	**Turbid Upper Water Column**	**Barrier Backisland Exposed Sandflat**	**Softbottom Mud-Sand Seabed**
L8	Biotope examples	**Redfish *(Sciaenops ocellatus)***	**Plovers, Pacific sand crab *(Emerita analoga)***	**Adult White Shrimp (*Penaeus setiferus)***

Figure 14c. Classification Hierarchy: Nearshore Marine

L1	Ecological Region	**Biogeography- Regions 1-24 of North American and U.S. Waters**		
L2	Regime	**Marine**		
L3	System	**Nearshore Marine (supratidal to 30 m depth adjacent to continent or large islands with no apparent freshwater input)**		
L4	Geoform Hydroform	Upwelling, Downwelling, Current System, Wave Zone, Ice, Open Water, Island, Embayment, Wetland, Channel, Open Coast, Bank, Reef, Seabed		
L5	Zone	**Water Column** Upper Water Column Lower Water Column	**Littoral** Littoral Supratidal Littoral Intertidal	**Bottom** Subtidal Epibenthic Subtidal Subbenthic
L6	Macrohabitat examples	Surf Zone, Eddy Tidal Current Stratified Layer, Groundwater Seep, Turbidity Maximum, Benthic Boundary Layer	Rocky Shore, Flat, Beach, Tidal Channel, Tidepool, Flooded soil, Bottomland Slough Island Outcrop, Dune Overwash, Tidal Channel	Soft Bottom Hard Bottom Sand Bottom Reef Unconsol. Sediments Bar, Bank Moraine, Lava Field, Mud Slump, Bench, Wall, Ledge, Sink, Pinnacle
L7	Habitat examples	Upper Water Column	Shore- Foreshore, Backbeach, Ridge, Swale, Flat- Mudflat Surface, Sandy Beach	Reef- Forereef, Back Reef, Spur and Groove, Fragments, Reef Rubble, Softbottom Sandwaves
L8	Biotope examples	Drift Algae, Floating Sargassum, Phytoplankton bloom, Copepod *(Acartia tonsa)*	Macoma clam sp.	Flatfishes, Winter flounder *(Pleuronectes americanus)*

Figure 14d. Classification Hierarchy: Marine Neritic

L1	Ecological Region	Biogeography- Regions 1-24 of North American and U.S. Waters		
L2	Regime	Marine		
L3	System	Neritic (from 30 m depth to the shelf break at approx. 200 m depth, or to 200 m depth contour around islands)		
L4	Geoform Hydroform	Ring, Up/Downwelling, Current, Ice, Open Water, Wave Zone	Neritic Island, Embayment, Wetland, Channel, Open Coast	Reef, Canyon, Mound, Trench, Bank Plain, Rise, Ridge, Seabed
L5	Zone	**Water Column** Upper Water Column Lower Water Column	**Island Littoral** Littoral Supratidal Littoral Intertidal	**Bottom** Subtidal Epibenthic Subtidal Subbenthic
L6	Macrohabitat examples	Tidal Current, Benthic Boundary Layer, Surf Zone, Eddy	Rocky Shore, Flat, Beach, Flooded Soil, Bottomland, Slough, Island Outcrop, Dune	Softbottom, Hardbottom, Sandbottom, Coral Reef, Unconsol. Sediments, Hydrothermal vent, Subduction Seep Bar, Bank, Moraine, Lava Field, Mud Slump, Bench, Wall, Ledge, Sink, Pinnacle
L7	Habitat examples	Floating Sargassum Mat	Basalt Rocky Shore	Soft Bottom Foramaniforan Ooze Seabed
L8	Biotope examples	Juvenile Loggerhead seaturtle *(Caretta caretta)*	Kelp Forest (*Macrocystis pyrifera*)	Ghost crab *(Chaceon fenneri)*

Figure 14e. Classification Hierarchy: Oceanic

L1	Ecological Region	Biogeography- Regions 1-24 of North American and U.S. Waters		
L2	Regime	Marine		
L3	System	Oceanic (beyond the shelf break or > approx. 200 m depth, or > 200 m depth around islands)		
L4	Geoform Hydroform	Gyre, Ring, Up/Downwelling, Ice, Open Water, Wave Zone	Atoll, Oceanic Island, Embayment, Wetland, Channel, Open Coast	Reef, Bank, Canyon, Seamount, Trench, Plain, Guyot, Slope, Rise, Ridge, Seabed
L5	Zone	**Water Column** Epipelagic (0-200 m) Mesopelagic (200-1000 m) Bathylpelagic (1000-4000 m) Abyssalpelagic (4000-7000 m) Hadalpelagic (> 7000 m)	**Island Littoral** Littoral Supratidal Littoral Intertidal	**Bottom** Upper Slope (< 200 m) Continental Rise (200-1000 m) Bathyl (1000-4000 m) Abyssal (4000-7000 m) Hadal (> 7000 m)
L6	Macrohabitat examples	Turbidity Plug Flow, Mixed Layer	Rocky Shore, Flat, Beach, Creek, Pool Flooded soil Bottomland Slough	Softbottom, Hardbottom, Sandbottom, Deep Coral Reef, Unconsol. Sediments, Hydrothermal Vent, Subduction Seep Bar, Bank Moraine, Lava Field, Mud Slump, Bench, Wall, Ledge, Sink, Pinnacle
L7	Habitat examples	Upper Water Layer Density Front	Oceanic Atoll Interior Lagoon Patch Reef	Sulfurous Hydrothermal Vent
L8	Biotope examples	Yellowfin tuna *(Thunnus albacares)*	Lionfish *(Pterois volitans)*	Vesicomyid clams *(Calyptogena soyoae)*

Modifiers to the Classification Units

Modifiers are descriptors or metrics outside of the formal hierarchy that provide additional information about a particular classification unit and can be applied at any level of the classification. Modifiers provide additional information that refines the description of a type, and provides further scientific insight to the functioning of the ecosystem and the environmental conditions that make a habitat favorable or unfavorable for an organism. Classes of modifiers include substrate type, water mass characteristics, physical attributes, and biological attributes.

Modifiers are sometimes integral to the definition of a unit and required for classification of a specific habitat type. In other cases, the habitat can be adequately defined without specifying modifiers. The characteristics of a classification unit will determine whether it is appropriate to apply specific modifiers. For example, a large-scale geoform is appropriately characterized by water mass characteristics of salinity, temperature, and photic zone. The spatial scale of a bar-built estuary, on the other hand, is often sufficiently large that it would represent multiple salinity or temperature regimes. In this example it would be appropriate to apply the salinity and temperature modifiers to one of the macrohabitats within the bar-built estuary geoform, where the modifiers are descriptive of differences between classification units.

Modifiers usually will be applied at the habitat and biotope levels. At the habitat level, substrate modifiers are generally required to define the habitat unit. At the biotope level, modifiers that describe the spatial distribution, patchiness or density of vegetation or colonizing fauna are important distinguishing features. A comprehensive list of modifiers, their definitions and usage is provided in Appendix 2.

Future Development and Refinement of the Classification

The CMECS is currently a classification framework and list of types at an early stage of maturity. It will evolve into a fully populated classification with lists of fully described units at each level as it becomes more broadly used and information is integrated into the framework. The scientific basis for the classification is outlined here, the population and full codification of the classification units will occur as the framework is tested and applied. The process for updating and populating the classification is discussed below.

Classification Development

Types of Updates

The long-term process for inputting new information into to the classification will result from wide application by the management and conservation community (see Appendix 4). This will lead to population and refinement of the classification system. Along with each application; the data, metadata, user analysis and comments will be available for evaluation, refinement and updating of the classification. Updates to the classification will be of four kinds:

> *Retesting and refinement* of existing classification units will be performed on an ongoing basis as information is submitted from pilot applications.
>
> *New classification units* that are encountered in field applications will be classified with the assistance of the end-user. If appropriate, new units will be added to the type catalog.
>
> *Changes to the hierarchy* will be considered on an ongoing basis to improve the usability of the classification. Alterations or expansions will be addressed based on input from the user community and on continuing testing and evaluation of the hierarchy.
>
> *New rules, methods and modifiers* will be evaluated as the classification is applied and tested and as new technologies are developed.

Data should be stored and served from a central database. An official updated version of the classification, along with a means to provide user feedback and to download information and updates, should become available to all interested end-users. Data, metadata, reporting requirements, data inputs and updates will be presented via the internet (http://www.csc.noaa.gov/benthichab/documents.htm), and the information will be publicly available.

Crosswalks

The coastal/marine ecological classification was developed with three critical goals in mind:

- Form an umbrella framework that permits comprehensive integration of existing and new local, regional and continental scale classification systems for coasts and oceans.
- Develop a capability for cross-comparison of coastal and ocean habitats throughout the North American continent.
- Provide a process for gathering new data that will support the classification of coastal/marine systems.

Numerous existing classifications currently in wide use have been crosswalked to the CMECS framework. In Appendix 5, this report examines several important frameworks that are commonly applied and that were used in the development of the national classification. They include:

1. Cowardin et al. (1979)
2. Dethier (1992)
3. Greene et al. (1999)
4. Allee et al. (2000)
5. Madley et al. (2002)
6. BCMEC (Zacharias et al. 1998, Zacharias and Roff 2000)
7. Costello (2003)

These well-used classification systems represent different types of ecological systems and habitats across different continent and oceans. The discussion of each of these classifications in Appendix 5 indicates where elements of these classifications, or entire existing classifications, fit within the CMECS framework, highlighting the commonalities and differences among them and the convergence of concepts and definitions. This discussion underscores a primary reason that the national classification has been developed; the need to integrate multiple frameworks into a single unifying classification. Such a tool can be used to accommodate each user group's individual goals and needs, while using a common language to allow integration and comparison across different systems.

The development of the finest levels of the national classification will entail an ongoing process. The habitat and biotope levels will be populated through implementation of pilot projects and with data on eco-types, habitats and species assemblages. Subsequent updates will provide additional unit definitions and a translation table that, to the extent possible, will facilitate the direct transfer of data from other classifications to the national classification standard.

Pilot Applications

As a part of the process of developing and testing the emerging classification, pilot projects will be undertaken to assess the function of the classification hierarchy, units and typology. Existing datasets of disparate types or entirely new projects can be used to evaluate a range of habitat units and physical environments and to test data models of the new framework. There are three types of applications for use of the classification in coastal and marine environments:

Type 1 applications are those that apply the classification to existing work, both classifications and data sets, using crosswalk and translation tables. This will require the creation of a method for converting existing classification schemes and units into the new scheme and units.

Type 2 applications are those where the new classification, its rules, methodology and units are used from the beginning of the project to classify an area. Rules of the classification will be applied in all phases of the project, including project design, determination of the geographic area, scales applied, gear and methods, data collection, data reporting and analysis and interpretation.

Type 3 applications are hybrids of Type 1 and Type 2 applications, to be used in areas that transcend boundaries of existing studies and data, requiring both translation and new application of the classification. The new methodologies will be applied to the new sections, scales, levels and units to be classified, and crosswalk and translation tables will be used in carrying existing data into the classification.

A process will be required for distributing and receiving information and data that will populate the database and refine the classification framework. The details of this process will be implemented as a follow-on project to the development of this classification. The first step of any pilot project will be an evaluation of the appropriateness of the project for use with the classification. It will be determined if the project will be a *Type 1, 2 or 3* application, and parameters will be established for the collecting and reporting of data. An analysis will be done on the results of the pilot study. This includes the results of the study, analysis of where the classification succeeds and where it fails, absorption of new types into the database and the generation of their definitions, incorporation of new structure to the framework, incorporation of all metadata, and a procedure for disseminating the newly updated classification. Much of the transfer of this information will be web-based, and the classification and central database of types will be accessible via the internet. Two *Type 1* pilot studies have been completed for a shallow lagoon estuary in Florida Bay and Neritic bottom habitat in the South Atlantic Bight with a recent version of CMECS and results were used to refine the hierarchy. The project reports are included as Appendix 6, and summarized here:

Testing the Classification Standard with Pilot Projects

As a first test of the emerging classification, two pilot projects were undertaken to assess the function of the classification hierarchy and typology. Existing datasets of disparate types were chosen in order to evaluate a range of habitat units and physical environments and to test two different data models within the new framework. The pilots selected were of the Florida Keys benthic survey (Haddad et al. 2000; Madley et al. 2002) and the SEAMAP project of the South Atlantic Bight (Seamap 2001).

Both pilots were effective in several aspects of the classification to varying degrees with pros and cons. The pilot testing process was an effective means of finding gaps in the hierarchy, determining the level of detail of the data appropriate to this framework, and indicating directions for improvement in the hierarchy.

One outcome of the application of the classification in the Florida Keys pilot is the recognition that because habitat information is acquired from a distance or via remote imagery, elements of the data required for full classification can be lacking. Bottom habitats, substrate types and geoform features may be obscured by overlying vegetation or fauna (the biotope community), making it difficult to ascertain the some of the essential components of the habitat. Some water mass characteristics (energy, photic regime, oxygen) and hydroform features (currents) are particularly difficult to discern remotely. This is not always the case, but often is, and such characteristics as dissolved oxygen and nutrient load are not quantifiable from remote technologies. Often, even routinely measurable characteristics such as temperature and chlorophyll are not measurable at depth in the water column, and multiple water column layers are not resolvable. Thus, a map showing classified data developed from remotely sensed images will often be valid for only very shallow systems and display a mix of water column parameters, habitat layers and the overlying biotope- depending on what is visible to the imaging system. This highlights the need for ground sampling of the substrate and possibly other variables in order to completely classify to the lowest and most critical levels of the hierarchy. Even then, multiple layers and the underlying substrate are often difficult to evaluate and quantify completely.

Working through the upper levels of the hierarchy was revealing as well, because the pilot exercise indicated how much information about those levels is available from the data, the metadata or by inference. In the case of Florida, Level 1 is known by the location of the study area. Level two, system, is evident from the range of depths involved: nearshore marine, and estuarine are covered by this pilot. Because bathymetry is not included in the data presented, it can only be inferred from the nature of the study in a nearshore shallow water reef and grassbed habitat, that the neritic system of depth greater than 30 m was not included. Characterization at Level 4, Geoforms, is easily accomplished since this level deals with large geographic features such as reef, embayment and open water that are apparent from the graphics provided in the report, although hydrographic features such as major currents are not knowable from the data. Aspects of Level 5, the vertical zone, are evident from the data: the benthic regime and the littoral regime are being mapped by definition and are included. We can assume that all the vertical depths covered by the study, being measured by remote aerial photography, are photic. The water column zone is also within the domain of the study, although it is not clear from the data that any water column properties or habitats were measured or characterized.

Formerly in the hierarchy a middle level was occupied by the “energy level” and was the first level in this pilot where there clearly is not enough data available to assign classes. Knowledge of energy would require additional sampling from the ground. Based on these findings and findings of an expert workshop, the decision was made to convert energy to a modifier and remove Level 5. For Level 6, macrohabitat, the SEAMAP study provides data where certain elements corresponding to geomorphology are mapped and others are not due to the limitations of the methodologies used in sampling. Units of geomorphic structure such as hardbottom, softbottom, reef can be detected by the camera and are classed in both the original and pilot studies. No element of small scale hydromorphic structure such as currents or upwellings can be detected nor were mapped in the original study. Furthermore, many modifiers and finer scale structures for Level 6, such as substrate type, relief or grain size were not detectable by the photography.

Finally, the habitat and biotope levels (7 and 8) were largely detectable and classifiable using the remote sensing and ground truthing tools applied in the original study. Sufficient data were provided to develop a comprehensive habitat list for the translated pilot study. Information about some of the biotope communities was also available in a general way from ground observations provided, although these were only mentioned categorically and not mapped explicitly.

In summary, the simple and rapid assessment tool of remotely sensed images, with ground truthing was able to provide much, but not all, of the information required by the classification to characterize the habitat and biotope to a level that would be extremely useful in conservation management. In the specific case of the Florida Keys seagrass biotopes, information about the underlying substrate that would be especially useful in making resource management decisions to conserve seagrass habitat, was lacking. Additional work is required to completely record and map the relationships between habitat/biotope and species/species complexes associated with the habitat, and the classification lays a strong foundation for this activity.

Delimiting areas of unique and endangered habitat, biodiversity hotspots, and developing maps that demonstrate key relationships between habitat elements, such as the interaction between seagrass and substrate between soft corals and bottom type, can be accomplished with the information provided in the pilot classification. With additional in situ measurements, complete characterization of the environment to the biotope and sub-biotope levels would be possible.

The data gathered for SEAMAP were of a very different type and were much more spatially extensive than for the Florida pilot. However, the SEAMAP data were focused more narrowly on the determination of hardbottom areas, so less information was available concerning fine-scale structure of the bottom, water quality parameters and biological associations. SEAMAP data included no remotely sensed images. Most of the study area was at great depth, which rendered remote sensing inapplicable. Furthermore, depths often precluded direct observation and ground truthing of the in most of the area. Limited in this way by the tools at hand, the final presentation of the data provided only a narrow look at the distribution of hardbottom without regard to form or structure. Nonetheless, the information provided in the data and metadata afforded an opportunity to classify the region at a much greater degree than intended or attempted by the SEAMAP working group.

As with the Florida Keys pilot, the information presented in the SEAMAP report was tested by insertion in the upper levels of the national classification to the extent possible.

At Level 1 the study area encompasses the Carolinian, Gulf Stream and Floridian-Bahamian biogeographic regions. At Level 3, the area includes the Estuarine, Nearshore Marine, and Neritic Systems. Level 4 large geographic features were within the range and scale of the SEAMAP methodology, but mapping them was not within the scope of the project and features were not identified in the data. Insufficient continuous data were gathered by SONAR or video to directly characterize large geographic features on the bottom, such as seamounts, etc. According to SEAMAP protocols, trawl transects longer than 1 hr were not used due to the bias introduced by long trawls into fisheries data, so by definition larger geographic features were often not recorded. However, from existing maps and knowledge of the exact positions of the SEAMAP transects, it is possible and would be a relatively simple matter to superimpose major geographic features in the sampled areas, as well as hydrographic features such as the Gulf Stream current, from existing maps and known data.

The vertical zone, Level 5 is known, since the project is a benthic mapping enterprise, and the littoral and benthic zones were directly mapped. As in the Florida study, the water column was a component of the area sampled, but no direct parameters of the water column (currents, temperature, transparency) were measured as part of this project. It can be assumed that both photic and aphotic bottom were measured in the course of the transects, but no data were provided that indicated which zones were where, or which habitat features or biota were detected within each classification zone. The energy regime was not measured in the study and information for this Type 1 pilot was not available for assessment. Energy was formerly a level in the hierachy, but one important outcome of these pilots and other work was the decision to remove energy as a level from the hierarchy and introduce it as a modifier. There are apparently very few measurements of energy in studies or existing datasets of this type that would be useful to the classification and the parameter itself is so variable in space and in time, that it was deemed more appropriate as a modifier than a hard level of the hierarchy.

The level on which the original data of the SEAMAP study was almost exclusively focused was geomorphic structure, would be Level 6 in the national classification. The parts of the study conducted by side-scan SONAR, uniboom, video and observation gathered data that enabled classification of the bottom geomorphology. The position of these habitats could not be determined because position information was not included with the SEAMAP data. The SEAMAP classification is extremely coarse and did not discriminate these geomorphic features, calling all of them "Hardbottom." But the original data that was provided with the SEAMAP report and the ancillary classification of Ross et al. (1987) enabled a benthic habitat classification of bottom geomorphology using a subset of the data.

The types in the Ross et al. study corresponded to types in the national classification and were nearly identical to (but fewer in number than) several of the sea-floor types developed by Greene et al. (1999), the source material for Level 6 of the national classification. This pilot exercise emphasizes that habitat can occur at different levels of the hierarchy at different scales, depending on the biota being considered. The "habitats" in this pilot were in level 6 and 7, rather than the "biotope" level 8, and included very little additional modifier data. Yet, the data and metadata were sufficient to enable characterization of the area within the hierarchy of the national coastal/marine classification, yielding useful value-added information about the habitat. Although incomplete, the data presented classes are sufficient for characterizing bottom to a degree that is useful to managers seeking to relate hardbottom habitat to living resources and to make decisions about how to manage and conserve these important areas.

Field Sampling Methodology

An important subsequent step to this classification framework is the development of a detailed field sampling methodology that describes the standards for inventory and classification. Definition of the scale, measurements, appropriate technologies, gear, sampling schedules and variables appropriate for the study should be addressed. Only through application of standard methods can consistent classifications and maps be developed across the coasts and oceans of North America. The CMECS will be made widely available so that interested users may make us of and contribute to the classification. Partnerships will be fostered between developers of the classification and end-users to encourage distribution and application.

Conclusion

The CMECS initiative represents an ambitious effort to develop a new, comprehensive ecological classification for coastal/marine environments. This process has been borne through the synthesis of information from end-users, classification experts and existing classifications to create a new and overarching framework. The resulting classification system provides the template and the process for standardized inventory, classification, mapping and assessment activities – and contributes to a growing catalog of classification units. An increasingly rich database will provide insight into habitat form and function, and the relationships between coastal/marine biodiversity and these habitats. The classification will support the improved ecosystem-based management of our coasts and oceans.

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Appendix 1: Description Of Units

Level 1 Ecological Region

(Scale: 100 km^2 to > 1,000 km^2)

The level 1 ecological regions are large areas, both nearshore and oceanic, that have in common a relatively distinct climate, physical structure or biota. The extent and characteristics of the regions are similar to those of the Large Marine Ecosystems (Sherman and Alexander 1986, Sherman 1991) but the boundaries differ due to the focus on habitat for all types of flora and fauna, and to the focus on coastal areas. The descriptions are summarized here and fully detailed in a Commission Environmental Cooperation report (Wilkinson, et al. in press).

Table 5. The Ecological Regions of Coastal North America.

Region	Ecoregion Name
Region 1	Bering Sea
Region 2	Beaufort/Chukchi Seas
Region 3	Arctic Basin
Region 4	Central Arctic Archipelago
Region 5	Hudson/Boothian Arctic
Region 6	Baffin/Labrador Arctic
Region 7	Acadian Atlantic
Region 8	Virginian Atlantic
Region 9	Northern Gulf Stream Transition
Region 10	Gulf Stream
Region 11	Carolinian Atlantic
Region 12	South Florida/Bahamian
Region 13	Northern Gulf of Mexico
Region 14	Southern Gulf of Mexico
Region 15	Caribbean Sea Region
Region 16	Middle American Pacific
Region 17	Mexican Pacific Transition
Region 18	Gulf of California
Region 19	Southern Californian Pacific
Region 20	Montereyan Pacific Transition
Region 21	Columbian Pacific
Region 22	Alaskan Fjordland Pacific
Region 23	Aleutian Archipelago
Region 24	Hawaiian Archipelago

1. Bering Sea

The Bering Sea is the world's third largest semi-enclosed water body, bounded by the Bering Straight in the north and the arc of the Aleutian Island chain in the south. It is divided in half by physiography, with a broad shelf to the east, and much deeper oceanic plains to the west. Noted in particular for its wide coastal shelf and high productivity, the Bering Sea is of special conservation importance to marine mammals, and fisheries, and is a unique sub-polar ecosystem.

2. Beaufort/Chukchi Seas
The Beaufort and Chukchi Seas border the Arctic Ocean and is shared by the U.S., Canada, and Russia. It is bounded by the Bering Straight in the southwest, permanent sea ice of the Arctic Basin (Region 3), and follows the Arctic coastal shelf along the north shore of Alaska and Canada's Yukon and Northwest Territories to Amundsen Gulf. This sparsely populated region, particularly well known for its coastal oil and gas activities, is also home to 40 species of fish and significant concentrations of marine mammals like the beluga whale, polar bear and ringed seal.

3. Arctic Basin
The Arctic Basin region is essentially the core northern parts of the Arctic Ocean that remain under permanent ice cover. This region encompasses the northwesterly most part of the Canadian Arctic and the central core of the Arctic Archipelago, north of the Boothia Peninsula. The two sub-divisions share climatic characteristics such as ice cover. The Arctic Basin is a large, deep depression that reaches 3,600 meters in depth, with no coasts. The Arctic Archipelago is composed of waters mostly 200 to 500 meters deep, and includes thousands of islands with jagged coastlines making it one of the biggest archipelagos in the world with one of the longest coastlines.

4. Central Arctic Archipelago
The Central Arctic Archipelago includes thousands of islands with jagged coastlines making it one of the biggest archipelagos in the world and one of the longest coastlines. This region's very cold sea water and northern latitude, as well as the little influence warmer southern waters have on the realm, make for its relatively constant cover of ice sheets and ice pack. The boundary of the region is a complicated border that winds around a series of Arctic islands. Its northwestern-most border includes Prince Regent and Peel Sounds (Canada). The region is composed of waters mostly 200 to 500 meters deep, and includes most of the Arctic Islands east of the Arctic Basin Region, such as Ellesmere Island, the Queen Elizabeth Islands and the northeastern part of Victoria Island.

5. Hudson/Boothian Arctic
The primary characteristic of the Hudson Boothian Arctic region is its Arctic water mass with seasonal ice regimes. The Hudson Bay tidal flats and inland marsh areas harbor some of the world's largest concentrations of breeding, molting and migrating shorebirds and waterfowl. Aside from Hudson Bay, vast and open seascapes are rare in much of this region. It is generally comprised of a patchwork of interconnecting bays, fjords, channels, straits, sounds, basins, shoals, sills and gulfs.

6. Baffin/Labradoran Arctic
The Baffin/Labradoran Arctic region forms a transition between the cold northern waters and the more temperate southern waters of the Northwest Atlantic. Sea ice is common throughout much of the region, depending on the season and latitude. Ice begins to form off the coast of Labrador in November or December. By February or March, ice regularly reaches the northeast coast of Newfoundland, accompanied by thousands of icebergs.

7. Acadian Atlantic

The Acadian Atlantic Region extends along the eastern North American continent from Cape Hattaras northward around the Scotian Shelf and Newfoundland, then northwestward into Baffin Bay. The region crosses climate zones from temperate to sub-Arctic to Arctic, hugging the east coast as far north as Newfoundland, then separated from the Canadian coast by the Baffin/Labradoran Arctic coastal region **(**Region 6). On its seaward boundary, this region borders the offshore zone that is influenced by the Gulf Stream. The area encompasses a coastline formed by and heavily influenced by glacial processes, resulting in complex geomorphologies, rocky coastal zones and resistant bedrock formations. Numerous coastal watersheds deliver fresh water to important estuaries, and the region supports key ecological assemblages and commercially important fisheries.

8. Virginian Atlantic

The Virginian Atlantic region supports key ecological assemblages and commercially important fisheries with ranges that extend northward to Canada. Chesapeake Bay, the largest estuary in the United States, lies within this region. The region is also home to a historically enormous oyster fishery that has dwindled in recent years due to pollution, overfishing and disease. The region extends along the eastern North American continent from Cape Hattaras northward to Cape Cod. The region lies within the temperate climatalogical zone, and is interposed between the east coast and the Northern Gulf Stream Transition Region offshore (Region 9).

9. Northern Gulf Stream Transition

The Northern Gulf Stream Transition region is an area of the Western North Atlantic offshore of the Acadian Atlantic and the Virginian Atlantic regions. The waters of the Northern Gulf Stream Transition Region consist of open ocean and do not border any continental land mass. The region is influenced by the Gulf Stream current to the east and south, the coastal waters of northeastern North America to the west, and the Labrador Current to the north and west. Region 9 extends from offshore of the tip of Cape Hatteras in North Carolina northward to offshore of Labrador and is completely marine in character. The area overlays several important bathymetric features of the northwestern Atlantic including the Canyon Lands.

10. Gulf Stream

The Gulf Stream region is defined by and dominated by the Gulf Stream current. The region starts at the Straits of Florida (USA) at its southern extreme, and continues northward and seaward of the coastal Atlantic Bight following the Gulf Stream current to the Outer Banks of North Carolina (USA) and Cape Hatteras (USA), where the region terminates as the current veers northeastward (out of the area of study).

11. Carolinian Atlantic

The Carolinian Atlantic region extends from the southern Atlantic coast of Florida, where the continental shelf and the Gulf Stream diverge from the coast, north to the Outer Banks and Cape Hatteras. The region is defined by a broad shelf, which extends up to 150 km from the coast at Georgia, and by several coastal plain watersheds that terminate at the coastal margin. The region extends to the edge of the Continental Shelf at the Florida- Hatteras Slope, also the nominal western boundary of the Gulf Stream.

12. South Florida/Bahamian Region

The South Florida/Bahamian Region is a small region with generally clear waters, coral reef formations, and carbonate substrate—generally tropical in its ecological character. Climate, substrate and biota are influenced primarily by the Gulf Stream and the warm waters the current carries adjacent to and through the region. The region includes coastal waters off southern Florida, the Florida Keys, Florida Bay, The Florida Keys Reef Tract, Biscayne Bay, and the nearshore region where the Continental Shelf break and the Gulf Stream most closely approach (five kilometers) the coast.

13. Northern Gulf of Mexico Region

The Gulf of Mexico is a semi-enclosed sea encompassing about 630,000 square miles. The Northern Gulf of Mexico region extends from Gullivan Bay on the west coast of Florida to Rio Panucho in the state of Tamaulipas in northern Mexico, a coastline of about 30,000 km. Most of the oceanic input to the Gulf is from the Caribbean Sea through the Yucatan Channel, forming the Loop Current, which winds north then east through the Gulf, outflowing through the Straits of Florida. A broad Continental Shelf covers about a third of the entire Gulf. Mangroves, salt marshes and beds of submersed aquatic vegetation (SAV) dominate the coastal floral communities. The Gulf of Mexico contains over 60% of the tidal marshes of the U.S.

14. Southern Gulf of Mexico

The Southern Gulf of Mexico region includes the southern tropical portion of the Gulf, a semi-enclosed sea basin with tropical currents and high nutrient load. Waters off the states of Veracruz, Tabasco, Campeche and Yucatan, Mexico are included in this region.

15. Caribbean Sea

The Caribbean Sea is a semi-enclosed tropical sea formed by the arc of the Greater and Lesser Antilles and the Atlantic coasts of Venezuela and Colombia, Central America and the Yucatan Peninsula. Waters off the States of Quintana Roo, Mexico, and U.S. waters around the Commonwealth of Puerto Rico, the Territory of the U.S. Virgin Islands (USVI), and Navassa Island are included in this region.

16. Middle American Pacific Region

The Middle American Pacific region—largely free of the southernmost winter influence of the California current and therefore described as a year-round tropical sea—supports important fisheries such as yellowfin and skip jack tuna, as well as shrimp. Although relatively small, the region has bathymetry that is quite complex and diverse, including a narrow continental shelf, a continental slope, part of the Mesoamerican Trench, part of the Guatemala Basin, and the Tehuantepec Ridge. Waters off the Mexican states of Oaxaca and Chiapas are included in this region.

17. Mexican Pacific Transition

The Mexican Pacific Transition region is basically a tropical sea that is seasonally affected by the southernmost winter influence of the California Current. The Mexican Pacific Transition is a fairly complex, with a narrow shelf that drops off steeply to great ocean depths close to the coast. It is incised by several canyons and the Mesoamerican Trench that drops to depths between 4000 and 5,000 meters. In addition, the region is dotted by numerous submarine hills and mountains, and includes a rift system and volcanic cones that have emerged from the depths of the ocean. The region also has a great diversity of coastal systems and subsequently high species diversity. Waters off the states of Jalisco, Colima, Michoacán, Guerrero and Oaxaca and Mexico are included in this region.

18. Gulf of California Region

The Gulf of California is a semi-enclosed sea with tropical characteristics during summer and temperate through winter. The region is known for its exceptionally high rates of biodiversity and primary productivity, due to a combination of its topography, southern latitude and upwelling systems. Waters off the states of Nayarit, Sinaloa, Sonora, Baja California and Baja California Sur, Mexico, are included in the region. The southern border is generally considered to stretch from Cabo Corrientes (Jalisco) on the mainland to the tip of the Baja California Península.

19. Southern Californian Pacific

The Southern Californian Pacific region stretches along the Pacific Coast from the Southern tip of Mexico's Baja California at Cabo San Lucas north to Point Conception, California in the United States. It is influenced by the north-south flow of the California Current, local upwelling, and the California Countercurrent, and extension of the Equatorial Countercurrent bringing warmer subtropical waters.

20. Montereyan Pacific Transition Region

The Montereyan Pacific Transition stretches along the central California coast from Point Conception to Cape Mendocino. The region has moderately high productivity associated with the seasonal upwellings that occurs along its coasts. The Montereyan Pacific Transition includes a series of submarine canyons and seamounts, including one of the largest canyons on the Pacific coast of North America. It's proximity to shore attracts deep-water species of whales, dolphins and seabirds to the coastal areas of the region.

21. Columbian Pacific

The Columbian Pacific region stretches along the Pacific coast from Cape Mendocino in the South, northward to include the Straight of Juan de Fuca and end at northern tip of Vancouver Island, in the North. The region is home to abundant plant and wildlife, but also has one of the fastest growing human populations in North America.

22. Alaskan Fjordland Pacific

The Alaskan Fjordland Pacific region is home to abundant plant and wildlife and includes the complex, crenelated fjord coastline along western Canada. The region is shared by Canada and the United States and extends from Cape Cook on Vancouver Island north through the Gulf of Alaska and out to the end of the Aleutian Island chain (the latter shared with the Bering Sea Region).

23. Aleutian Archipelago

The Aleutian Archipelago Region contains the longest archipelago in the world as well as the Aleutian Trench 3700 km long and 7,680 meters deep. High-velocity currents move through straits and passes that connect the temperate North Pacific Ocean in the Alaskan Fjordland Pacific region to the subpolar Bering Sea. Along the Archipelago the greatest flow is northward from the lower latitude Pacific Ocean toward the Arctic Ocean. The region is considered a transition zone between the polar seas of the Bering and the Arctic and the temperate waters of the mid-latitude, northern Pacific Ocean.

24. Hawaiian Archipelago

The Hawaiian Archipelago region follows the Hawaiian archipelago, which stretches 2450 km from the Big Island of Hawaii northwest to Kure Atoll. It is composed of 8 main volcanic oceanic islands, 124 smaller islands, atolls, banks, and numerous seamounts. It is among the most isolated island systems in the world. The region also includes Johnston Atoll 800 km southwest of Hawaii.

Additional ecological regions not mapped but that include U.S. possessions:

25. Central Pacific

The Central Pacific region lies in the central insular area of the Pacific consisting of small coral islands and atolls from the near the Equator to the north. The region includes islands and atolls within the U.S. EEZ (Exclusive Economic Zone) stretching from Wake Atoll (northernmost of the Marshall Island Archipelago) to Howland and Baker Islands (northwestern-most of the Phoenix Islands), west to Jarvis Island (Equatorial Line Islands), north to Palmyra Atoll and Kingman Reef (Northern Line Islands), and west-northwest to Wake Atoll.

26. Samoan Region

Southwest Pacific region includes the volcanic and corals islands of eastern half of the Samoan Archipelago within the EEZ of the U.S. encompassing American Samoa. This region stretching from Swains Island (south southwest of Hawaii), southeast to Rose Atoll, northwest to Tutuila Island, and north to Swains Island.

27. Mariana Region

The Northwest Pacific region includes all the volcanic and raised limestone islands and submerged banks of the Mariana Archipelago to the limits of the EEZ of the U.S. and stretches from Guam Island north to Farallon de Pajaros.

Level 2 Regime

Scale: 10 km^2 to > 1000 km^2

Fresh Water Influenced- those waters that receive fresh water input from land and whose salinity is reduced to <30 psu for at least one month during the year.

Marine- those waters that receive no significant fresh water input from land and are substantially at full oceanic salinity (>30 psu) throughout the year.

Level 3 System

Scale: 1 km^2 to > 1000 km^2

Systems in the Fresh Water Influenced Regime

Estuarine system- enclosed or semi-enclosed coastal areas that receive fresh water input during at least part of the year and possess a horizontal salinity gradient. Also, shallow coastal waters that may not be significantly enclosed but are dominated by fresh water input from land during part of the year, effectively creating a definable estuary. Estuarine systems are those in which the mean salinity of the upper water layer is reduced to 30 psu or below during at least one month of the year. *(see also estuarine ecological systems)*

Estuarine-Influenced system- unenclosed areas that are influenced by outflow from an estuary during at least part of the year. These waters generally lie adjacent to estuaries and receive mesohaline waters from the estuary proper, although they have weaker estuarine characteristics. These waters may be in the form of a river plume or fresh water slug that extends far from the estuarine source. In general, estuarine-influenced systems are not in contact with the coastal landform, while estuarine systems are.

Systems in the Marine Regime

Nearshore Marine system- those waters in the region between the coastal land margin and the 30 m depth contour and where the salinity is substantially marine, i.e. >30 psu throughout the year.

Neritic system- those waters between the 30 m depth contour and the continental shelf break, nominally at about 200 m depth, and where the salinity is substantially marine, i.e.>30 psu throughout the year. Although relatively farther from land than coastal systems, these regions can receive significant runoff influence from land and the water column is in close contact with the bottom relative to oceanic systems.

Oceanic system- those waters of the 'open ocean,' in areas beyond the shelf break in depths generally greater than 200 m, extending to the maximum ocean depths. These waters are removed from primary continental influences, and the sea bottom interacts little or not at all with the water column.

Note: At Level 4 and below in the hierarchy, the units are listed without definitions because the units repeat in many sections and definitions would be space-consuming and repetitive. Definitions for all units are found in the glossary.

Level 4 Geoform/Hydroform Units

Scale: 10,000 m^2 to 100 km^2

Geoform and hydroform units are broad classes of complex physical features that contain many smaller components including macrohabitats and habitats. Certain geoforms occur at different scales, and may be listed as units at more than one level in the hierarchy.

Geoforms in Estuarine, Estuarine-Influenced and Nearshore Marine Systems

Island *(see also island ecological systems)*
Atoll *(see also atoll ecological systems)*
Reef *(see also reef ecological systems)*
Wetland *(see also wetland ecological systems)*
Lagoon *(see also lagoon ecological systems)*
Embayment
Marine lake
Large banked channel
Headland
Delta
Dune system
Marine terrace
Peninsula
Chenier
Submerged bank
Shoal
Large submerged channel
Open coast
Seabed

Hydroforms in Estuarine, Estuarine-Influenced and Nearshore Marine Systems

River *(see also river ecological systems)*
River plume
Fresh water lens
Seep
Open water
Current system *(see also current ecological systems)*
Front
Ice *(see also ice ecological systems)*
Benthic boundary layer
Sea surface

Geoforms in Neritic systems

In the neritic system, several benthic features in addition to many in the shallower systems are important. Many units were directly adopted from the classification by Greene et al. (1999) from the level referred to as megahabitat features:

Deepwater reef
Submarine canyon
Mound
Trench
Plain

Ridge
Bank
Deep shelf
Marine terrace
Deep slope
Subduction zone
Island
Island arc
Seabed

Hydroforms in Neritic systems

The neritic water column is defined as waters from depths of 30 m to the shelf break (~200 m). In the water column, hydrographic features are identifiable water circulations, discontinuities or barriers that affect biological processes by containing, dispersing, transporting them, or concentrating food and spawning individuals. Hydrographic features in the neritic water column include:

Warm core ring
Cold core ring
Upwelling
Downwelling
Current system
Mesoscale eddy
Open water
Stratified layer
Frontal boundary
Plunging current
Sea surface
Benthic boundary layer

Geoforms in Oceanic systems

Within the neritic and oceanic systems, several additional benthic features are important. The units from the classification by Greene et al. (1999) were directly adapted from the level referred to in the source material as megahabitat features. In littoral zones, geomorphic features are part of islands or reefs. In these systems, large geographic features occur on the sea bottom or on islands and reefs. Those forms associated with the bottom are:

Island
Reef
Submarine canyon
Mound
Trench
Seamount
Plain
Guyot
Rise
Ridge

Bank
Marine Terrace
Deep Shelf
Deep Slope

Hydroforms in Oceanic systems
The oceanic water column is defined as waters from depths greater than about 200 m, or beyond the shelf break. In the water column, hydrographic features are identifiable water circulations, discontinuities and barriers that affect biological processes by containing, dispersing, transporting, or by concentrating food and spawning individuals. Hydrographic features in the oceanic water column are:

Current system
Mesoscale eddy
Open water
Stratified layer
Mixed Layer
Frontal boundary
Plunging current
Benthic boundary layer
Sea surface
Cold core ring
Warm core ring
Surface currents
Convergence
Divergence
Current system
Density current
Upwelling
Downwelling
Eddy
Gyre
Open water

Level 5 Zone
100 m^2 to 10,000 km^2

The major zones of all systems are:
Littoral
Water Column
Bottom

Within the littoral zone for all systems, the water column and underlying benthic substrate are considered together to form an integrated habitat unit. Waters at the littoral margins are sufficiently shallow that they can be considered part of the same benthic or littoral habitat that they overlay. At a certain point in the seaward depth gradient, the water depth becomes deep enough that the water column and bottom become separate environments, although both are strongly influenced by each other. At the point where waters are deeper than the low low water, below the intertidal zone, the bottom is permanently covered by water and the systems divide into water column and bottom zones. This holds true in all littoral zones for all systems.

Subzones are recognized as vertical divisions within each zone. In all of the estuarine and marine systems, the subzones of the littoral zone are based on the relationship of the tide to the land margin:

Supratidal- above higher high tide, the zone influenced by sea spray and other marine processes that impact the land
Intertidal- within the zone influenced by the tide, between higher high tide and lower low tide.

In the estuarine, estuarine-influenced, nearshore marine and neritic systems, the two subzones of the water column are characterized by their vertical position relative to a pycnocline density discontinuity, if present. The pycnocline is a region of rapid density change with vertical position, caused usually by temperature (thermocline) or salinity (halocline) stratification. The subzones are the upper water layer and the lower water layer vertically bracketing the pycnocline. If there is no stratification, the entire water column is considered to be the upper water layer.

For the oceanic system, subclasses of the water column are defined only by depth of the water. Subclasses for vertical divisions in the water column are defined by depth, following the work of Holthus and Maragos (1995) and distinguished as:

Sea Surface 0 m
Epipelagic (0-200 m)
Mesopelagic (200-1000 m)
Bathylpelagic (1000-4000 m)
Abyssalpelagic (4000-7000 m)
Hadalpelagic (>7000 m)

Subzones of the oceanic bottom are:

Upper slope (0-200 m)
Continental Rise (200-1000 m)
Bathyl (1000-4000 m)
Abyssal plain (4000-7000 m)
Hadal (>7000 m)

Level 6 Macrohabitat

100 m^2 to several 1000 m^2

Macrohabitats are large physical entities that consist of multiple smaller habitat units and are centers for several types and communities of organisms.

In estuarine and nearshore marine systems, macrohabitats include:

Rocky shore
Sandy shore
Flat
Sand beach
Flooded soil
Slough
Mollusk reef
Worm reef
Coral reef
Mangrove swamp

In benthic zones of neritic and oceanic systems, the macrohabitats (following Holthus and Maragos, 1995 and Greene 1999) are:

Softbottom
Hardbottom
Sand bottom
Unconsolidated sediments
Bank
Bar
Moraine
Lava field
Mud slump
Marine bench
Wall
Ledge
Sink
Pinnacle
Mollusk reef
Worm reef
Coral reef

Macrohabitats are also created by persistent oceanographic features. In all systems, macrohabitats include the following elements:

Surf zone
Sea surface
Current
Eddy
Stratified layer
Cold seep

In the estuarine system, macrohabitats additionally include the turbidity maximum and in the oceanic system the geothermal vent.

In neritic and oceanic systems, macrohabitats are defined following Holthus and Maragos, (1995) and Greene et al. (1999):

Softbottom

Hardbottom
Sand bottom
Beach
High island
Low island
Reef
Atoll
Dune
Bank
Bar
Moraine
Lava field
Mud slump
Bench
Wall
Ledge
Sink
Pinnacle

Level 7 Habitat

1 m^2 to 100 m^2

The units proliferate exponentially at the habitat level due to their number and to their occurrence in multiple branches of the hierarchy. Habitats are created by specific local geoforms and hydroforms, as well as by combinations of substrates and modifiers. The more modifiers that can be applied, the more specifically the habitat can be defined. For example the substrate "gravel" and the local geological formation "beach" combine to form the habitat "gravel beach." Therefore, the habitat unit list becomes a sequence of permutations of a basic set of building blocks that include substrate, energy, local morphology and so forth. Below are listed examples of the more prominent habitats as identified in a variety of classifications. Many more examples of habitats and some of their associated biotopes are listed in Appendix 2.

Hardbottom
Oyster reef
Coral head
Coral reef
Low coral island
Patch reef
Barrier reef
Fringing reef
Linear reef
Bar barrier reef
Spur and groove
Sand channel
Submerged bank
Sand Ripples

Sand Waves
Reef slope
Bedrock shore
Dune
Foredune
Backdune
Dune crest
Rocky shore
Emergent wetland
Sand flat
Mud flat
Sand beach
Gravel beach
Cobble
Creek
Pool
Flooded soil
Ice
Unconsolidated soft bottom
Tidal creek
Tidepool
Wetland
Cave
Hole
Overhang
Channel
Bench
Wall
Ledge
Pinnacle
Trench
Submarine canyon
Piling
Artificial reef
Riprap
Tidal fresh water marsh
Saltwater marsh

Level 8 Biotope

1 m^2 to 100 m^2

Biotope examples for selected habitats are provided in the accompanying classification spreadsheet in Appendix 7.

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Appendix 2: Modifiers

The habitat level is the most locally focused and the development of a large catalog of habitat types is emerging as the classification is applied in ecosystems and environments of the coastal U.S. and around the world. Several reef, wetland and aquatic bed habitats are illustrated in tests of the classification in Volume 2 of this document.

Water Mass Physicochemical Modifiers

Suites of modifiers can more fully characterize the water mass associated with an ecological unit. The water mass type can be represented by salinity, depth, oxygen, temperature and turbidity. These are dynamic water quality parameters, characteristically variable in marine and estuarine waters on both temporal and spatial scales. As modifiers, these qualities are represented as an average type, summarized by a single descriptive name, which captures the broad range of variation experienced by the biota in these locations on an annual basis. In practice repeated sampling will add definition to the true character of these parameters and provide valuable information on the variability of the system, which can be critical to describing the impact of the physical environment on biology. The appropriate scale for use of these modifiers is wide-ranging. They are applicable in areas where low variability of these fluid characteristics render them meaningful. In the open ocean, which is homogeneous over large spatial scales, these are applicable at the highest levels of the classification. Bottom water anoxia, for example, covers thousands of km^2 in the Gulf of Mexico, and typing of this water mass can be done at Level 3 and 4 of the classification with a high degree of significance. In highly dynamic and variable estuaries water mass parameters are meaningful only on an averaged basis or on smaller spatial and temporal scales.

Salinity

Salinity regime is grouped into the classes in units of PSU (practical salinity units, similar to parts per thousand) following Cowardin (1979), Dethier (1990) and with ranges slightly modified from Howes (1994, 2002):

Salinity Class	Salinity Level
fresh	0 psu
oligohaline	>0-5 psu
mesohaline	5-18 psu
polyhaline	18-30 psu
euhaline	30-40 psu
marine	=35 psu
hyperhaline	>40 psu

As for all of the water characteristics presented here, the classes defined for the upper water mass are applicable to the underlying bottom layer as well, if applicable. An underlying benthic area subjected to overlying waters of a particular regime will be designated according to the category of the overlying water. For example, salinity of a benthic habitat will be classed as that of the overlying water's salinity. Particularly in the case of salinity, this will require measurement of bottom water characteristics, as the tendency of the coastal water column to stratify will often ensure that water mass characteristics at the surface are not the same as at the bottom.

Oxygen
Oxygen is critical to aerobic organisms and aerobic processes, such as chemical oxidation and microbial respiration. Lack of oxygen can cause motile organisms to swim or move away and can kill organisms that cannot move. The well-known "dead-zone" in the northern Gulf of Mexico bottom waters off of coastal Louisiana is an example of the result of low oxygen conditions on the ecosystem. Oxygen classes are difficult to fix because solubility of O_2 in water changes with temperature and salinity. However, the selected ranges represent a good average classification of most of the waters and conditions that will be encountered by application of this classification. The oxygen regime modifier is classified according to the following ranges:

Oxygen Class	Concentration
anoxic	0-2 mg/L
hypoxic	2-4 mg/L
oxic	4-10 mg/L
Saturated	10-12 mg/L
Supersaturated	>12 mg/L

Temperature
Classes for water mass temperature are established in this report as:

Temperature Class	Degrees
frozen	≤ 0° C with surface ice
superchilled	≤ 0° C without ice
cold	0-10° C
temperate	10-20° C
warm	20-30° C
hot	>30° C

The classification must encompass a large climatic range to cover the range of temperatures on the North American continent. Temperature class are established in intervals of 10°C, sufficient in both dynamic range and resolution to provide meaningful categories yet a parsimonious number of classes. Temperature categories are based on the BCMEC classification for Canada (Howes, 1994,2002; Zacharias et al., 1998), modified to add the higher temperature ranges experienced in the subtropics and tropics. The caveat that differential surface and bottom characteristics are axiomatic in the water column holds for temperature as well as salinity.

Turbidity
Turbidity is important for organisms that hunt for prey or escape using visual cues, and of course for photosynthetic organisms. Classes for the turbidity modifier have not previously been established in a coastal-marine classification system. The proposed classes for turbidity based on simple secchi depth readings are:

Turbidity Class	Secchi Depth Reading
0-1 m	extremely turbid
0-2 m	highly turbid
2-4 m	turbid
5-20 m	clear
>20 m	extremely clear

An important qualitative characteristic of turbidity is the provenance of the attenuating substance- whether the reduced water clarity is derived from chlorophyll pigments (i.e. phytoplankton blooms), from color due to dissolved substances in the water (gelbstoffe, tannin), from mineral imported terrigenous sediments or from carbonate particulates in resuspension. It is proposed that this qualitative assessment be classified in addition to a qualitative or quantitative evaluation of the degree of turbidity in the water column. The following qualitative classification of turbidity type and provenance should be applied to the degree best discernable in the field:

Turbidity type

chlorophyll- attenuation produced by chlorophyll a, b, c or d as constituents of live phytoplankton in the water column

mineral particulates- attenuation produced by suspended inorganic sediments derived from soil and rock weathering

carbonate particulates- attenuation produced by suspended precipitated $CaCO_3$ in the water column, generally creating an opaque "milky" appearance

colloidal precipitates- dispersed particulates which precipitate out of the dispersion medium (water) to form aggregations such as marine snow

dissolved color- substances dissolved in water that have color and absorb light within a specific wavelength band depending on the color

detritus- attenuation due to larger organic detritus particles in suspension

mixed- attenuation due to a variety of the above sources and substances

Turbidity provenance

autochthonous (e.g.bloom)- generated in situ by biogenic processes

allochthonous- originating outside of the system and transported into the system

resuspended- deposited materials that are mixed into the water column by currents (e.g. bottom sediments)

precipitated- solutes such as $CaCO_3$ that precipitate out of solution

terrigenous origin- materials, water or energy in a water body in land drainage

marine origin- materials, water or energy originating in the ocean

Physical Modifiers

Energy

Modifiers are used to describe the energy regime of the macrohabitat unit. CMECS follows a simplification of the concept introduced by Dethier (1990), and as employed in several subsequent classifications (Holthus and Maragos 1995, Howes 1994,2002, Schoch 1999, Allee et al. 2000). The work of Schoch (1999) provides the basis for a detailed near-shore classification of energy intensity and type on land-sea margins. This classification utilizes a very simple energy related to the force of water movement, whether tidal, wave or current. This force is an important sieve that determines the kinds of animals and flora that can maintain attachment or position in a particular habitat. Energy level also determines the substrate type by suspending, transporting and sorting fractions of substrate particulates of smaller grain size. A winnowing of, or absence of, fine sediments characterizes high current and wave energy areas. Finally, energy can shape the bed form (sand waves, sand ripples) and erode or accrete geoforms. Highly impacted areas are typified by the presence of erosive features, such as beach scarps or bare rock substrates.

The energy modifier applies to all three zones in the classification (littoral, water column and bottom). Within the littoral and subtidal benthic zones the energy acts on shaping the geoforms. Within the water column, the energy is related to current speeds (in knots), wave intensity and tidal motions. The concept is modified from Dethier (1990) and Zacharias et al. (1998) as follows:

Energy	Intensity
no/low energy	no or only very weak currents (<2 kn) or wave action (gentle swell)
moderate energy	wind waves or moderate tidal currents (2-4 kn)
high energy	strong currents (>4 kn), oceanic swell, breaking waves

The terminology of "degree of exposure" common in many other classifications is not used in the CMECS in favor of the more accurate term "energy." Exposure is a subjective term that includes qualification of both the direction of the feature relative to hydrodynamic energetics and the energy of the system at a given point in time. An exposed and open coast may in fact be very quiescent depending on the season or direction facing. "Energy," along with a quantitative scale, is a more accurate indicator of the actual force with which a particular coastal or marine feature is impacted.

Tide Range

Tide Class	Range
micro	<0.25 m
small	0.25- 1 m
moderate	1-5 m
large	>5 m

Depth

Dethier (1990) introduced depth as a modifier in nearshore systems. This has been modified with an additional "very shallow" class as follows:

Depth Class	Range
very shallow	0-5 m
shallow	5-15 m
deep	>15 m

Photic Regime

Photic regime is also a highly variable parameter. In many nearshore cases, light penetrates deeply, and the photic zone extends to the bottom of the water column; in others, almost the entire water column is dark. All systems are aphotic for at least part of every day, during nighttime. Degree of exposure of a particular place to light depends on the depth, sun angle, time of year etc. Moreover, the depth of the shift from photic to aphotic occurs at different points in the water column, depending on the ecosystem, watershed, the amount of turbidity in the water, etc. The important functional distinction of the photic regime is between the part of the water column within which plants can photosynthesize and animals can feed and defend visually, and where they cannot.

Vertical subclasses are relative to the penetration of light: photic and aphotic, for both water column and benthic zones:

photic zone- that region of the water column that is lighted, i.e. ambient light is > 2% of surface light. This is ecologically significant because it is considered the photosynthetic compensation point, where respiration equals autotophic production

aphotic zone- that part of the water column below the compensation depth that receives less than 2% of the surface light, and where plants cannot achieve positive photosynthetic production

Photic	Daylight Illumination
aphotic	Constantly dark
seasonally aphotic	Seasonally receives light
photic	Always receives light

Spatial Modifiers

A set of modifiers is established to fully describe the configuration of spatial elements that form a habitat unit or other classification unit. These modifiers indicate such characteristics as the degree of complexity of the unit and the relationship of elements within the unit, such as one being included within another, or two elements of equal scale that interact. These modifiers provide information that may be useful in determining functionally why a particular habitat unit is of importance and how it provides an ecological service to the associated biota.

primary element- the dominant physical structure within a habitat unit

pure occurrence- an element that entirely comprises a single habitat unit

complex unit- two or more interacting elements that form a single habitat unit (eg. tidal creek in a salt marsh is a salt marsh tidal creek, a complex unit)
dominant- in a complex habitat unit, if one of the elements within a unit is spatially dominant, that unit is identified as the dominant element of the mixture, and further qualified by the secondary element(s)
matrix- if a habitat element that lies within an undifferentiated substrate (e.g. cobble in a sand matrix)
inclusion- a small element embedded within a spatially dominant type
variable- units that change significantly through time in one or more attributes (e.g. a sand spit with highly variable morphology)
highly structured- have a high degree of physical complexity and heterogeneity (e.g. a coral reef)
moderately structured- have a high degree of physical complexity but are generally homogeneous (e.g. a mangrove prop root zone)
unstructured- exhibit a low degree of physical complexity and are homogeneous (e.g. a soft sand bottom)

Geomorphologic Modifiers

In littoral and bottom zones, in all systems, the set of modifiers used to further describe structure is: **profile, slope, relief, substrate, size**.

Profile refers to the elevation of the feature relative to surrounding level of the water or bed:

Profile	Relative Height
none	0
low	0-2 m
medium	2-5 m
high	>5 m

Slope refers to the angle of the substrate; Greene's (1999) geological classification is followed here to characterize slope as:

Slope	Vertical Angle
flat	0-5°
sloping	5-30°
steeply sloping	30-45°
vertical	45-90°
overhang	>90°

Relief is a qualitative variable that refers to the texture or roughness of the geomorphic structure. The quality is somewhat scale dependent because the method of perception, the resolution and the spatial scale will bear on the apparent relief. However, in practice, the roughness will be most applicable at the lowest levels of the hierarchy where it will impact the behavior of individual organisms- the macrohabitat, habitat and biotope. Therefore, the definitions of relief are set to the spatial context of a 1-1000 m^2:

smooth- no perceptible texture
irregular- perceptible texture or feature that is heterogeneous and non-regular in either frequency, direction or amplitude
variable- perceptible texture or feature that is regular in either frequency pattern but irregular in direction and/or amplitude
rippled- closely spaced, regular, repeating vertical variations in height of a sandy or muddy bottom with a very short wavelength (cm)
waves- regular, repeating vertical variations in height of a sandy or muddy bottom with an intermediate wavelength (<1m)
undulating- regular, repeating vertical variations in height of a sandy or muddy bottom with a long wavelength (>5 m)

The surface **type** describes the material of which the substrate is composed, based on its grain size:

Substrate	Grain Size
mud	<0.07 mm
sand	0.07-2 mm
gravel	2-4 mm
pebble	4-74 mm
cobble	74-257 mm
boulder	>257 mm

The composition of the substrate is defined as follows:
peat- organic material laid down and consolidated into sediment
clay- fine mineral particulates of kaolin with high cohesiveness
silt- very fine mud particles laid down after water transport and deposition
carbonate muds- fine particulates of calcium carbonate with high cohesiveness
carbonate rock- sedimented or biogenically deposited carbonates which have undergone diagenetic transformation into rock
limestone- generic class of calcium carbonate rock
organic material- dead plant and animal tissue that partially decomposes to form sediments
pavement- hard rock substrate that is flat and low profile
shell hash- substrate that is substantially composed of small bits of broken shell remnants
igneous- rock that is volcanic in origin
metamorphic- rock that is formed from several distinct rock types that are fused through great pressure and temperature
sedimentary- rock that is formed from gradual deposition of sediments, dewatering and diagenesis
ooze- decomposed tests of sedimented microscopic organisms deposited on the bottom. Types of oozes include globagarina, diatomaceous and foraminifora
mix- combination of two or more substrate types

Biological Modifiers

Trophic Status

Trophic status is a general categorization of the abundance of dissolved macronutrients (DIN and DIP) and level of primary productivity of a unit. In broad terms, the trophic status gives an indication of the health of the system via the balance of production and consumption and is measured by chlorophyll concentration in water columns and by total biomass in macroalgal and rooted vascular plant communities. For water column phytoplankton communities, the modifier classes are:

Trophic Status	Chlorophyll Level
oligotrophic	< 5 μg/L chlorophyll a
mesotrophic	5-50 μg/L chlorophyll a
eutrophic	> 50 μg/L chlorophyll a

The classes were derived, with modification, from the NOAA Estuarine Eutrophication Survey (NOAA 1997). For macrovegetation in littoral zones, emergent in wetlands and in benthic zones, the modifier classes are:

Trophic Status	Biomass
oligotrophic	<50 mg dry wt/m^2
mesotrophic	50-1000 mg dry wt/m^2
eutrophic	>1000 mg dry wt/m^2

Cover Type

For vegetation and faunal distribution within a particular habitat the following cover type modifiers are available:

vegetated- a habitat or biotope unit that is characterized by a cover of rooted or attached vegetation
colonized- a habitat or biotope unit that is characterized by a growth, colonization or encrustation of a specific fauna or faunal community
mixed- a unit that is significantly covered by vegetation and colonies of animals
bare- a substrate that is unvegetated and uncolonized*.
grazed- vegetation cover that exhibits obvious consumption by herbivores
hole- within a vegetation bed, a discrete section of vegetation that is devoid of cover
scour- area that is eroded by water action

***** methodology will determine threshold for unvegetated and for uncolonized

Cover Class

The degree of cover for each cover type can be assessed with the following cover classes:

bare- operationally 0% cover
sparse cover- a cover of < 10%
moderately sparse cover- cover of 10- 25%
moderate cover- a cover of 25-75 %

moderately dense cover- a cover of 75%-90%
complete cover- a cover of 90-100%
patchy cover- a distribution of vegetation that is non-heterogeneous resulting in large spatial variation in density of cover.

Anthropogenic Modifiers

impounded- areas that are cut off from natural hydrological flow by building or placing barriers such as levees or dams, either to retain water or to prevent inundation
polluted- waters or substrates that receive nutrient, sewage, heavy metal or pesticide inputs from anthropogenic sources that are significantly above natural loading levels or abundances (e.g. EPA standards or local total maximum daily loads-TMDLs)
dredged- bottom that is mechanically dredged specifically for mining sediments or other materials (e.g. shell), for deepening or widening channels (e.g. for navigation or alteration to hydrology), or for other bathymetric modification.
developed- coastal or marine areas that are modified and on or in which artifical structures are constructed (e.g. residences, drilling platforms).
deposited- materials such as sand or shell that are placed on or in an area of coast or a water body.
artificial reef- large. solid, persistent constructions placed on the sea bottom specifically for colonization by reef-dwelling biota.

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Appendix 3: Glossary

Abiotic A non-living (physical or chemical) component of the environment.
Abyssal Deep bottom area or portion of submerged earthform between 4000-7000 m.
Abyssal plain The ocean floor offshore from the continental margin, usually very flat with a slight slope.
Abyssal zone The bottom from a depth of approximately 4,000 m to 7,000 m.
Abyssalpelagic zone The pelagic environment from a depth of 4,000 m to 7,000 m.
Aeolian Pertaining to the erosion, transport, and deposition of material by wind.
Ahermatypic coral A coral that does not build reefs.
Algal ridge Asymmetric wave-resistant ridge of a crustose coralline algae; a ridge of coralline algae that is found on the outer edge of some coral reefs.
Algal turf A dense growth of often filamentous algae.
Allochthonous Refers to something formed elswhere than its present location. Antonym of autochthonous.
Alluvial fan A fan-shaped deposit of sand, mud, etc. formed by a stream where its velocity has slowed, such as at the mouth of a ravine or at the foot of a mountain.
Anchialine Modifier of coastal lagoon/lake/pond coastline and reef islets; marine or brackish water bodies that lack surface connection to the sea, usually located near the coast in permeable substrates and which by the presence of salt and tidal fluctuations show subsurface hydrologic connections to the sea.
Andesite Igneous volcanic rock, less mafic than basalt, but more mafic than dacite; rough volcanic equivalent of diorite.
Anoxic The condition of oxygen deficiency or absence of oxygen. Anoxic sediments and anoxic bottom waters are commonly produced where there is a deficiency of oxygen due to very high organic productivity and a lack of oxygen replenishment to the water or sediment, as in the case of stagnation or stratification of the water body.
Anticline A fold of rock layers that is convex upwards. Antonym of syncline.
Aphotic Light level modifier of the deep epipelagic ocean ecosystem, and turbid regions of all other waters; areas never reached by natural light.
Archipelago A group of islands; an expanse of water with scattered islands.
Atoll Earthform consisting of a ring-like perimeter reef area often with reef islet, enclosing a lagoon area.
Autochthonous Refers to something formed in its present location. Antonym of allochthonous.
Back reef The inner part of a barrier reef or atoll.
Baffling A reduction in the energy of flowing water (typically caused by plant material), such that sediment particles may settle from suspension.
Bank Submerged earthform with a crest at a depth of 20-200 m in oceanic waters and of 0-5 m in nearshore and neritic waters.
Bar and spit Low accumulations of sand or sediments forming intertidal or subtidal extensions of reef islets.
Bar-built estuary An estuary that is formed when a barrier island or sand bar separates a section of the coast where fresh water enters.
Barrier island A sedimentary island, generally elongate and low, that is built by longshore transport or wave action parallel to the coast.

Barrier reef A reef growing offshore from a land mass and separated from the shoreline, often by a lagoon or estuary.

Basalt Highly mafic igneous volcanic rock, typically fine-grained and dark in color; rough volcanic equivalent of gabbro.

Basement rock The oldest rocks in a given area; a complex of metamorphic and igneous rocks that underlies the sedimentary deposits. Usually Precambrian or Paleozoic in age.

Basin Any large depression in which sediments are deposited.

Bathyl Deep bottom aras between depths of 200- 4000 m.

Bathyl zone The sea bottom between a depth of 1000 m and approximately 4,000 m.

Bathylpelagic zone The pelagic environment from a depth of 1,000 m to 4,000 m.

Bathymetry Pertaining to the depth and relief of water basins.

Bathypelagic Intermediate layer of the ocean between depths of 1000 and 4000 m between mesopelagic above and abyssopelagic below.

Beach A sloped sediment shoreline composed of sand, gravel, cobble, mud, boulder sized sediments, sometimes with beach rock.

Bedload Sedimentary material subject to transport by flowing water (e.g. currents) which is moved by rolling, pushing, and saltation. The size of particles moved is proportional to the strength of water movement.

Bedrock The general term referring to the rock underlying other unconsolidated material, i.e. soil.

Benthic Defining a habitat or organism found on the sea bottom; demersal.

Benthic microalgae Microscopic plants, which inhabit the sediment surface (or substrate) including diatoms and dinoflagellates.

Benthic Of or pertaining to the bottom of a water body.

Benthic Pertaining to the seafloor (or bottom) of a river, coastal waterway, or ocean.

Benthos Organisms that live on or in the sea bottom.

Bight Wide bay formed by a curve in a shoreline.

Bioclastic Sediments made up of broken fragments of organic skeletal material, e.g. shells.

Biodiversity The number of species in an area or biological collection.

Biogenous sediment The type of sediment that is made up of the skeletons an shells of marine organisms.

Biogeography The distribution of one or more species that is defined by abiotic factors (temperature, salinity, surface currents, etc.).

Biomass The weight of a population of fish, the spawning adult portion of that population, or the weight of several populations.

Biota The living components of the environment.

Biotic Pertaining to a living component of the environment

Bioturbation The disturbance of sediment by organisms, e.g. burrows, trails, or complete mixing.

Bioturbators Organisms, mainly worms or crustaceans, that disturb the sediment by burrowing or during feeding. Their activities mix the sediment layers and may cause substantial sediment resuspension.

Bloom A sudden increase in the abundance of an alga or phytoplankton resulting in a contiguous mass of highly concentrated phytoplankton in the water column.

Boundary current Large-scale water stream in the upper ocean separates water masses; is driven by a combination of wind temperature, geostrophic or coriolis effects.

Calcareous ooze A type of biogenous sediment that is made of the calcium carbonate shells and skeletons of marine organisms.

Calcareous Composed of calcium carbonate.
Canyon See submarine canyon.
Carbonate A mineral composed mainly of calcium (Ca) and carbonate (CO_3) ions, may also include magnesium (Mg), iron (Fe) and others; rock or sediments derived from debris of organic materials composed mainly of calcium and carbonate (e.g., shells, corals, etc.) or from the inorganic precipitation of calcium (and other ions) and carbonate from solution (seawater). For example, limestone or dolomite.
Carbonate bank A narrow (10s of meters), fairly flat, shallow, submarine plateau of carbonate rock, more common from the middle-late Paleozoic to the present, e.g., the Bahama Banks.
Carbonate geology Rocks made from calcium carbonate or limestone. This rock is usually formed from marine sediments and coastal shallow water process in tropical areas.
Carbonate platform A broad (100s of meters), flat, shallow submarine expanse of carbonate rock, more common in the early-middle Paleozoic.
Catchment The area of land which collects and transfers rainwater into a waterway.
Central rift valley A depression in the mid-ocean ridge.
Channel elongate depression bordered by raised semi-parallel banks that constrain directionally flowing water; the banks can be above the water's surface or completely submerged.
Clay A weathered form of aluminosilicate mineral particles, less than 0.002 mm in diameter.
Coarse sediment A sediment comprising coarse-grained material such as sand or gravel particles.
Coastal biogeographic Provinces The distribution of marine species in shallow water along the coastlines of islands and continents as defined by abiotic factors (e.g. sea surface temperature, salinity and major ocean currents).
Coastal lagoon Coastal waterways in which waves are the principal factor that shapes the overall geomorphology. Characterized by a sandy barrier that can partially or totally constrict the entrance, backed by a mud basin, and typically have negligible river input.
Coastal morphology The form and configuration of the coast.
Coastal protuberance A prominence or bulging out of the coastline, typically formed from deltaic sediments.
Coastal waterway A body of water situated on or near the ocean coast, with some association with the ocean. Includes embayments, wave-and tide-dominated estuaries, wave- and tide-dominated deltas, coastal lagoons, and tidal creeks.
Community The populations that live and interact physically and temporally in the same area.
Conceptual Model A depiction or representation of the most current understanding of the major ecosystem features and processes (including biological, physical, chemical and geomorphic components) of a particular environment (e.g. estuaries).
Continental margin The edge of a continent; the zone between a continent and the deep-sea floor of the abyssal plain.
Continental rise Part of the **continental margin**; the ocean floor from the **continental slope** to the abyssal plain. The continental rise generally has a gentle slope and smooth topography.
Continental shelf The part of the continental margin from the coastal shore to the shelf break and continental slope; usually extending to a depth of about 200 meters and with a very slight slope, roughly 0.1 degrees; includes continental and oceanic sediments down to the ocean floor.
Continental slope Part of the **continental margin**; the ocean floor from the **continental shelf** to the **continental rise** or oceanic trench. Usually to a depth of about 200 meters. The continental slope typically has a relatively steep grade, from 3 to 6 degrees.

Convergence Zone The line where two oceanic water masses meet, resulting in the sinking of the denser one.
Coral knoll (pinnacle) A column of coral within the lagoon of an atoll.
Coral reef The massive deposition of calcium carbonate by coral polyps of colonial stony corals and other organisms producing large living hard structures. Coral reefs can range in size from a few feet to thousands of miles.
Coral rubble Coral fragments.
Coralline algae Green and red algae that deposit calcium carbonate in their thallus.
Crustacean Invertebrates including lobsters, crabs, shrimps, and barnacles; characteristically have a segmented body and exoskeleton, and paired, jointed limbs.
Current system Areas strongly influenced by large, unidirectional, organized, coherent flows of water in horizontal motion. These include freshwater inflows and tidal flows. Geostrophic flows are currents in the deep ocean that flow along lines of constant pressure or baroclinic surfaces. Wind-driven currents along the shore called longshore currents flow parallel to the land and play a role in sediment transport and structuring of the habitat. Current systems play an especially important role by governing productivity, providing transport for early life-history stages and adults, and flushing pollutants out to sea.
Current A horizontal movement of water.
Cut-Off Embayment Typically small basins within wave-dominated estuaries or wave-dominated deltas that have been bypassed by the principal fluvial current flow, and therefore have restricted exchange with the main body of the coastal waterway.
Deep Shelf and Terrace (Horizontal habitat located from ca. 40 m - 500 m) Insular habitats on or above the deep shelf consisting of horizontal or nearly horizontal natural topographical features interrupting a steeper slope and often occurring in a series. These habitats extend seaward from the shelf of an island or bank (depth range between 40 to 500 m).
Deep Slope (Vertical habitat located from ca. 40 m to 500 m) Insular habitats on or above the deep slope characterized by a steep (often vertical) slope extending seaward from the shelf of an island or bank (depth range between 40 to 500 m). These habitats may be colonized by some low-light coral and bryozoans.
Deep-sea fan A fan-like accumulation of sediment at the base of a submarine canyon.
Delta A low, nearly flat accumulation of sediment deposited at the mouth of a river or stream, commonly triangular or fan-shaped.
Demersal Fish that live on or near the ocean bottom. Also called benthic fish, groundfish, or bottom fish.
Deposit feeder An animal that feeds on organic matter that settles on the bottom.
Deposition Any accumulation of material, by mechanical settling from water or air, chemical precipitation, evaporation from solution, etc.
Detritus Dead organic matter and the decomposers that live on it; when broken up by decomposers, detritus provides energy to many coastal ecosystems.
Diagenesis All of the changes that occur to a fossil (or more generally any sediment) after initial burial; includes changes that result from chemical, physical as well as biological processes.
Diatomaceous ooze A biogenous sediment that consists mostly of the siliceous frustules of diatoms. It is known as diatomaceous earth when found inland.
DIN See dissolved inorganic nitrogen.
Dinoflagellates Unicellular, eukaryotic, mostly autotrophic organisms with two unequal flagella.

DIP See dissolved inorganic phosphorus.

Dissolved Inorganic Nitrogen (DIN) Nitrogen compounds, present post-filtration, that are detectable by accepted analytical chemical methods, e.g. nitrite, nitrate, and ammonium.

Dissolved Inorganic Phosphorus (DIP) Phosphorus compounds, present post-filtration, that are detectable by accepted analytical chemical methods, e.g. orthophosphate and pyrophosphate.

Downwelling Hydroform created by convergence of surface currents that causes surface waters to sink, creating vertical and horizontal displacement of water and possibly carrying organisms to lower depths.

Drowned river valley (or coastal plain) estuary An estuary formed by sea level rise; generally a bedrock valley which has been submerged and has not been significantly infilled by sediment. Also Embayment.

Ebb tide A falling tide - the phase of the tide between high water and the succeeding low water.

Ecosystem A community or communities of plant and animal species, as well as all of the abiotic component of the environment that influence those communities.

El Niño Southern Oscillation (ENSO) Irregular cyclical condition in which warm surface water moves into the eastern Pacific, collapsing upwelling and increasing surface water temperatures and precipitation along the west coast of North and South America.

Embayment Coastal water body that is partially enclosed or surrounded by a landmass but that has a significant open connection to the sea.

Endemism An organism or group of organisms restricted to a specific location.

Energy (hydraulic) Energy or intensity of water turbulence or movement, current speed.

Epifauna Benthic fauna living on the substrate but do not burrow into it (as on a hard seafloor) or on other organisms.

Erosion Mechanical breakdown of material (e.g. rock) due to chemical, physical or biological processes.

Escarpment A steep or vertical cliff, either above or below sea level.

Estuarine system Enclosed or semi-enclosed coastal areas that receive fresh water input during at least part of the year and possessing a horizontal salinity gradient. Also, shallow coastal waters that may not be significantly enclosed but are dominated by fresh water input from land during part of the year, effectively creating a definable estuary. Estuarine systems are those in which the mean salinity of the upper water layer is reduced to 30 psu or below during at least one month of the year.

Estuarine Pertaining to coastal areas where freshwater enters the ocean in coastal wetlands, bays, and lagoons and marine waters that are periodically influenced by the fresher outflows from estuaries; areas of variable salinity at the ocean margin.

Estuarine-Influenced system Unenclosed areas that are influenced by estuarine outflow during at least part of the year. These waters generally lie adjacent to estuaries and receive estuarine flows from the estuary proper, although have weaker estuarine characteristics. These waters are unenclosed and may be in the form of a river plume or fresh water slug that extends far from the estuarine source. In general, estuarine-influenced systems are not in contact with the coastal landform, while estuarine systems are.

Estuary A coastal ecological system that is partially enclosed, receives fresh water input from land and has a horizontal fresh-salt salinity gradient; the average salinity of estuarine waters is defined as being 30 psu for at least one month per year.

Euryhaline Organisms able to tolerate a wide range of salinity.

Eutrophication The process in which excess nutrients added to system lead to algal blooms, depletion of dissolved oxygen, and often, fish kills.

Exclusive Economic Zone (EEZ) A zone 200 nautical miles (370 km) wide along the coast where nations have exclusive rights to any resource. It was initiated by the United Nations Convention on the Law of the Sea (UNCLOS).

Exclusive Economic Zone (EEZ) Adjacent to state waters, which extend 3 miles out from the coast. The U.S. EEZ includes waters from 3 to 200 nautical miles from shore.

Facies Sum total of features that reflect the specific environmental conditions under which a given sediment was formed or deposited. The features may be lithologic, sedimentological, or faunal.

Fault A fracture, or large crack, in the Earth's crust where one side moves up/down/sideways relative to the other.

Fine sediment A sediment comprising fine-grained material such as mud or clay particles.

Fishery Management Council One of eight regional councils around the United States that are responsible for developing Fishery Management Plans in each region. Evolved out of the Magnuson-Stevens Fishery Conservation and Management Act of 1976.

Fishery The combination of fish and fishers in a region, the latter fishing for similar or the same species with similar or the same gear types.

Fjord An estuary with a seaward sill that is formed in a deep valley created by a retreating glacier.

Flood tide A rising tide - the phase of the tide between low water and the subsequent high tide.

Flushing Exchange of water between an estuary or coastal waterway and the ocean.

Fluvial Pertaining to a river or freshwater source.

Foraminiferan ooze A biogenous sediment that consists mostly of the calcareous shells of foraminiferans.

Fore reef The outer part of a barrier reef or atoll.

Fracture Submerged geoform consisting of a large-scale elongated crack in the deep ocean floor; a fault line or zone attributed to differential movements of the ocean crust.

Fresh water lens Trapped parcel of fresh water within waters of higher salinity; often in reference to the thin layer of fresh water riding atop marine waters in a river plume entering a marine environment.

Fresh Water Water typically derived from inland sources or rainfall, with less than 0.03% ionic content.

Fresh Water-Influenced All waters that receive fresh water input from land.

Fringing reef A coral reef that develops as a narrow band close to a shore.

Front The area at the juxtaposition of two or more different water masses. The front is the discontinuity at the interface between the water masses characterized by sharp horizontal changes in water mass characteristics such as temperature, salinity or nutrients. Fronts are found in the upper layers of the estuary.

Gastropods (class Gastropoda) Snails and other mollusks that typically possess a coiled dorsal shel1 and a ventral creeping foot.

Geomorphology/Geomorphic The study of the nature and history of landforms and the processes which create them.

Geothermal vent Submerged geoform consisting of a vent of hot, mineral rich water on the ocean floor, generally located on or near spreading oceanic ridges or on the continental margins of subduction trenches.

GIS An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.

Glass sponge Deep-water sponge with a skeleton of fused silica spicules.

Globigerina ooze The tests of dead protozoans of the genus Globigerina a protozoan belonging to the Order Foraminifera. The ooze covers some 36% of the world's ocean floor.

Gorgonian (order Gorgonacea) Colonial anthozoan that secretes a skeleton made of protein.

Gravel Grains with diameters between 2 and 4 mm.

Great Ocean Gyre A large, nearly circular system of wind driven surface currents that center around latitude 30° in both hemispheres.

Groundwater seep Flowing subsurface water into a coastal waterbody.

Guyot Submerged earthform at depths of >200m consisting of a flat-topped seamount with a cap of the carbonate remains of a drowned atoll.

Gyre Large cyclonic current that moves water in a circle pattern from the tropics to the polar seas.

Habitat Area of Particular Concern (HAPC) A habitat area designated by a Fishery Management Council under the Magnuson-Stevens Fishery Conservation and Management Act of 1976.

Habitat The physical environment in which an organism lives including the geographic place, the structure and substrate and all environmental variables influencing it.

Hadal Deepest deep bottom area or portion of submerged geoform at depths of >7000 m.

Hadal zone The sea bottom below 7,000 m.

Hadalpelagic Deepest layer of the ocean waters >7000 m deep below the abyssopelagioc layer.

Halophytic Salt-tolerant vegetation.

Headward The landward or upstream section of an estuary or coastal waterway

Hermatypic Reef building organisms or species.

High island geoform Forms an island with an elevation more than 10 m above high tide

Hoa Reef-top subtidal feature.

Hydrothermal vent A place on the seafloor, generally associated with spreading centers, where warm to super-hot, mineral-rich water is released; may support a diverse community of organisms.

Hypersaline Extremely salty, having much more salt than normal seawater (>35 psu).

Ice In the Arctic region including the northern coast of Alaska, these habitats are formed when freezing sea water forms into frazil crystals, thickens into sludge, and coagulates into sheet ice (ice formed into a smooth thin layer), pancake ice (ice formed into small plates), or ice floes (single pieces of ice ranging from 10 m to over 10 km) of various shapes and sizes. Generally, these habitats break out into two types (1) fast ice formed along coasts where it is attached to the shore and (2) free floating pack ice such as icebergs calved from glaciers.

ICOLL Intermittently Closed and Open Lakes and Lagoon, referring to coastal lagoons and some wave-dominated estuaries under low runoff conditions. Usually formed by a hydrological cycle that is strongly seasonal, that during the dry season allows sedimentation and closing of the mouth. During the wet season, high hydraulic pressure overcomes the barrier, temporarily opening the mouth.

Igneous rock Any rock solidified from molten or partly molten material.

Infauna Benthic fauna living in the substrate and especially in the soft seafloor.

Infratidal The zone just below the intertidal where the bottom is not exposed at low tide, but is influenced by tidal water motions and processes.

Interstitial fauna Animals living between sediment particles

Interstitial water The water contained between sediment particles.

Intertidal (littoral) zone The area on a seacoast between the highest and lowest tide.

Invertebrate animal without a backbone. In fishery-management terms, this refers to shellfish, including lobsters, clams, shrimps, oysters, crabs, and sea urchins.

Island arc A curved chain of islands that rise from the sea floor, usually near a continent. The convex side usually faces the open ocean, while the concave side usually faces the continent, e.g., the Aleutian Islands in Alaska; **volcanic arc**- syn.

Island Emergent land mass larger than 1 km^2 in area, completely surrounded by water. Aquatic habitats that are associated with land masses completely surrounded by water or elevated ridges extending from the seafloor covered with shallow water (banks) which may support unconsolidated sediments (shoals), rocks, or shallow reefs rising above the surface of the water.

Isobath A line on a map connecting points of equal bathymetry, i.e., equal depth, in the ocean or another water body.

Isopleth A line on a map connecting points at which a given variable has a specified constant value.

Karst A type of topography formed by dissolution of rocks like limestone and gypsum that is characterized by sinkholes, caves, and subterranean passages.

Kelp Brown algae characterized by their large size and complexity. Some, like the giant kelp, form dense kelp beds or kelp forests.

Lag A coarse-grained residue left behind after finer particles have been transported away, due to the inability of the transporting medium to move the coarser particles.

Lagoon Coastal water body entirely or almost entirely enclosed by a landmass with minimal connection to the sea; a shallow, sheltered body of water separated from the open sea by coral reefs, sand bars, and/or barrier islands.

Lava Any molten material that is extrusive or volcanic, or the rock that forms from a molten extrusive.

Levee Raised embankment of a river, showing a gentle slope away from the channel. It results from periodic overbank flooding, when coarser sediment is immediately deposited due to a reduction in velocity.

Limestone A carbonate sedimentary rock composed of more than 50% of the mineral calcium carbonate ($CaCO_3$).

Lithogenous sediment A marine sediment that is derived from the breakdown, or weathering, of rocks. Also see red clay.

Lithosphere The crust and the top part of the mantle that covers the earth's surface. It is broken into separate lithospheric plates.

Littoral zone The zone on the coast where land meets sea. Often called the intertidal zone but is more comprehensive, including the supratidal and infratidal zones.

Loess A widespread, loose deposit consisting mainly of silt; most loess deposits formed during the Pleistocene as an accumulation of wind-blown dust carried from deserts, alluvial plains, or glacial deposits.

Lowland Large area of relatively low relief, usually applied to coastal regions that do not rise high above sea level. *upland, highland* – ant.

Macroalgae Large algae including red, green and brown algae.
Macrofauna large animals (for example, fish).
Macrotidal Coastal ocean or waterway with a high mean tidal range, e.g. greater than 4 metres.
Magma Molten rock generated within the Earth; forms intrusive (solidifies below the surface) and extrusive (solidifies above the surface) igneous rocks.
Marine terrace Platform of marine deposits (typically sand, silt, gravel) sloping gently seaward. Such a platform may be exposed along the coast, forming cliffs, due to uplift and/or the lowering of sea level, e.g., Marine terraces of coastal Southern California.
Marine Waters that receive no fresh water input from land and are substantially of full oceanic salinity (>30 psu) throughout the year.
Marl A loose, crumbly deposit consisting of clay and calcium carbonate and formed in marine or freshwater conditions.
Megafauna Larger animals (for example, whales).
Meiofauna Microscopic animals that live on the bottom; often used as a synonym of interstitial fauna.
Meroplankton Planktonic organisms that spend only part of their life in the plankton.
Mesopelagic zone The pelagic environment from a depth of approximately 100 to 200 m to 1,000 m.
Mesotidal Coastal ocean or waterway with a moderate mean tidal range, e.g. between 2 and 4 meters.
Metamorphic rock Any rock derived from other rocks by chemical, mineralogical and structural changes resulting from pressure, temperature or shearing stress.
Microtidal Coastal ocean or waterway with a low mean tidal range, e.g. less than 2 metres.
Mid-ocean ridge The continuous chain of volcanic submarine mountains and elongated rises on the ocean floor and extending around the earth, where basalt periodically erupts, forming new oceanic crust; similar to continental rift zones; includes the Mid-Atlantic Ridge and East Pacific Rise.
Mineralization The process of replacing any organism's original material with a mineral.
Mixed layer The upper water layer in a two-layer system that is mixed by the wind or by convection in circulation from top to bottom of the layer, extending from the water surface to the density-stability discontinuity (pycnocline).
Mollusks (phylum Mollusca) Invertebrates with a soft, unsegmented body, a muscular foot, and, with some exceptions, a calcareous shell.
Moraine A mound or ridge of sediment and rock deposited by a glacier.
Mound Elongate offshore ridges or mounds of unconsolidated substrate or rocky remnants of eroding headlands (bars) or shallow masses of limestone biogenically created by corals and coralline algae (shallow reefs). Both bars and shallow reefs project off the seafloor and may have a limited terrestrial component.
Mouth The entrance of the coastal waterway, the connection of a coastal waterbody to the sea, or the place where the sea meets or enters the coastal waterway.
Mudflat A muddy bottom that is exposed at low tide.
Mud Fine sedimentary material, typically comprising both inorganic (mineral) and organic material.
Native species A local species that has not been introduced.
Neap tide Tide smaller than the mean tidal range and of minimum monthly amplitude. Occurs about every two weeks, during half-Moons.

Nearshore marine system Those waters in the region between the coastal land margin and the 30 m depth contour and where the salinity is substantially marine, i.e.>30 psu throughout the year.

Negative estuary an estuary in which evaporation exceeds freshwater inflow and therefore hypersaline conditions exist.

Nekton Organisms that swim strongly enough to move against the current.

Neritic (or coastal) zone The pelagic marine environment above and on the continental shelf, landward of the shelf-slope break and having a depth of from 30m-200m.

Neritic system Those waters between the 30 m depth contour and the continental shelf break, nominally at about 200 m depth, and where the salinity is substantially marine, i.e.>30 psu throughout the year. Although relatively farther from land than coastal systems, these regions can receive significant runoff influence from land and the water column is in close contact with the bottom relative to oceanic systems.

Non-point sources A source of sediment or nutrients that is not restricted to one discharge location.

Oceanic crust The Earth's crust which is formed at mid-oceanic ridges, typically 5 to 10 kilometers thick with a density of 3.0 grams per centimeter cubed.

Oceanic system Those waters of the 'open ocean,' in areas beyond the shelf break in depths generally greater than 200 m, extending to the maximum ocean depths. These waters are removed from primary continental influences, and the sea bottom interacts little or not at all with the water column.

Oceanic trench Deep steep-sided depression in the ocean floor caused by the subduction of oceanic crust beneath either other oceanic crust or continental crust.

Oceanic zone The pelagic marine environment beyond the shelf-slope break with a depth greater than 200m.

Open coast Unenclosed and exposed coastal margin.

Open water Areas of the water column waters not enclosed or bounded by land and not having strong hydromorphological structure or other identifiable hydrographic feature.

Organic material Once-living material (typically with high carbon content), mostly of plant origin.

Outcrop Any place where bedrock is visible on the surface of the Earth.

Overwash Deposit of marine-derived sediment landward of a barrier system, often formed during large storm events.

Oyster reef A dense reef-forming bed of bivalve mollusk filter-feeders present in estuaries and marine environments, usually requiring moderate to high current speeds.

Particulate Nitrogen (PN) Nitrogen compounds associated with or a constituent of mineral particles and organic material.

Passive continental margin A continental margin that is located at the "trailing edge" of a continent and as a result shows little geological activity. Compare active continental margin.

Patch reef A discontinuous reef growing in small areas, separated by bare areas of sand or debris, often part of a larger reef complex.

Peat A deposit of partly decayed plant remains in a very wet environment; marsh or swamp deposit of plant remains containing more than 50 percent carbon.

Pelagic fish Fish that live in the open ocean at or near the water's surface and usually migrate long distances. Examples include swordfish, tuna, and many species of shark.

Pelagic Marine waters over the continental slope or rise in water depths >200m.
Peninsula A large, prominent landform contiguous with and attached to the mainland, that juts into and is mostly surrounded by water.
Photic zone The surface layer where there is sufficient light for photosynthesis to occur.
Phytoplankton Microscopic, planktonic plants which exist within the water column.
Pillow lava Lava extruded beneath water characterized by pillow-type shapes.
Pinnacle A column of coral within the lagoon of an atoll (also coral knoll).
Plate Rigid parts of the Earth's crust and part of the Earth's upper mantle that move and adjoin each other along zones of seismic activity. The theory that the crust and part of the mantle are divided into plates that interact with each other causing seismic and tectonic activity is called **plate tectonics**.
Point source A source of sediment or nutrients into a water body that is restricted to one discharge location.
Population A group of organisms belonging to the same species and living in the same place.
Prograde The outward building of a sedimentary deposit, such as the seaward advance of a delta or shoreline.
PSU Practical salinity units- unit of measurement of salinity similar to part per thousand (ppt).
Pycnocline The transitional zone in the water column between layers of two densities. pycnocline or sharp density gradient; this parcel includes the air-water interface. Pycnoclines are generally formed by salinity or temperature differences between the upper and lower water layers and create effective barriers to transport across layers.
Quartz A highly resilient mineral based on silica (SiO_2).
Radiolarian ooze A type of biogenous sediment that consists mostly of the silica shells of radiolarians.
Reef A large ridge or mound-like structure within a body of water that is built by calcareous organisms such as corals, red algae, and bivalves.
Reef crest The shallow outer edge of the reef slope of a coral reef.
Reef flat The wide and shallow upper surface of a coral reef.
Reef slope The outer, steep margin of a coral reef. Also see fore reef.
Reef top surface feature of the seaward margin of windward reefs.
Residence Time The average time a hypothetical particle of water spends in solution between the time it first enters and the time it is removed from a coastal waterway.
Resuspension Process in which sediment particles on the substrate are brought back into water column suspension by waves, tides, or wind.
Ridge Elevated geoforms extending vertically from the seafloor covered with shallow water (banks) which may support unconsolidated sediments (shoals), rocks, or shallow reefs rising above the surface of the water.
Rift A long, narrow crack in the entire thickness of the Earth's crust, which is bounded by normal faults on either side and forms as the crust is pulled apart; To split the Earth's crust.
River Lotic deeper water habitats within a channel that are influenced strongly by the energy of flowing water and habitats formed by or associated with rivers/streams and their margins.
River plume Turbid fresh water flowing from land and generally in the distal part of a river outside the bounds of an estuary or river channel.
Salinity The total mass of salts dissolved in seawater per unit mass of water; generally expressed in parts per thousand.

Salt marsh A macrohabitat comprised of emergent rooted macrophytes in a soft sedimentary substrate tolerant of long periods of partial submersion along the shores of estuaries and sheltered coasts.

Salt wedge A layer of denser, saltier seawater that intrudes into coastal waters in the form of a wedge along the seabed and flows landward along the bottom in estuaries. The lighter fresh water from riverine sources overrides the denser salt water.

Salt A substance that consists of ions that have opposite electrical charges.

Sand Grains with diameters between 0.06 mm to 2 mm.

Sargasso Sea The region of the Atlantic Ocean north of the West Indies that is characterized by floating masses of Sargasso weed, a brown alga.

Seabed Subtidal ocean bottom, completely covered by the water at all times. Distinct from the bottom within the littoral intertidal zone.

Seafloor spreading The process of adding to the Earth's crust at mid-ocean ridges as magma wells up and forces previously formed crust apart.

Seagrass Rooted, grass-like flowering angiosperms, such as eelgrass, that are adapted to live at sea, submersed, and can tolerate a saline environment.

Seamount A submarine volcano in the abyssal plain

Sedimentary rock Any rock resulting from the consolidation of sediment.

Shear boundary The boundary between two plates that move past each other on the earth's surface. Also see fault.

Sheet runoff (or Surface Runoff) The flow across the land surface of water that accumulates on the surface when the rainfall rate exceeds the infiltration capacity of the soil.

Shelf break The section of the continental shelf where the slope abruptly becomes steeper, usually at a depth of 120 to 200 m.

Siliceous ooze A type of biogenous sediment that consists mostly of the silica shell and skeletons of marine organisms. Also see diatomaceous ooze and radiolarian ooze.

Sill A sheet-like igneous intrusion that parallels the plane of the surrounding rock. In a fjord, the sill is at the marine or ocean end member presenting a barrier to flow, trapping the bottom water.

Silt Grains with diameters between 0.002 mm to 0.06 mm.

Sinkhole A natural depression in the surface of the land caused by the collapse of the roof of a cavern or subterranean passage, generally occurring in limestone regions.

Softcoral Colonial anthozoans with no hard skeleton.

Soil Unconsolidated materials above bedrock.

Sorting An expression of the range of grain sizes present in a sediment. A well-sorted sediment has a narrow range of grain sizes, whereas a poorly sorted sediment has a wide range of grain sizes.

Spring tide Periodic and regular tide of maximum amplitude, greater than the mean tidal range; occurs about every two weeks, when the Moon is full or new.

Stenohaline Organism that can tolerate a narrow range of salinities.

Strand Plain A series of dunes, typically associated with and parallel to a beach, and sometimes containing one or more small creeks or lakes.

Stratification The separation of the water column into layers, with the densest at the bottom and the least dense at the surface. A stratified water column is said to be stable. An unstable column results when the surface water becomes more dense than the water below.

Stratigraphy The study of rock layers, especially their distribution, environment of deposition, and age; **stratigraphic**.

Stratum A layer of sedimentary rock; plural is **strata.**

Subaerial Occurring on land or at the earth's surface, as opposed to underwater or underground.

Subduction A geologic process in which one edge of one crustal plate is forced below the edge of another.

Subduction zone A long narrow area in which subduction is taking place, e.g. the Peru-Chile trench, where the Pacific Plate is being subducted under the South American Plate.

Submarine canyon Submerged earthform consisting of an incised large scale submarine feature on a high angle slope normally associated with the continental shelf.

Submerged bank Large, relatively flat shoal or other expansive submerged feature that is markedly shallower than surrounding ocean bottom. e.g. Georges Bank with water depth between 30-50 m.

Subsidence The sudden sinking or gradual downward settling of the Earth's surface with little or no horizontal motion.

Substrate The sediment and other material that comprises the seabed (or floor of coastal waterway); The type of bottom or material on or in which an organism lives.

Subtidal Permanently below the level of low tide, an underwater environment.

Supratidal Above the level of high tide, a terrestrial environment that is influenced by proximity to the sea including by sea spray, sea breezes and aeolian processes, and geological and biological "spillover" such as dune development.

Surface (mixed) layer The upper layer of water that is mixed by wind, waves, and currents.

Suspended sediment Sedimentary material subject to transport by flowing water (e.g. currents) that is carried in suspension. Typically comprises relatively fine particles that settle at a lower rate than the upward velocity of water eddies.

Talus Blocks and boulder materials accumulated at the base of high angle solid substrate shoreline often associated with cliffs or marine benches or ramps.

Tectonic Describing the forces that cause the movements and deformation of Earth's crust on a large scale, also describes the resulting structures or features from these forces.

Terminal moraine A mound or ridge of sediment and rock deposited to the front of a glacier.

Tidal creek Coastal waterway in which tides are the principal factor that shape the overall geomorphology. Typically occur on prograding, muddy coasts and contain a narrow channel that drains the immediate hinterland that is fringed by intertidal habitats.

Tidal current An alternating, horizontal movement of water associated with the rise and fall of the tide, these movements being caused by gravitational forces due to the relative motions of Moon, Sun and Earth.

Tidal prism Volume of water moving into and out of an estuary or coastal waterway during the tidal cycle.

Tidal range The difference in water level between successive high and low tides.

Tidal wetlands A coastal area that experiences periodic inundation as a result of daily tides.

Tide-dominated delta Coastal waterway in which tides are the principal factor that shapes the overall geomorphology, and river input is sufficient to have filled the basin. Typically funnel-shaped, and the wide entrance may form a coastal protuberance that contains elongate tidal sand banks that fringed by inter- and supra-tidal habitats.

Tide-dominated estuary Coastal waterway in which tides are the principal factor shaping the overall geomorphology. Typically funnel-shaped with a wide entrance containing elongate tidal sand banks. The margins are fringed by extensive intertidal habitats, separated by tidal channels.

Topography The relief features of the Earth's surface, above and below sea level; the set of landforms in a region.

Total Nitrogen (TN) Includes DIN, PN, but not gaseous N (e.g. N2).

Transgression A rise in sea level relative to the land.

Trench An elongated submerged geoform depression on the deepest margin of the ocean floor generally at depths >7000 ,; typically associated with subduction zones along boundaries between oceanic and continental plates.

Turbidite The sediments or rocks that formed as a result of a turbidity flow.

Turbidity current A bottom fast-flowing current that moves down a slope, depositing suspended sediments over the floor of a body of water.

Turbidity flow A flow of dense, muddy water moving down a slope due to a turbidity current.

Turbidity The condition resulting from the presence of suspended particles in the water column which attenuate or reduce light penetration.

Undifferentiated Unable to distinguish between. Undifferentiated rocks for which it is not possible to specify finer age divisions.

Upland An area that is higher relative to the surrounding areas, but not mountainous;

Upwelling Hydroform created by wind action or divergent surface currents that cause deeper waters move up to replace the surface water. These areas are often exposed to nutrient-rich deep waters rising to the surface from below the pycnocline. The transport of bottom water rich in nutrients enhances the growth of phytoplankton and other autotrophs. In these areas, life can be abundant. Can occur in the subtidal zone.

Vertical Accretion Accumulation of sediments or other material resulting in the building-up or infilling of an area in a vertical direction.

Volcanic Describes the action or process of magma and gases rising to the crust and being extruded onto the surface and into the atmosphere; also applies to the resulting igneous rocks that cool on the surface of the Earth, including beneath water, which typically have small crystals due to the rapidity of cooling.

Washover/Back barrier Deposit See overwash.

Water column The vertical column of seawater that extends from the surface to the bottom.

Water mass A body of water that can be identified by its temperature and salinity.

Wave The undulation that forms as a disturbance moves along the surface of the water. Waves can be described by their height (the vertical distance between crest and trough), wavelength (the horizontal distance between adjacent crests), and period (the time the wave takes to move past a given point).

Wave-dominated Delta Coastal waterway in which waves are the principal factor that shape the overall geomorphology, and river input is sufficient to have filled in the basin so that there is limited space for continued sediment accumulation. They are characterised by a sandy barrier and a river channel that has a direct connection with the sea.

Wave-dominated Estuary Coastal waterway in which waves are the principal factor in shaping the overall geomorphology. Characterised by a sandy barrier (partially constricting the entrance) that is backed a broad central basin and a fluvial delta, where the river enters the basin.

Wetland Partially or permanently flooded, softbottom flat that is vegetated by vascular plants.

Zooplankton Non-photosynthetic, heterotrophic planktonic organisms, including protists, small animals, and larvae, which exist within the water column.

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Appendix 4: Methodology Development

There are two kinds of methodology associated with the coastal/marine classification: classification methodology and the field sampling methodology. This document outlines the classification methodology below. Field methodologies will be determined in a separate project as described in the section on future activities for the refinement of the CMECS.

Classification methodology refers to the rules that determine how different criteria are used to classify a unit, and how to create a standard definition of a type. Standardized information about a habitat is particularly important, as the local nature and small spatial scale of the habitat units can lead to different descriptions and concepts of a specific habitat. The methodology also includes a set of crosswalks from existing, commonly used classification systems in Appendix 5. The methodology also details applications of this classification to existing pilot projects, which is included in Appendix 6.

The classification is structured as a sequence of nested levels, each level containing a list of units that can be identified using appropriate measurements and applying specific rules and criteria. When the criteria match the data, the user may continue to the next finer level in the classification. If there is no match, the level can be flagged as lacking sufficient information and the user can attempt to move to a finer level where there may be sufficient data to develop a positive match.

Organizing the Project

1. Identify the goals of the classification exercise. Determine if this classification is appropriate to meet those goals and identify the levels of the classification that would be most relevant to meet specific objectives.

2. Identify the geographic scope of the project and establish the project boundaries.

3. Specify the spatial scale(s) needed to portray the appropriate level(s) of the classification. Identify the required map scale and minimum map unit for classification products.

4. Review existing classification efforts in the project area and assess utility of these efforts relative to project goals. Identify additional requirements for data development.

5. If field sampling is planned, develop sampling protocol appropriate to goals and spatial scale.

6. Work downward in the hierarchy, identifying units for each level of the classification. The biological scale will depend upon the physical scale of interest. Use appropriate technology for sensing and measurement; express data in units defined in the classification and modifiers lists. At each step, compare incoming data to criteria list and identify the unit(s).

Application of the CMECS

7. **Ecological Region - Level 1**. Select biogeographic ecological region based on latitude and longitude of target area.

8. **Regime - Level 2**. Determine if target area is fresh-water influenced or marine.
    a. Fresh Water (F)
    b. Marine (M)

    If no data available, use best judgment based on available information. For example: is there an apparent fresh water source like a river channel? Are turbidity plumes visible in the field or from remote sensing? Is there historic salinity data available that indicates a fresh water source?

9. **System - Level 3**.
    a. If Level 2 is F (fresh water-influenced), determine if target area is or contains an estuary (E) or estuarine-influenced (I) waters.
    b. If Level 2 is M (marine), determine depth regime from sampling, from historical data or from nautical charts, and assign system
        i. Nearshore Marine (N)
        ii. Neritic (T)
        iii. Oceanic (O)

    If no data are available, use best judgment based on available information and proximity to shore? Are bathymetric maps or other historical data available?

10. **Geoform/Hydroform - Level 4**. Determine if target is a geoform, hydroform or combination and select identifying unit(s) from the catalog of types.

11. **Zone - Level 5**. Determine if target area is littoral (L), water column (W) or bottom (B) or combination and select subzone, if possible.
    a. Within each zone, a measurement or direct observation is required to determine subzone: upper or lower water column= U or L; intertidal or supratidal littoral zone= I or S; epibenthic or subbenthic= E or C. For oceanic subzones, see Level 5 subzones chart.

12. **Macrohabitat - Level 6**. Identify the macrohabitat feature using standard methodology and identify its spatial scale. [what standard methodology?] Check characteristics in units catalog and assign unit identifier and code.

13. **Habitat - Level 7**. Identify the discrete macrohabitat subunits, and classify the different habitat using the modifiers, such as substrate type, that make it distinct. A selection of modifier choices is available in the habitat menu and modifier menus.

14. **Biotope - Level 8**. Determine biotope type through use of existing lists, or by applying sampling protocols for measuring biotic cover, its fidelity [can't determine fidelity from a sample, fidelity is an aggregate measure across samples], composition and abundance in relation to the habitat units.

<u>Documenting the Classification Units</u>

15. After classifying each level, refer to modifiers and select all that apply or that are relevant to objectives.

16. After classifying each level, assign code that identifies the unit.

17. After classifying at each level, refer to objectives and determine whether they have been completely met. If yes, proceed to assignment of final classification type and to cataloging of data and units. If no, return to the next finer level at a smaller spatial scale and continue classification procedure.

18. Assign code and assemble final classification code for unique biotope identifier.
19. If habitat determination is inconclusive, record incomplete code and submit description of habitat including measurements, substrate, morphology and species names of biota.

20. Make any comments regarding unclassifiable features, difficulties, ambiguities and suggestions for improvement to classification.

Appendix 5: Crosswalks to Existing Coastal Classifications

The Coastal Marine Ecological Classification System (CMECS) was developed by NatureServe, (Madden and Grossman in prep.) with the participation of NOAA and two expert workshop panels convened in January and March 2003 (Madden et al. 2003). Three critical objectives provide the basis for the development of a widely applicable coastal marine classification framework:

- the capability for cross-comparison and classification of coastal and deepwater ocean sites throughout the North American continent
- fitting of existing classification data into a common framework
- comprehensive inclusion of local and regional classification systems into an umbrella framework.

Toward these goals, and especially in support of the third objective, the coastal/marine classification framework must be crosswalked to existing classifications currently in use. The overall concept of this report is to identify essential elements of major coastal/marine classifications, the commonalties and differences between them and indicate where existing classifications can be crosswalked to the CMECS classification. The characteristics of the CMECS classification are compared to existing classifications, indicating how and where they fit together and where they diverge (Table 1). The Madden et al. (2003) report describes the basic coastal/marine classification developed for NOAA, refined in this document by Madden and Grossman (in prep). This report examines seven major classification frameworks that were used in the development and assembly of the national classification. They are:
1. Cowardin et al. (1979)
2. Dethier (1990)
3. Greene et al. (1999)
4. BCMEC (Zacharias et al. 1998, Zacharias and Roff 2000)
5. Allee et al. (2000)
6. Madley et al. (2002)
7. Costello (2003)

Significantly, these are major classifications that generally focus on different types of ecological systems in different parts of the continent (or planet). The patchwork nature of this distribution is a primary reason that several classification frameworks have been used to assemble a single unifying classification that can be used to accommodate each user group's individual goals and needs.

The development of the CMECS classification is ongoing- the lower levels are being populated with habitat types via implementation of pilot projects and by continued interaction with experts in local systems. Subsequent reports will be issued that incorporate additional classification systems and translation tables that will enable direct utilization of data from other systems and pilot projects in the CMECS classification system.

Table 1. Comparison of major coastal, estuarine and marine classification systems

	Cowardin	Dethier	Greene	Allee	SCHEME	BCMEC	BIOMAR	CMECS
Geographic scope of classification	All of NA coasts, wetlands, coastal rivers, lakes and nearshore marine habitat	Developed for local coastal WA estuarine and coastal marine habitats but applicable to similar coastal areas	Developed for coastal CA deep seafloor habitats but applicable to other areas; Coast to deep ocean	All of NA coasts, estuaries, wetlands and marine systems	Developed for local coastal FL classification of seagrasses, hardbottom, corals in shallow water	Developed for coastal and oceanic regions of BC, Canada but widely applicable to similar areas	Developed for all of coastal UK but applicable to coastal Europe and other areas; extensive catalog of habitats and biotopes	Developed for coastal NA but intended for global applicability; to be integrated with OBIS database. For estuaries, wetlands, marine systems. Articulates and interacts with Terrestrial and Fresh water classifications
L1-Ecological Region	Upper level biogeography similar to CMECS; based on Bailey'a (1976) map.	None	None	Life Zones- large spatial scale based on climate	None	Regionalization developed for Provincial marine areas in hierarchical classification	None	Upper level biogeography based on CEC (in press) map similar to Bailey (1976) map but with enhanced emphasis on coasts.
L2- Regime Fresh/Marine	Five systems include coastal fresh waters, estuaries and marine systems	None- combined with System level- see below; requirement for estuaries to be semi-enclosed	None- developed for Marine Benthic system	Explicit at L3	No explicit level; salinity introduced as modifier	No specific division of fresh/marine but salinity is a "theme" variable for classification	None- developed for marine communities	Distinguishes coastal waters (both continental and island) that receive fresh input as distinct from true marine waters
L3- System Estuary/Marine	Covered as systems described above	At System level divides Marine and Estuarine systems	Bathymetric and geomorphological divisions at this level correspond to neritic and oceanic distinctions in CMECS	Similar function performed by Continental/non-continental division at L4 and depth range at L5	Classification is for estuarine and marine habitats but no distinct level for salinity	As above, but because the BCMEC includes the shore, estuaries are included, as is the nearshore and offshore marine system	Estuaries and lagoons are distinct from beach and marine physiographies and salinity regimes	Distinguishes three marine systems based on depth, distinct estuarine waterbodies and systems that experience freshwater plumes in marine waters
L4- Hydro/Geoform	No explicit reference; physical structures are treated as zones and substrates	No explicit recognition of large structures at this level	Megahabitat structures at Subsystem level correspond to some large features	Explicit classification of large hydro and geoforms but as two separate levels at L8 and L9	Classification of large geoforms at Class level; no hydroform analog	No specific sets of physical units are provided	Several large-scale types are provided for open and enclosed types; no hydroforms documented	Bases classification on physical structures beginning at large spatial scales similar to Greene and Allee and working to finer physical scales at lower layers
L5- Zone Lit/WC/Bottom	Subsystems are defined based on hydrography and tidal amplitude	Subsystem for intertidal and subtidal; no water column class	Mega and mesohabitats correspond to intertidal and subtidal	Classification of water column and bottom occurs at a high level (above geo and hydroform	Shallow water based; No distinct water column class; tidal marsh is a separate class but no explicit division based on litoral/benthic	Classification of pelagic ecounits based according to salinity and stratification and benthic ecounits according to several themes	No water column; several classes for vertical zonation in littoral and subtidal habitat	Distinguishes littoral zone, bottom and water column as encompassing distinct habitats
L6- Macrohabitat	No explicit level for macrohabitat;	Specific features are not defined as macrohabitat but	Yes macrohabitat features explicit; some littoral,	Recognized as local geomorphic types. Energy and	Implicit recognition of macrohabitat	No specific pre-defined habitat units.	No explicit recognition of macrohabitat types	Spatial progression from Level 4 and Level 5 physical features to smaller

	broad categories of elements such as "streambed" and "reef" are analogous to macrohabitat	substrate is basis of classification at this level and is analogous to many macrohabitat features in CMECS	bottom features from L5 in CMECS defined in this category	Photic regime are also given explicit levels (L7, L10)	features via classes at L2 and L3 Subclass 2 and Subclass 3.	Classification is designed to find patterns in data by which to draw boundaries around areas called ecounits	but several such as barrier beach and islands correspond to physiographic types	scales divides features into macro-units containing multiple habitats; gives context for Level 7 habitats
L7-Habitat	Habitat features are in either class or subclass categories, with at least modifier required for each level	Local geomorphic features combined with substrate and modifiers identifies habitat; includes explicit energy/exposure level	Yes- specifically identifies habitat with subclass for slope; modifiers for chemistry, biology, substrate	Yes- local geomorphic features combined with substrate and modifiers identifies habitat. Termed eco-unit	Yes- local geomorphology combined with modifiers identifies habitat. Becomes more specific than CMECS, analogous to sub-habitat	Habitat is implicitly described as the summary of five physical themes, including substrate to delineate unique classes	Yes- primary emphasis is on rock vs sediment distinction and energy exposure	Specifically defined as physical subsets of larger coastal, bottom and hydroform features, combined with modifiers for energy and water mass characteristics. Habitat is specific for each Ecological region
L8-Biotope	Dominance types include plants and animals dominant and commonly associated with habitat	Diagnostic species dominance types and common species are listed	Does not have an explicit level in hierarchy but identifies species associated with habitats	Refers to dominant species associated with specific habitat	No specific level for biology but biota occupies several classes and taxonomic modifiers are provided	A successor to the BCMEC included assessment of physical factors' relationship to biotopes as a means of habitat classification	Yes- biotope and biotope complexes are used explicitly and assigned to habitat classes	Derived from Biomar biotopes and biotope complexes relating dominant fixed biota to habitat; also classifies vagile and migratory species use of habitat at multiple points in hierarchy

1. Classification of Wetlands and Deepwater Habitats of the United States

The Cowardin classification

Cowardin, W. M. V. Carter, F. C. Golet and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service. FWS/OBS-79/31 GPO 024-010-00524-6 Washington DC 103 pp.

The Cowardin system (Cowardin et al. 1979) was designed by the U.S. Fish and Wildlife Service in the late 1970s with the goal of inventorying wetland and deepwater habitats of the United States. The intent was to arrange ecological taxa, to define concepts and terms consistently, and to identify map units. The target audience of this product was the coastal resource management community. The Cowardin classification was the first detailed classification system for coasts at the habitat level that encompassed the entire United States. It became a very successfully applied tool and provided the basis for many coastal classifications to follow (e.g. Dethier 1992, Weiland 1997, Greene et al. 1999, Allee et al 2000, Madden and Grossman, in prep). Although inclusive of deepwater habitats, the Cowardin system is really derived from a wetland-centric perspective, and heavily emphasizes wetland habitat types, particularly coastal marshes. The classification of Cowardin has four levels: system, subsystem, class, and dominance type, but each level is accompanied by modifiers, effectively doubling the number of levels. Many of the modifiers in Cowardin are treated as fixed classes in the Coastal Marine Ecological Classification Standard (CMECS) by Madden and Grossman (in prep).

In addition to marine and estuarine habitats shared in common with the CMECS classification, the Cowardin system encompasses lacustrine and palustrine systems at Level 1 as well. Lacustrine systems are excluded from CMECS. Elements of rivers (the channels at river mouths, and river currents) and elements of wetlands are part of CMECS, but they are lower level hydro and geomorphic features rather than the system-level classification branches they represent in Cowardin. Although the CMECS system includes aspects of wetlands, the classification is focused more on estuarine, coastal and marine areas and less on wetland delineation than Cowardin, and consequently is less developed in terms of wetland hierarchical classes.

Boundaries between terrestrial and aquatic systems and between coastal and deepwater sections in the Cowardin and CMECS classifications are defined differently. The marine system of Cowardin ends at the continental shelf break, while in CMECS, it extends to the deepwater oceans. In Cowardin, criteria for determining the upland extreme of the domain are soil and vegetation-based: the upper extent of hydric soils and of hydrophytic cover, reflecting the more terrestrial focus of the system. In the CMECS scheme, inland boundaries of the domain are physically defined- upper splash and spray zone above high tide level on marine coastal shores (currently defined as the splash and aerosol zone on marine coasts, but flexible), or the head of tides in estuarine and palustrine systems. The boundary between wetland and deepwater habitat in the estuarine and marine systems in the Cowardin classification is at mean low water at spring tide.

The marine and estuarine systems of Cowardin are differentiated into subtidal and intertidal subsystems at Level 2 for marine and estuarine systems. Level 3 is the class level, based on a few substrate types- rock bottom or shore, unconsolidated bottom or shore, reef, aquatic bed, and three types of wetland in estuarine intertidal. Subclass at Level 4 includes substrate type (mud, sand, gravel, cobble, etc), followed by dominance type, which is analogous to biotope in CMECS.

Estuarine systems are defined at the highest level in Cowardin, whereas in CMECS, the estuary is a Level 3 unit within the fresh water influenced regime, a reflection of the wider geographic domain and scope of that classification. An advantage of the CMECS system in this regard is that estuarine is further split into two categories: estuaries in the nearshore and estuarine-influenced areas in the neritic, i.e. waters of greater than 30 m depth. Estuaries are often considered extended systems (Hopkinson and Wetzel 1989) that influence areas far larger than the physical boundaries of the estuary itself. The CMECS classification is designed to encompass these extended estuarine systems.

The proposed CMECS system also differs from the Cowardin in that there is an explicit energy class in the modifier list (following Dethier 1990 see below) providing a means of distinguishing habitat units based on energy. CMECS includes far more detail in the description of the water mass characteristics via the modifiers, including temperature, light, oxygen, turbidity, trophic sstatus and salinity. The vegetated bed is absent as a class in CMECS, following Dethier's model (1990), while it is a class in Cowardin. Both systems contain functional classes based on tide-intertidal and subtidal. CMECS adds supratidal habitats influenced by marine waters but not directly submerged under normal circumstances.

The two classifications are similar in several other ways: both include biogeographic ecoregionalizations that are similar in boundaries and criteria, both have upper levels that differentiate between marine and estuarine systems, both examine pelagic and benthic regimes, and both use substrate as a variable that defines habitat. In terms of underlying rules, the determination of boundaries is similar in the two systems in a major respect: there is a quantitative definition of boundaries, such as the lower depth limit for wetland (2m) that Cowardin allows to be flexible due to the variable nature of such boundaries. In this case, the lower depth level can extend to the lower depth limit of wetland plants if greater than 2 m. The CMECS classification uses the same flexibility in the rule set in establishing both physical boundaries and classes within the hierarchy, depending on local conditions.

Cowardin et al. propose a nationwide regionalization of the coastal U.S., based on the division of the United States coasts as defined by Ketcham (1972) and drawn alongside terrestrial eco-regions by Bailey (1976, 1978). The ten coastal provinces are generally determined by climate, though in the coastal realm, ocean currents and landforms also play a role in the divisions. The boundaries of the CMECS classification at Level 1 often conform closely to those of the Cowardin ecoregions in many parts of the continent, with some additional detail provided in the latter as a result of work by CEC (1997) and expert determination of important biogeographic features and discontinuities in the coastal margins. The regionalization scheme for coasts and oceans of North America presented at Level 1 in Madden and Grossman (in prep) is the result of work by the Commission for Environmental Cooperation (CEC), the environmental arm of NAFTA (CEC in press). Because the CEC classification extends further seaward than the Cowardin classification, reaching the abyssal plains of the open oceans, there are additional regions beyond the shelf break that define these areas.

The eastern seaboard ecoregions of the U.S. reflect the same nomenclature, boundaries and rationale in both Cowardin and CMECS classifications, being from north to south: the Acadian, Virginian and Carolinian regions, which break at the Avalon Peninsula, Cape Cod, Cape Hattaras, respectively. The southern boundary of the Carolinian in Cowardin occurs at Cape Canaveral, while in CMECS it occurs further south at Palm Beach. In fact, the South Florida/Bahamian ecoregion of the CMECS system conforms exactly to the boundaries of the terrestrial ecoregion of Bailey: Palm Beach to Gullivan's Point on the south west coast of Florida, while Cowardin calls the ecoregion the West Indian and sets the analogous boundaries farther north at Cape Canaveral and Cedar Key. The Louisianian province of Cowardin thereafter extends to Port Aransas, TX, while the Northern Temperate Gulf of Mexico extends from Cedar Key to Rio Panucho just south of the Texas border. On the west coast, the regions do not match as neatly- Cowardin shows just two- the Californian ending at Cape Mendocino and the Columbian terminating at Vancouver Island. In the CEC regionalization, the Eastern Pacific and Montereyan cover the California coast, with the Columbian coinciding with Cowardin's. CMECS also provides additional ecoregions in Alaska: the Bering/Chukchi and the Aleutian Archipelago, which are subsumed in the super-region Arctic and Fjord provinces in Cowardin.

The lowest level unit in the Cowardin system is the dominance type, which reflects the predominant plant or animal form in the habitat. This is analogous to the biotope level in the CMECS and BIOMAR systems, and dominance type in Dethier 1992 and eco-unit in Allee et al 2000. The Cowardin system ends at this level, referring to flora and fauna associations that are characteristic of specific habitats. This and lower levels are left open to development by users applying the classification to specific regions.

The Cowardin system has been remarkably robust and successful, measured by the number of daughter classification systems spawned by it, including the Dethier (1990), the Brown (1993), and Wieland (1993), the Greene et. al. (1999), the Allee (2000) the Madley et al. (2002) and the CMECS systems. The concept of a universally applicable coastal habitat classification could be construed as being initially tested and validated by the Cowardin system.

2. A Marine and Estuarine Habitat Classification System for Washington State

The Dethier classification

Dethier, Megan. 1990. A Marine and Estuarine Habitat Classification System for Washington State. Washington State Dept. of Natural Resources.

One of the successful daughter classifications that is modified from Cowardin et al. (1979), is The Marine and Estuarine Habitat Classification System for Washington State (Dethier 1990, 1992). The Dethier framework adds energy as a level, significantly enhancing the utility of the classification not only for Washington State, but for use in high-energy coasts throughout the continent. This modification is an excellent example of how adaptation to regional characteristics, such as the high-energy coastline of the Pacific Northwest, led to customization of an existing classification system to reflect local features. The resulting fragmentation of the national classification of Cowardin illustrates the need for a new national standard that includes the multitude of local enhancements to the original classification system.

The classification framework developed by Dethier et. al. (1990), made several important departures from Cowardin. Although some changes were designed to adapt the system specifically for the Washington coast, some were refinements to the general organization and conceptualization of the Cowardin classification. Chief among the modifications, similar to CMECS, was the narrowing of the focus to marine and estuarine systems, leaving rivers and lakes outside the scope of the classification. Removal of subclass aquatic bed (a change also adapted by CMECS), enabled the identification of substrate associated with a particular vegetation type in vegetation-dominated areas. There was no ability to tie substrate and vegetation type in the Cowardin system with the exclusive designation of aquatic bed.

Among other key contributions of the Dethier system are a compendium of exact definitions for systems (marine and estuarine), and for the categories allocated within these systems for classification.

System, at the highest level, is divided into substrate type, then energy and finally dominance type and diagnostic species (plant or animal). Energy level is indicated by many designations, depending on the system: enclosed, open, partly protected (marine intertidal), high, moderate, low (marine subtidal), open, partly enclosed, lagoon and channel/slough (estuarine). This amount of differentiation seemed excessive to accomplish distinctions based on energy, and it was determined that only three relative energy levels need be defined. Energy designations in CMECS are of no, moderate and high intensity.

CMECS moves the substrate to the habitat level (Level 7) while in the Dethier system (and Cowardin system) it is relatively higher in the classification. The focus of the Dethier classification tends to be on benthic habitats while CMECS strives to place equal emphasis on habitats in the water column. In both the CMECS and Dethier classifications, shallow (<15 m) and deep (>15 m) are included as modifiers for subtidal systems, and backshore and eulittoral for intertidal systems.

Salinity regime is also a modifier in the estuarine system and exactly coincides with CMECS, which uses the classes:

fresh (0-0.5 PSU)
oligohaline (0.5-5 PSU)
mesohaline (5-18 PSU)
polyhaline (18-30 PSU)
euhaline (30-40 PSU)
hyperhaline (>40 PSU)
marine (constant 35 PSU)

Several surveys of fauna that have been conducted in State of Washington waters and benefit the application to a standard classification system. The Puget Sound Expedition, for example, covered some of the areas where the rigid methodology imposed by a classification system would assist in creating a comparative dataset- requiring site locations, geologic and vegetational context, etc. The Puget Sound Ambient Monitoring Program entitled "A Conceptual Model for Environmental Monitoring of a Marine System" (Newton, et al. 2000) provides a useful set of key attributes which can be used in developing the relational structure among levels in the classification hierarchy for Washington State.

3. A Classification Scheme for Deep Seafloor Habitats

The Greene Classification

Greene, H.G. M.M. Yoklavich, R. M. Starr, V. M. O'Connell, W. W. Wakefield, D. E. Sullivan, J. E. McRea, Jr. and G.M. Caillet. 1999. A classification scheme for deep seafloor habitats. Oceanologia Acta. 22(6)663-678.

The classification system of Greene et al. (1999) is focused on marine benthic deepwater habitats, with the goal of understanding and predicting spatial distributions of fish species. Although the system is based on Cowardin (1979) and Dethier (1992), the Greene classification represents a departure from classification of coastal habitat and a moves into the deep ocean, dealing entirely with geologic structure of the bottom. Within a framework of five levels (System, Subsystem, Class, Subclass, and modifiers), the Greene classification characterizes units as megahabitat, on a scale of 1-10 km, mesohabitat (10-1000 m), macrohabitat (1-10 m) and microhabitat (<1 cm). Megahabitats include seamounts, lava fields, banks, reefs and submarine canyons. Mesohabitats include small seamounts, canyons, banks, landslide fields and reefs. Macrohabitats include bedrock outcrops, biogenic reefs, kelp beds, and caves. Microhabitats include small seafloor materials and features such as pebbles, cracks, crevices, fractures, individual gorgonian corals and sea anemones. In the Greene classification, the System level has only one category- the marine benthic system. Other elements at the analogous level in the CMECS classification include estuarine or fresh water Systems, which Greene leaves to other, existing classifications (Cowardin 1979, Dethier 1990).

The Subsystem level of the Greene classification includes both mega and mesohabitats and is based on both physiography and depth. The seven Subsystem elements are: Continental Shelf from the intertidal to the 200 m isobath, Continental Slope, Continental Rise, Abyssal Plain, Trenches, Submarine Canyons, and Seamounts. The Subsystems at Level 2 in Greene are large geological features, corresponding in part to the fourth level in CMECS (for example seamounts and submarine canyons), and in part to the third level in CMECS (the shelf break). Along with oceanic islands, estuaries and other water column features these structures reflect a definition as geological or hydrographic entities rather than elements of the depth-defined categories of Nearshore, Neritic and Oceanic. At Level 2, Greene's classification is more highly resolved in the deepwater features. The CMECS resolves these features at Level 4 as a function of the importance of highlighting the division between Nearshore features and Neritic features at a high level to permit the introduction of estuaries and coastal features at Level 3. In Greene, geologic features are further subdivided by depth, such as Top, Flank and Base for Seamount, and Head, Upper, Middle and Lower for Submarine Canyons. These kinds of distinctions are made at the habitat level (Level 7) in CMECS.

Because the Greene classification is focussed entirely on the seafloor, the third level of Greene (Class, which includes meso and microhabitats) is represented several levels further down in CMECS. Such features are represented at Level 6 and Level 7 in CMECS as macrohabitat and habitat, and include such mesoscale features as bar, sediment wave, cave, ledge, pinnacle. The additional levels add complexity to the hierarchy of CMECS, but since the national classification must accommodate detailed distinctions associated with intertidal vs water column vs benthic, it is important that additional levels interpose the Class and Subclass elements of Greene to convey this information. Nonetheless, all of the elements of Greene's Class level are included in the CMECS classification and can easily be crosswalked. Similarly, the Subclass level of Greene is incorporated in toto in CMECS as part of Levels 6 or 7, with modifiers used to incorporate Greene's substratum textures and slope. Madden also includes a relief modifier for geomorphic structure class (following Iampietro and Kvitek unpub.) at this level, which is absent in Greene. The classes of Greene's slope subdivision are used without modification in CMECS:

flat (0-5°)
sloping (5-30°)
steeply sloping (30-45°)
vertical (45-90°)
overhang (>90°)

In general, all of the geologic-based elements of the Greene classification were used in the national classification, but sorted among several levels due to the need for a greater number of divisions to cover the larger domain of habitats. All of the elements present in Greene's classification are easily crosswalked to the national classification on a one-to-one basis. Further, the national classification includes hydrodynamic energy regime and hydrodynamic features as separate levels, both of which are absent or greatly reduced in Greene. It may be that such hydrodynamic structures in the water column are not required to gain predictive power in assessing fish distributions, but CMECS consider it important to test the national classification using these features.

4. Marine and Estuarine Ecosystem and Habitat Classification

The Allee classification

Allee, R. J., Dethier, M., Brown, D. Deegan, L. Ford, G.R., Hourigan, T. R., Maragos, J., Schoch, C., Sealey, K., Twilley, R., Weinstein, M. P., and Yoklavich, M. 2000. Marine and Estuarine Ecosystem and Habitat Classification. NOAA Technical Memorandum. NMFS-F/SPO-43.

The Allee et al. 2000 and CMECS systems reflect the same common goal of comprehensiveness and exhibit an ecosystem-based philosophy. The target domain of both systems is the coastal marine systems of the U.S. coasts. CMECS represents a recasting and refinement of the Allee system, providing new classes, additional elements within classes, and quantitative definitions of many of the components. The Allee et. al. (2000) classification and revision (Allee 2001) covers the entire U.S. coastal margin from the landward extent of tidal influence to the outer edge of the continental shelf and is hierarchical in design, and comprehensive in scale and scope. The target audience of both systems is local, regional and national coastal resource managers, with specific goals of the identifying essential fish habitat and defining marine protected areas.

The Allee report presented a prototype multi-scale system applicable at the national level, employing physical and biological criteria. The highest level is the Life Zone, based on climate, approximating Hayden et al.'s (1984) basis on Regions of Oceanic Currents. One of the primary differences between the CMECS and Allee hierarchies is the inclusion of a biogeographic regionalization as the highest level in CMECS, replacing Life Zones of the Allee structure. The disaggregation of the North American coasts into 24 ecological regions allows more site-specific definition and geographical information to be included in the hierarchy.

The Allee system distinguishes water vs land division at Level 2, then fresh water vs marine/estuarine division at Level 3. A useful enhancement of the CMECS scheme involves simplification of the hierarchy by including more information in fewer levels. The "saving" of a class at level 2 by removing the water/land distinction is an example of this. Since this is a coastal marine classification, no further re-statement of this is necessary. Level 3 in CMECS is occupied by the Estuarine, Estuarine-Influenced, Nearshore Marine, Neritic and Oceanic Systems. One goal of the CMECS framework was parsimony in the classification structure. The application of the classification will produce maps, the fewer types that adequately describe a unique habitat will lead to less computational and methodological overhead and fewer ecological types to track in the system's catalogue.

Further advantage is gained by combining the marine aspect of Level 3 in Allee with the continental aspect in Level 4 to save an additional level. This is an important distinction- by removing the continental influence at Level 4 and introducing it at level 2 in CMECS, estuaries and other coastal features influenced by continental watersheds or other continental processes are automatically included in the appropriate hierarchical branch, while at the same time being linked to the shallow depth associated with the inner continental shelf (the nearshore continental is depth-limited to 30 m or less). The distinction of benthic vs water column is defined at Level 5 in Allee, as in CMECS Level 5, except the addition of the littoral zone (as in BIOMAR) adds a third element to this level in CMECS.

Level 6 in Allee of shelf vs slope vs abyssal is subsumed as a subclass of the oceanic water column class. This level in Allee is inconveniently placed, as the characteristics of the three elements are not logical members of the classes above them. For example, having followed the continental branch at level 4, one is confronted by shelf, slope and abyssal at level 6. But continental automatically eliminates slope, abyss and likely a large part of the shelf as choices here. The configuration is made more efficient by moving Level 6 to a higher position in the hierarchy (Level 3 in CMECS) and adjusting the depth criterion so that "shallow" and "continental" are conveyed by a single, more meaningful variable- "nearshore marine," which is defined as <30 m in CMECS

Additional attributes that are important in the Allee system are the incorporation of explicit measures of energy- wind, wave, current and river flow velocity at Level 7, similar to the system developed by Dethier (1990), and to the SCALE system of Schoch (1999). Level 7 in Allee, representing wind and wave energy, is changed in a number of ways in CMECS- the concept is treated as a modifier in CMECS and a class for wind energy is dropped, as the critical relevant variable of interest is hydrodynamic energy, regardless of the source. While wind is a causative agent of waves, seiches and current energy, it is not the direct cause of any aquatic ecological function except the transport of sea foam and spray. So hydrodynamic energies are emphasized instead of wind. The concept of exposed or open and protected in Allee (as in Dethier and BIOMAR) is subsumed in the energetic elements of the hydrodynamics and thus description of exposure is dropped as well. "Exposed" and "protected" are subjective judgements about energy impacts based on the geomorphology of an area. The relevant characteristics of the energy regime from observed morphologies are waves and currents. In CMECS, the energy regime is made the driving factor by requiring the assessment of the energy, in the form of wave/current intensity and current directionality at the site of interest, regardless of how the system is shaped physically. The physical shape of the system is captured in Level 4 where large-scale morphological characteristics are assessed.

Local level hydromorphic and geomorphic features, Levels 8 and 9 in Allee are combined in CMECS under the rubric "habitat." They are hydrological and geological analogues of the same process- physical structure on a large scale, and merely applied in the water column or benthic branches as applicable. Level 10, photic/aphotic in Allee is eliminated in CMECS (as is also in the revision of Allee in 2002) and treated as a modifier. Level 12 applies to the biological elements, and is analogous to the Biotope of Level 8 in CMECS. The most resolved level (Level 13) in Allee lists local modifiers that describe Eco-units. An eco-unit represents the biological community and its habitat, analogous to the Biotope of the BIOMAR and CMECS systems.

The Allee system was the first truly national classification since Cowardin and presents several significant enhancements to the Cowardin system including: 1) a focus on universal applicability, across a variety of target regions, 2) a stronger focus on marine and estuarine landscapes, and 3) linkages between geoform, energy and biology. Madden and Grossman (in prep) derives in many ways from Allee et al., (and others), but with important deviations and enhancements based on input for a large group of experts. Many of the class elements from Allee are present in the

CMECS classification, rearranged, combined, further resolved, making the classification more versatile, logical and applicable.

5. British Columbia Marine Ecosystem Classification

BCMEC

Zacharias, M.A., Howes, Don E., Harper, J. R., and Wainwright, Peter. 1998. The British Columbia Marine Ecosystem Classification: Rationale, Development, and Verification. Coastal Management 26:105-124.
Howes, Zacharias, Canessa Roff and Hines. 2002. British Columbia Marine Ecological Classification.
Roff, J. C. and L. Taylor. 2000. Geophysical Approaches to the Classification, Delineation and Monitoring of Marine Habitats and their Communities. Unpublished ms.

The BCMEC classification was developed for the coast of British Columbia. The Marine Ecosections and Ecounits components of the larger BCMEC classification uses a 1:250,000 scale for organizing depth, current, exposure, relief, salinity, slope, stratification, substrate and temperature information as a means of characterizing habitats. The system is targeted to coastal planning and resource managers in support of development of a marine protected areas (MPA) strategy, coinciding with one of the projected uses of the CMECS classifications.

The BCMEC system is similar to the CMECS and Allee classifications in that it has a strong focus on water mass characteristics. The BCMEC also follows separate tracks in the hierarchy for what the authors term benthic and pelagic "ranges," as in the U.S. national classification. These ranges are used to develop the benthic and pelagic ecounits, which combined, form the marine ecounit. The BCMEC system is quite advanced, with an explicit methodology defined and several examples of application.

Within the benthic range, the descriptive variables are depth, slope, relief, temperature, exposure, current and substrate, all of which are elements in common with CMECS, though the binning of the variables is somewhat different in the BCMEC system:

BCMEC		**CMECS**				
		Nearshore Marine	Neritic		Oceanic	
Shallow	0-20	0-30			Epipelagic	0-200
Photic	20-50		30-200		| Mesopelagic	200-1000
Mid-Depth	50-200				| Bethylpelagic	1000-4000
Deep	200-1000			>200	| Abyssalpelagic	4000-7000
Abyssal	>1000				|_Hadalpelagic	>7000

Depth is divided into five classes in both systems, but the CMECS system is made flexible to encompass different scales. At Level 3 in CMECS, three of the main divisions are based on use of 30 m as a nearshore demarcation, and use of the shelf break (approx. 200 m isobath) related to the neritic/oceanic boundary. In CMECS, depth sections are further divided according to standard oceanographic convention, which has relevance to fish assemblages as well as physical phenomena. BCMEC has one additional division in shallow waters at 50 m. This in fact is similar to the nominal infralittoral/circalittoral depth boundary in BIOMAR, which loosely tracks a vertical shift from vegetation to animal dominance in the UK. Testing will reveal whether this additional break should be incorporated into the national classification.

Slope is also an important variable in the BCMEC classification, incorporating three classes: 0-5%, 5-20%, >20%. The CMECS classification follows Greene et al. (1999) in using a five-element category for slope, because it is more comprehensive and resolved. In an application of BCMEC to the coast of British Columbia, only 0.1 % of the total study area (427 km2) was in the steepest class (>20%), but the likelihood that highly sloped features and overhangs represent unique and critical habitat (Greene et al. 1999) argues for the more differentiated scheme.

An outgrowth of the work of the British Columbia group is the biophysical model of shore zone habitat mapping. This classification, called Shore Zone, is a systematic methodology for mapping the shore. As with most of the other classifications described, the building blocks are physical-pictures are taken of the shoreline and classified into units ("shore units") based on geomorphologic features. Features are delimited based on areas of abrupt change (either structure or process e.g. waves). The biological units of the system are then mapped on top of the physical information. Physical mapping of the shore is required, and the biological units- biobands are spatially referenced to the physical units. The authors stress that biobands are descriptive evaluations and no functional relationships are imputed to the distribution of the biota. Species distribution within the biobands is also mapped.

The shore-zone system is an extremely powerful tool that will become part of the methodology for applying the national classification during pilot testing.

6. System for Classification of Habitats in Estuarine and Marine Environments

SCHEME

Madley, Kevin. 2002. Florida System for Classification of Habitats in Estuarine and Marine Environments (SCHEME). Report to EPA. Florida Fish and Wildlife Conservation Commission Florida Marine Research Institute. FMRI File Code 2277-00-02-F. 43 pp

The Madley et al. 2002 classification hierarchy focuses on estuarine and marine environments that are relevant to Florida coastal resource managers, that is, nearshore and neritic areas inhabited by corals, hardbottom and seagrass communities. The classification is in development and is presented in the form of an outline five levels in depth. Boundaries and the limits of the domain of the system are explicitly defined as from the high tide line to the edge of the continental shelf.

The SCHEME system uses five levels. These are:
Class
Subclass 1
Subclass 2
Subclass 3
Subclass 4

SCHEME employs a decision support key such that each subclass contains increasingly refined descriptors of the class above it. In this sense it is similar to the NMFS Our Living Oceans scheme (Brown et al., unpub.). The SCHEME classification structure is not based on fundamental ecological processes that underlie and connect the elements of the classes but entirely on empirical detail about the important primary habitats. The underlying structure might be considered to be spatial scale.

The entirety of the SCHEME system is focused at what represents the bottom three levels (eco units), of both the CMECS and Allee classifications, and was in fact designed to nest within the national classification system (Madley et al. 2002). SCHEME inserts into the CMECS framework beginning at the macrohabitat level (Level 6) for biogenic elements or at the habitat level (Level 7) for unconsolidated sediments, and has a total of four classes of the types: unconsolidated sediments, submersed aquatic vegetation (SAV), corals and hardbottom, and tidal marsh and swamp. The majority of subsequent detail in SCHEME is devoted to distinguishing between different types of the primary habitat (e.g. linear biogenic reef terrace with high profile), differing amounts of cover, degree of patchiness, or sorting of substrate type.

SCHEME notably lacks provision for significant description of geologic structure and for coastal geomorphological complexity such as beach, or rocky intertidal- there is no detailing of geological or hydrodynamic features. Further the energy signature is missing, likely reflective of the relative quiescent coastal environment of the Florida Gulf coast. This brings the issue of scales of measurement to the fore, as per cent cover and species evenness. Scale issues are discussed in detail, as the system has been applied on the ground, and maps have been developed. Therefore a mapping methodology and selection of minimum mapping units has been made, and mmu recommendations for each kind of habitat under different conditions. The system is application-oriented, that is, and many aspects of the classification structure are methodology driven- LIDAR, single beam SONAR, and remote photography are utilized in data acquisition for application of the classification. SCHEME's authors emphasize that the acquisition of some types of data may be difficult (e.g. tide or salinity) thereby precluding application of the classification if the sampling is over a short timescale. The variables of tide and salinity are specifically mentioned as variables that are not essential to conducting a classification survey. As in CMECS, there is provision for including this information as modifiers.

The SCHEME classification is enormously useful to the national classification in providing detailed information about specific habitat types; many aspects of SCHEME have been adopted into the lower levels of the CMECS hierarchy as habitat types for submersed vegetation, coral and soft bottom habitat in sub-tropical systems.

7. BIOMAR

Connor, D. W. 1997. Marine biotope classification for Britain and Ireland. Joint Nature Conservation Review, Peterborough, UK.

The BIOMAR classification system by Conner et al. 1997 is designed to classify coastal habitats in Ireland and Great Britain. The BIOMAR system has been incorporated to a large extent into the coastal and marine branches of the EUNIS system (European Environment Agency 1999) that is being developed for coasts throughout Europe.

The BIOMAR system is well developed, with a large number of types already catalogued. It is largely web-based (www.itsligo.ie/BIOMAR/about/Project.htm) and has a well-developed glossary of terms, sites and data. It has been vetted though a dozen workshops, and has been applied to many areas of the northeast Atlantic. The spatial domain of the BIOMAR system is smaller than the CMECS system, as is covers marine habitats from high tide seaward, excluding salt marshes, and does not extend to the deep ocean. The goals of the BIOMAR system largely coincide with those of the CMECS national classification system. It is designed to be easy to use, comprehensive, portable over a wide area and large number of habitats, and provide a common nomenclature for classification for coastal systems. Its goal is to allow prediction of the distribution of marine biotopes from existing data.

The target domain of BIOMAR, called the Marine Seabed, is divided into Littoral and Sublittoral zones at Level 1. This division occurs at level 5 of the CMECS scheme, termed Littoral and Bottom. The BIOMAR subdivides classes into major substrate types- rock, mixed and sediment at Level 2. Level 3 in BIOMAR yields four positional classes relative to the tide, analogous to supra, inter, infra and subtidal in CMECS. Level 4 in the BIOMAR classification divides the soft sediments into three types according to substrate- gravel, sand and mud, and divides the rock substrates into three types according to energy level- wave exposed, moderately exposed, and sheltered. The biotope represents the lowest level in the BIOMAR hierarchy and is defined as the combination of a physical habitat and its community of animals and plants. An encyclopedia of Biotopes has been produced online.

The advantage of BIOMAR system is that it is very simple to use, and produces a compact matrix of habitat choices with zonation as one axis and substrate and energy as the other. The system has been successful, and provides a model for simplification, albeit the narrow focus and domain of BIOMAR lends itself to such simplification more easily than the CMECS classification.

Some of the obvious differences between the BIOMAR and CMECS classifications involve nomenclature. There are a number of similar or exact elements common to both classifications that have different names. The seashore is the littoral intertidal zone; the sublittoral zone is the subtidal zone. The infralittoral zone is the same connotation as the infratidal zone in the CMECS system- area at the littoral land-water interface, but below the lowest astronomical tide. This area is nonetheless influenced by tidal motions and currents, and is generally in the photic zone. BIOMAR tends to define its terms from a biological perspective, for example defining the infralittoral zone as that subtidal area generally densely covered with algae. The supralittoral is considered to be the area above the highest tide, yet influenced by the spray and salt of the ocean. This is called the supratidal zone in CMECS.

The circalittoral zone in the BIOMAR system is the region of the littoral below the vegetated zone- sparsely covered by algae and densely populated by animals. There is no counterpart in the US national classification for this region. This designation is quite different from anything in CMECS, being based solely on the criterion of whether or not the section is vegetated based on depth. This would argue for a photic-based differentiation, although that is not discussed in the BIOMAR literature. The BIOMAR system is noteworthy for its empirical-based hierarchy and lack of underlying basis in ecological processes.

Substrate and energy are important parts of the BIOMAR classification. The substrate classes for the BIOMAR system correspond to many in the CMECS system's Level 7 as follows:

Substrate	Grain Size
Bedrock	bedrock
Boulder	256->1024 mm diam
Cobble	64-256 mm
Pebble	16-64 mm
Gravel	4-16 mm
Coarse Sand	1-4 mm
Medium Sand	0.25-1 mm
Fine Sand	0.063-0.25 mm
Mud	<0.063 (silt/clay)

Many substrates that are defined in CMECS are not included in BIOMAR including silt, peat, clay, carbonate rock, organic material.

In BIOMAR, only the rocky substrates have energy designations, considered as exposed, moderately exposed and sheltered designations. This differs from the CMECS classification in that all substrates may be classified according to their energy environment, including softbottom and biogenic.

Estuarine systems are included in the BIOMAR system, but only as a subcategory of infralittoral rock and littoral sediments. It is clear that the BIOMAR system is less focussed on estuarine systems and connections of the coastal system to the upstream watershed, than on strictly marine systems closely associated with the coastline. There is no provision for water column habitat in BIOMAR as in CMECS, nor is there the provision for classification of deep ocean habitats beyond the neritic system.

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Appendix 6: Testing the CMECS Classification with Pilot Studies

The CMECS provides a powerful tool to organize and synthesize knowledge across new projects and existing classification applications. An important test of the CMECS is its ability to efficiently crosswalk current classifications and maps. Successful application tests the efficacy of the emerging classification standard using existing data, develops translations between existing units and existing classification structures, and populates the database by cataloguing habitat units into the proposed national standard.

The two pilots that are presented here test different parts and different uses of the classification. The pilots that were selected for this study draw on two comprehensive datasets: a benthic habitat map of the Florida Keys produced by the Florida Marine Research Institute and NOAA (FMRI 2000); and maps of the structure and bottom topography of the South Atlantic Bight from North Carolina to Florida produced by the SEAMAP project (SEAMAP 2001). The purpose of the Florida project was to map shallow water seagrass and coral habitat. The extensive tropical seagrass beds and coral reef resources of Florida are unique on the North American continent. The primary purpose of the SEAMAP project was to locate and map marine hardbottom habitat. Hardbottom is recognized as being of great importance to fish and invertebrates as spawning, feeding grounds and refugia. Much of the habitat data in SEAMAP is accompanied by biological trawl data.

These pilots represent two very different applications of the classification system. The scope and scale of the two natural systems are different. The length of coastline covered by the Florida study is on the order of 10^2 km along the Florida Keys and the SEAMAP site covers the coasts of four states, on the order of 10^3 km of Atlantic coastline. The methodologies by which data were collected are also different, as the Florida study was conducted with through interpretation of remotely sensed imagery and coordinated ground truthing, while the SEAMAP project utilized diverse and less-coordinated sampling methodologies including trawl data, SONAR, video and diver observation. The resolution of the Florida study is positionally accurate to 10 m. The SEAMAP study was much coarser, plotted on a 1 minute-square grid. The water depth covered by the Florida maps is limited to less than 10 m, the depth penetrable by the remote sensing technology employed, which was natural color photography flown by aircraft. The water depth covered in the SEAMAP project extended from the coastline to 200 m at the nominal shelf break. Habitat types presented in the two projects are quite different as well, demonstrated in the classification lookup tables in this report. The pilots cover different, though overlapping, levels of the national coastal/marine classification system.

This appendix provides brief information about the original source project, presentation of a lookup table translating the habitat units of the pilot to the units of the national classification, example maps of the distribution of ecological units for each pilot, and an analysis of the strengths and weaknesses of the classification discovered in the course of conducting the pilot project.

Coastal Marine Ecological Classification Standard
Pilot Project Information Template

PILOT PROJECT #1: FLORIDA KEYS
Project Name: Florida Bay and Florida Keys

Information Source: Benthic Habitats of the Florida Keys. 2000. Florida Marine Research Institute Technical Report No. TR-4.

Original Data Collection Contact: Bill Sargent, Kevin Madley
Florida Marine Research Institute
100 Eighth Ave. SE
St. Petersburg, FL 33701

Original Classification used: 24-class 2- level scheme developed by FMRI (later became SCHEME, also developed by FMRI).

Area: Florida Keys, Reef Tract, Adjacent Atlantic Ocean, Parts of Florida Bay adjacent to Keys

Major MPAs included: Florida Keys Marine Sanctuary, Dry Tortugas National Park, Everglades National Park, Biscayne National Park, Looe Key National Marine Sanctuary, John Pennekamp State Park

Local MPA Contact: Billy Causey, Florida Keys National Marine Sanctuary, Marathon, FL

Study Area Bounds: Florida Keys from Key Largo to Key West, and approx. 2 km on either side

Data Collection Period: December 1991-April 1992

Spatial Units: polygons >0.5ha; units smaller than 0.5 ha were represented as points

Map Scale: 1:51,500

Methodology: Aerial photographs by NOAA Remote Sensing Division. Each photograph covers an area of approx. 160 km^2. Three step photo-interpretation.

Accuracy: 5-10 m depending on habitat class. Ground truthing was conducted by FMRI.

Additional Variables (ancillary trawl, physico-chemical, biological data): None

Bathymetry: Not sampled

Florida Bay Florida Keys Subtropical Benthic System

Re-Classification in National Coastal/Marine Classification system
Level 1: Floridian/Bahamian Region
Level 2: Estuarine, Nearshore Marine
Level 3: Reef, Bank, Island, Embayment and Open System
Level 4: Photic Subtidal Benthic and Intertidal Littoral (water column not mapped)
Level 5: energy not measured
Level 6: Carbonate Basement, Fine Sands, Coral Head, Coral Reef, Fine Silt, Carbonate Sands, Organic Detritus, Shell Hash, Relict Oyster Shells
Level 7: Sandy Beach, Platform Reef, Patch Reef, Hardbottom, Softbottom Hardbottom, Softbottom, Reef
Level 8: Dense Mixed Seagrass Bed, Sparse Seagrass Bed, Soft Coral Community, Coral Reef Community

Introduction

This pilot project is an application of the NatureServe/NOAA Coastal Marine Ecological Classification System, designed to both test the effectiveness of the classification and to demonstrate the translation of habitat units from a local classification into the universal units of the national classification. The original dataset was acquired by remotely sensed natural-color photography and classified by the Florida Marine Research Institute (FMRI) GIS Department. The project resulted in a widely used benthic atlas depicting the upper middle and lower Keys, and adjacent bayside and oceanside benthic habitat. The classification used in the original atlas was a precursor to the SCHEME benthic classification for Florida by FMRI (Madley et al. 2002).

Transformation of units from the source data to the national classification was made using a translation table that in most cases resulted in refinement and standardization of the terminology, but in some cases also resulted in aggregation or disaggregation of the FMRI classes into new classification units in the national system. This reflects the importance placed upon rigorous maintenance of a classification structure and nomenclature that will permit as comprehensive and widely applicable a framework for all coastal areas nationally. The SCHEME classification was drawn upon heavily in constructing the lower levels of the national classification units for coral and vegetated bottom, and so translation did not require much transformation.

The national classification makes a sharp distinction between the habitat level, which is defined as a set of several physical variables that represent the confluence of substrate, energy, geomorphology and hydromorphology, and the biotope level, which is the intersection of the habitat and a characteristic biological community. The biotope is generally that non-mobile community that is fixed, growing on or in the habitat- often referred to as cover. Thus, the habitat level is structural and generally abiotic and the biotope level contains information about the fixed biology that is associated with a particular habitat. The species and species associations that commonly live in and use the habitat are not mapped here, as sampling of species associated with the habitats mapped was not part of the original FMRI study.

Development of Spatial Modifiers

As a result of this pilot study and other supporting research, it became apparent that a standard way of expressing spatial information about how the habitat is organized at the fine scale. A suite of spatial modifiers was developed to refine the definition of habitat units in terms of spatial qualities. These modifiers are to be applied at the habitat level, the biotope level or even the geo/hydromorphic structure level, as appropriate. Our purpose in developing this suite of modifiers was to create a standardized means of describing spatial relationships and distributions of habitat elements and features in a way that is universally applicable. It is evident from studying the numerous benthic classification systems in existence that it is at the lowest levels of classifications (habitat, eco-type, biotope, etc.), that colloquialism and local terminology is greatest. This "fracturing" of the terminology into vernacular that is associated with a local application is one of the greatest barriers to development of a universal standard classification. The intent of this section is to begin to develop a standard way of considering spatial relationships and to create a standard terminology for describing these relationships for the lowest levels of habitat classification.

- Solitary- presence of a single, isolated occurrence of a habitat unit or feature within the target spatial area (e.g. solitary coral patch reef)

- Aggregation- presence of multiple occurrences of the same habitat unit or feature within the target spatial area (e.g. aggregated patch reefs)

- Complex- presence of a combination of two or more habitat features creating a unique type within the target spatial area (e.g. solitary patch reef-sandy bottom complex- "reef halo")

- Inclusion- smaller, identifiable habitat features within a larger habitat type (e.g. rock outcrop inclusions in a sandy bottom)

- Matrix- a dominant, uniform habitat type (usually of simple structure, spatially) within which other types (usually of higher-order spatially) can occur (e.g. coral remnants within a sand matrix, rocky outcrops in an unconsolidated softbottom matrix)

- Vegetated- plant cover growing on or in the dominant feature or structure of the unit

- Unvegetated- no plant cover growing anywhere on or in the dominant feature or structure of the unit (bare)

- Colonized- sessile invertebrate fauna is present attached/growing on or within a spatial unit

- Uncolonized- no sessile invertebrate fauna is present attached/growing anywhere on or within a spatial unit

- Vegetated and Colonized – mixed plant and sessile invertebrate fauna cover growing together on or in the dominant feature or structure of the unit

- Sparse- vegetation cover or colonizing fauna cover is relatively low- <25%
- Intermediate- vegetation cover or colonizing fauna cover is moderate- 25%-75%
- Dense- vegetation cover or colonizing fauna cover is relatively high- >75%
- Continuous- vegetation cover or colonizing fauna cover that is homogeneously distributed in a non-varying spatial pattern within the unit
- Mixed density- vegetation cover or colonizing fauna cover of variable density that is non-homogeneously distributed within the unit ("patchy")
- Discontinuous- a special case of mixed density where vegetation cover or colonizing fauna cover of variable density that is non-homogeneously distributed within the unit, includes patches where no cover is present
- Inactive- evidence of structure-building biology which is not longer living or actively growing (eg. reef, moribund mangrove marsh)
- Unorganized- geomorphic structure indicating a broken, deconstructed pattern of that which is usually organized into a higher form (e.g. reef remnants, reef rubble, bolder shards)

The pilot study is presented in a look-up table (Table 1) that reflects the FMRI classification units in the first column and the national classification translation to the right of them. For the national classification, the bottom three levels (geomorphology, habitat, biotope) are displayed to demonstrate the full context of the habitat unit. A map legend and three example GIS tiles (Figures 1, 2, 3, 4) are were developed of the study area (Florida Keys) that show the translation graphically and reflect the greatest contrasts in habitat type from the upper to lower Keys and the greatest contrast of the FMRI and national classification schemes.

Analysis

One outcome of the application of the national classification in Pilot #1 was the recognition that in many cases, because habitat information is acquired from a distance or via remote imagery, elements of the data required for full classification can be lacking. The substrate (habitat) may be obscured by the overlying vegetation or fauna (biotope community), making it difficult to ascertain the habitat substrate. Thus, a map showing classified data will often display a mix of what in the national classification is classified as habitat and biotope- depending on what is visible to the imaging system. This is not considered to be a great problem, although it highlights the need for ground sampling of the substrate and possibly other variables in order to completely classify to the lowest levels of the hierarchy.

Working through the upper levels of the hierarchy was revealing as well, because the pilot exercise indicated how much information about upper levels is available from the data, the metadata or by inference. In the case of Florida, Level 1 is known by the location of the study area. Level 2, system, is evident from the range of depths involved: nearshore marine, and estuarine are covered by this pilot. Because bathymetry is not included in the data presented, it can only be inferred from the nature of the study in a nearshore shallow water reef and grassbed habitat, that the neritic system of depth greater than 30 m was not included. Characterization at Level 3 is a simple matter since this level deals with geographic features such as reef, embayment and open water. These features are obvious from the graphics provided in the report, although hydrographic features such as major currents are not knowable from the data. Aspects of Level 4, the vertical zone, are evident from the data: the benthic regime and the littoral regime are being mapped by definition and are included. All the vertical depths covered by the study, being measured by remote aerial photography, are assumed to be photic. The water column zone is also within the domain of the study, although it is not clear from the data that any water column properties or habitats were measured or characterized.

Level 5, energy level is the first level where there clearly is not data available that can be used to assign a class. Knowledge of this would require additional sampling from the ground. Level 6, geomorphic structure, again provides data where certain elements corresponding to geomorphology are mapped and others are not due to the limitations of the methodologies used in this study. Units of geomorphic structure such as hardbottom, softbottom, reef can be detected by the camera and are classed in both the original and pilot studies. No element of small scale hydromorphic structure such as currents or upwellings can be detected nor were mapped in the original study. Furthermore, many modifiers and finer scale structures for level 6, such as substrate type, relief or grain size were not detectable by the photography.

Finally, the habitat level (7) was largely detectable and classifiable using only the remote sensing and ground truthing tools applied in the original study. Sufficient data were provided to develop a comprehensive habitat list for the translated pilot study as well. Information about the biotope communities was also available in a general way from ground observations provided, although these were only mentioned categorically and not mapped explicitly.

In summary, the simple and rapid assessment tool of remotely sensed images, with ground truthing was able to provide a significant amount of the information required by the national classification to characterize the habitat and biotope to a level that would be extremely useful in conservation management. Additional work is required to completely record and map the relationships between habitat/biotope and species/species complexes associated with the habitat, but the classification lays a strong foundation for this activity.
Delimiting areas of unique and endangered habitat and biodiversity hotspots can be accomplished with the information provided in the pilot classification. Developing maps that demonstrate key relationships between habitat elements, such as the interaction between seagrass and substrate between soft corals and bottom type is less tractable without further information. With additional in situ measurements however, complete characterization of the environment to the biotope and sub-biotope levels would be possible.

Table 1. Translation look-up table relating FMRI classification to equivalent units in the National Coastal/Marine Classification.

FMRI (SCHEME)	Coastal/Marine Ecological Classification System		
	LEVEL 6 GEOMORPHIC STRUCTURE	**LEVEL 7 HABITAT**	**LEVEL 8 BIOTOPE**
Corals	**REEF**	**CORALS**	**CORALS**
Patch Reefs	**Coral Reef, Patch Reef**	**Coral Reef, Patch Reef**	**Coral Reef, Patch Reef Community**
Individual Patch Reef	Reef, Coral, Patch Reef, High Profile	Coral Reef, Patch Reef- Solitary	Siderastrea siderea, Colpophyllia natans, Montastraea
Aggregated Patch Reef	Reef, Coral, Patch Reef, High Profile	Coral Reef, Patch Reef- Aggregation	Siderastrea siderea, Colpophyllia natans, Montastraea, echinodermata
Halo (around single patch)	Reef, Coral, Patch Reef, High Profile	Coral Reef, Patch Reef- Softbottom complex	Siderastrea siderea, Colpophyllia natans, Montastraea, echinodermata
Aggregated Patch Reef with Halo	Reef, Coral, Patch Reef, High Profile	Coral Reef, Patch Reef- Softbottom complex	Siderastrea siderea, Colpophyllia natans, Montastraea, echinodermata
Coral or Rock Patches with Bare Sand	Reef, Coral, Patch Reef, High Profile	Coral Reef, Patch Reef inclusions in Softbottom matrix	Siderastrea siderea, Colpophyllia natans, Montastraea
Platform Margin Reefs	**Coral Reef, Platform Reef**	**Coral Reef, Platform Reef**	**Coral Reef, Platform Reef Community**
Shallow Spur and Groove	Reef, Coral, Patch Reef, High Profile	Coral Reef, Platform Reef, Spur and Groove Fore Reef	Acropora palmata, Agaricia agaricites Millepora complanata
Back Reef	Reef, Coral, Patch Reef, Low Profile	Coral Reef, Platform Reef, Back Reef	Acropora palmata, Agaricia agaricites Millepora complanata, softcoral, pioneering elkhorn
Drowned Spur and Groove	Reef, Coral, Patch Reef, Low Profile	Coral Reef, Platform, Inactive Platform Reef-Unconsol. Sftbtm. Cplx.	Thalassia, Syringodium
Remnant- Low Profile	Reef, Coral, Patch Reef, Low Profile	Coral Reef, Platform, Unorganized Active Reef	Thalassia, Syringodium
Reef Rubble	Reef, Coral, Patch Reef, Low Profile	Coral Reef, Platform, Inactive Reef Rubble	Thalassia, Syringodium
Hardbottom	**HARDBOTTOM**	**HARDBOTTOM**	**HARDBOTTOM Community**
Soft Corals, Sponges, Algae	Hardbottom, Carbonate, Flat relief, low profile	Carbonate Hardbottom, Colonized	Octocorals, sponges, softcorals, stony corals,
Hardbottom with Perceptible Seagrass (<50%)	Hardbottom, Carbonate, Flat relief, low profile	Carbonate Hardbottom, Vegetated	Thalassia, Halimeda, Udotea, Penicillus
	Hardbottom, Carbonate, Flat relief, low profile	Carbonate Hardbottom, Vegetated and Colonized	Octocorals, sponges, softcorals, stony corals, Thalassia, Halimeda, Udotea, Penicillus
	Hardbottom, Rock, Flat relief, low profile	Rock Hardbottom, Colonized	Soft corals, hard corals, Porites sp., Siderastrea sp., Manicina sp.
	Hardbottom, Rock, Flat relief, low profile	Rock Hardbottom, Vegetated	Soft corals, drift algae, seagrasses, Laurencia, Gracilaria, Euchema, hard corals, Porites sp., Siderastrea sp., Manicina sp.
	Hardbottom, Rock, Flat relief,	Rock Hardbottom, Vegetated and	Soft corals, drift algae, hard

	low profile	Colonized	corals, Porites sp., Siderastrea sp., Manicina sp.
Bare Substrate	**SOFTBOTTOM**	**UNCONSOLIDATED SOFTBOTTOM**	**UNCONSOLIDATED SOFTBOTTOM Community**
Carbonate Sand	Softbottom, sandy, carbonate, flat relief, low profile	Carbonate Sands, Unvegetated and Uncolonized	Carbonate Sands, Unvegetated and Uncolonized
Carbonate Mud	Softbottom, silty, carbonate/mud, flat relief, low profile	Carbonate Silt, Unvegetated and Uncolonized	Carbonate Silt, Unvegetated and Uncolonized
Organic Mud	Softbottom, mud/organic, flat relief, low profile	Organic Muds, Unvegetated and Uncolonized	Organic Muds, Unvegetated and Uncolonized
		Carbonate Sands, Vegetated and Uncolonized	polychaetes, benthic algal mat
		Carbonate Silt, Vegetated and Uncolonized	polychaetes, benthic algal mat
		Organic Muds, Vegetated and Uncolonized	polychaetes, benthic algal mat
		Carbonate Sands, Vegetated and Colonized	Carbonate Sands, Vegetated and Colonized
		Carbonate Silt, Vegetated and Colonized	Carbonate Silt, Vegetated and Colonized
		Organic Muds, Vegetated and Colonized	Organic Muds, Vegetated and Colonized
Seagrasses			**ROOTED VASCULAR PLANT BED Community**
Continuous Seagrass			**Continuous Vascular Plant Beds**
Moderate to Dense- Continuous Beds	Softbottom, flat relief, low profile	Softbottom, flat relief, low profile, Vegetated	Rooted Vascular Plant Bed, Continuous, Dense Thalassia
Sparse, Continuous Beds	Softbottom, flat relief, low profile	Softbottom, flat relief, low profile, Vegetated	Rooted Vascular Plant Bed, Continuous, Sparse Thalassia
Dense Patches in a Matrix of Sparse Seagrass (>50%)	Softbottom, flat relief, low profile	Softbottom, flat relief, low profile, Vegetated	Rooted Vascular Plant Bed, Mixed Density Thalassia, in Softbottom matrix
Patchy Seagrass			**Discontinuous Vascular Plant Beds**
Moderate to Dense, Discontinuous Beds with Blowouts	Softbottom, flat relief, low profile	Softbottom, flat relief, low profile, Vegetated	Rooted Vascular Plant Bed, Discontinuous Thalassia, in Softbottom matrix
Dense Patches in a Matrix of Hardbottom	Softbottom, flat relief, low profile	Softbottom, flat relief, low profile, Vegetated	Rooted Vascular Plant Bed-Hardbottom complex, Discontinuous Thalassia
Predominately Sand/Mud with Small Scattered Seagrass Patches (<50%)	Softbottom, flat relief, low profile	Softbottom, flat relief, low profile, Vegetated	Rooted Vascular Plant Bed-Unconsolidated Softbottom complex, Discontinuous Thalassia
Predominantly Macroalgae Cover with Scattered Seagrass Patches	Softbottom, flat relief, low profile	Softbottom, flat relief, low profile, Vegetated	Rooted Vascular Plant Bed-Macroalgae complex, Discontinuous Thalassia
Other	**BANK**	**SHALLOW BANK**	**SHALLOW BANK COMMUNITY**
Bank	Bank, flat relief, low profile	Carbonate Silt, Shallow Bank, Unvegetated and Uncolonized	
Other	**Other**	**Other**	
Land		Land	
Inland Water		Water	
Open Water		Water	

Dredged	Carbonate Silt, Disturbed, Human Impact, Dredged
Unknown Bottom/Uninterpretable	Unknown
Unknown Bottom/Uninterpretable Dredged	Unknown, Disturbed, Human Impact, Dredged
Restoration	--

The three GIS tiles show the application of the national coastal/marine standard to the data provided by the FMRI Florida Keys Mapping Project. It can be seen that in most cases, mapping of the habitat level (7) is possible from the data provided. Because the species and spatial information about vegetated bottoms are considered to reside on the next lower level (8-biotope) in the national classification, in areas where seagrass is reported in the original data, it was reclassified and mapped as level 8 in the national classification.

The exercise serves to reveal the benefits, limitations and data gaps of the data collection methodology for the original data for use in classifying benthic habitat. By classifying using remotely sensed images, the substrate underlying vegetated bottoms is not usually detectable. A combination of ground mapping and remote sensing would be required for better analysis of the factors connecting substrate type and seagrass distribution. The reliance on methodologies that do not completely capture all information about an ecological unit, particularly vertically stratified information where underlying layers are obscured, has led to the collapsing of many variables, such as habitat and vegetation, into a single level in many classifications- the two layers are simply not discriminated by the tools of remote sensing technology.

Another shortcoming in working with this data was the incomplete characterization of some of the information in the geomorphologic levels. While such geomorphology as “hardbottom” was readily discriminated by the methodology used, more detailed information about the type of substrate or profile or relief of the bottom was not. Therefore, in the translation to the national classification, much detail that would be recorded is simply left out.

In general, however, existing datasets and classifications provide a wealth of information that can be readily reclassified into a more universal scheme whereby inter-site comparisons and emerging pattern in the relationships between physical setting, habitat and biota can be elucidated. The successful classification of this existing dataset indicates that even incomplete information can be used to adequately characterize habitat with the national classification in ways that are of great utility to the end user.

Figure 1. Translation from FMRI classification to National Coastal/Marine Classification for Florida Keys Study, (FMRI 2000). Where categories for the original data and the national classification coincide, the national classification terminology is given first, with original FMRI term following in parentheses.

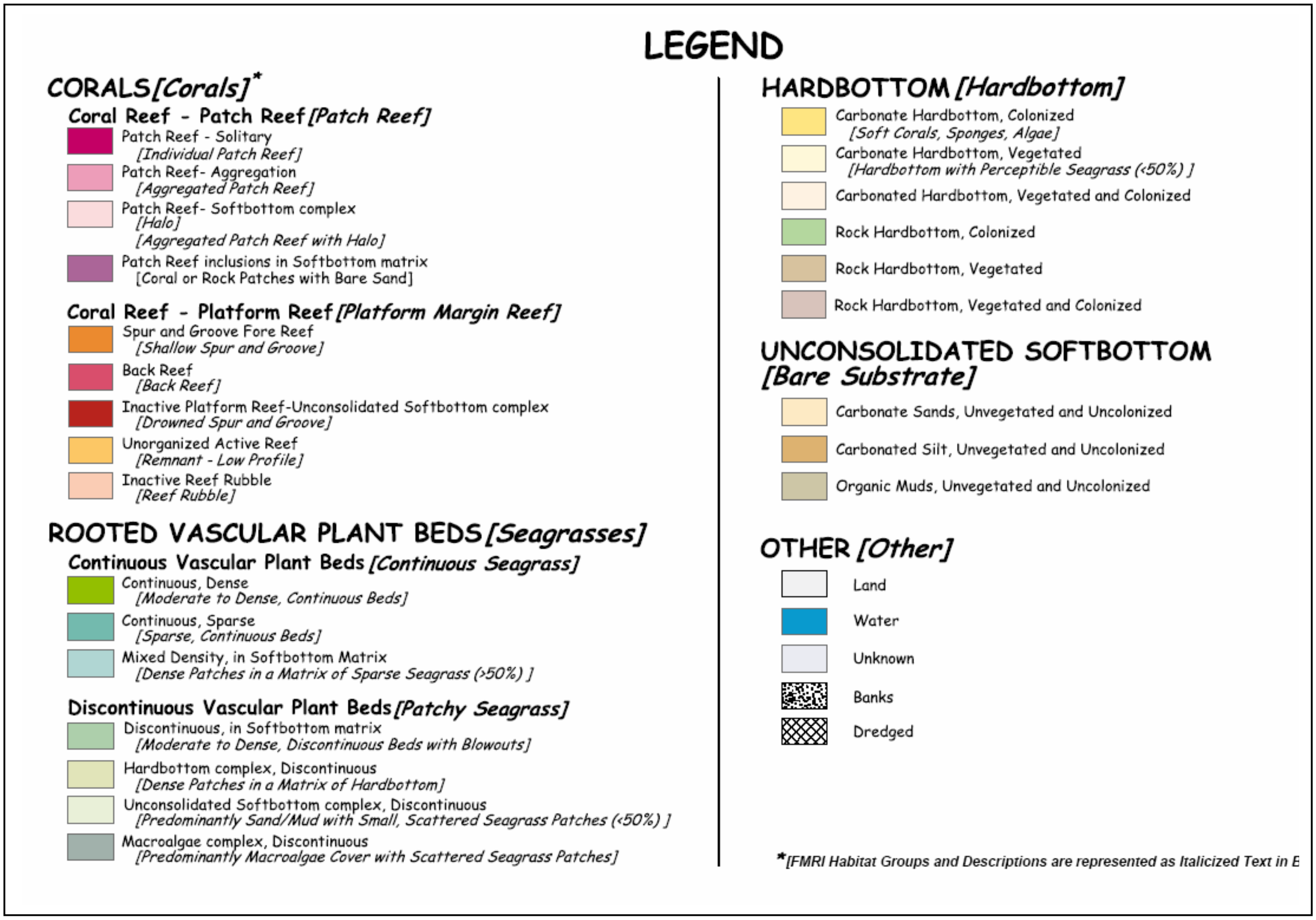


Figure 2. Upper Florida Keys, FMRI Tile #6 showing data for benthic habitats re-classified and mapped according to the national classification standard. See Figure 1 for legend.

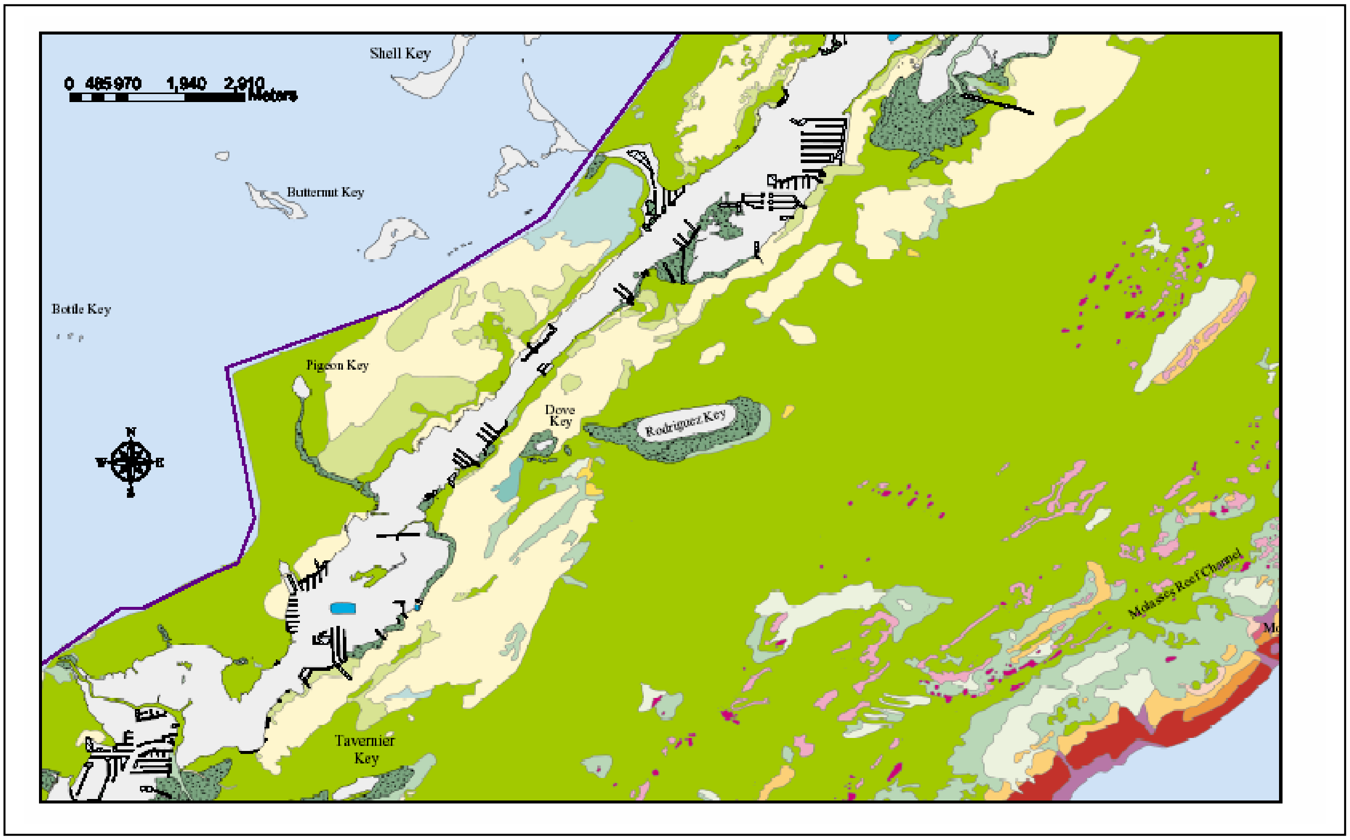
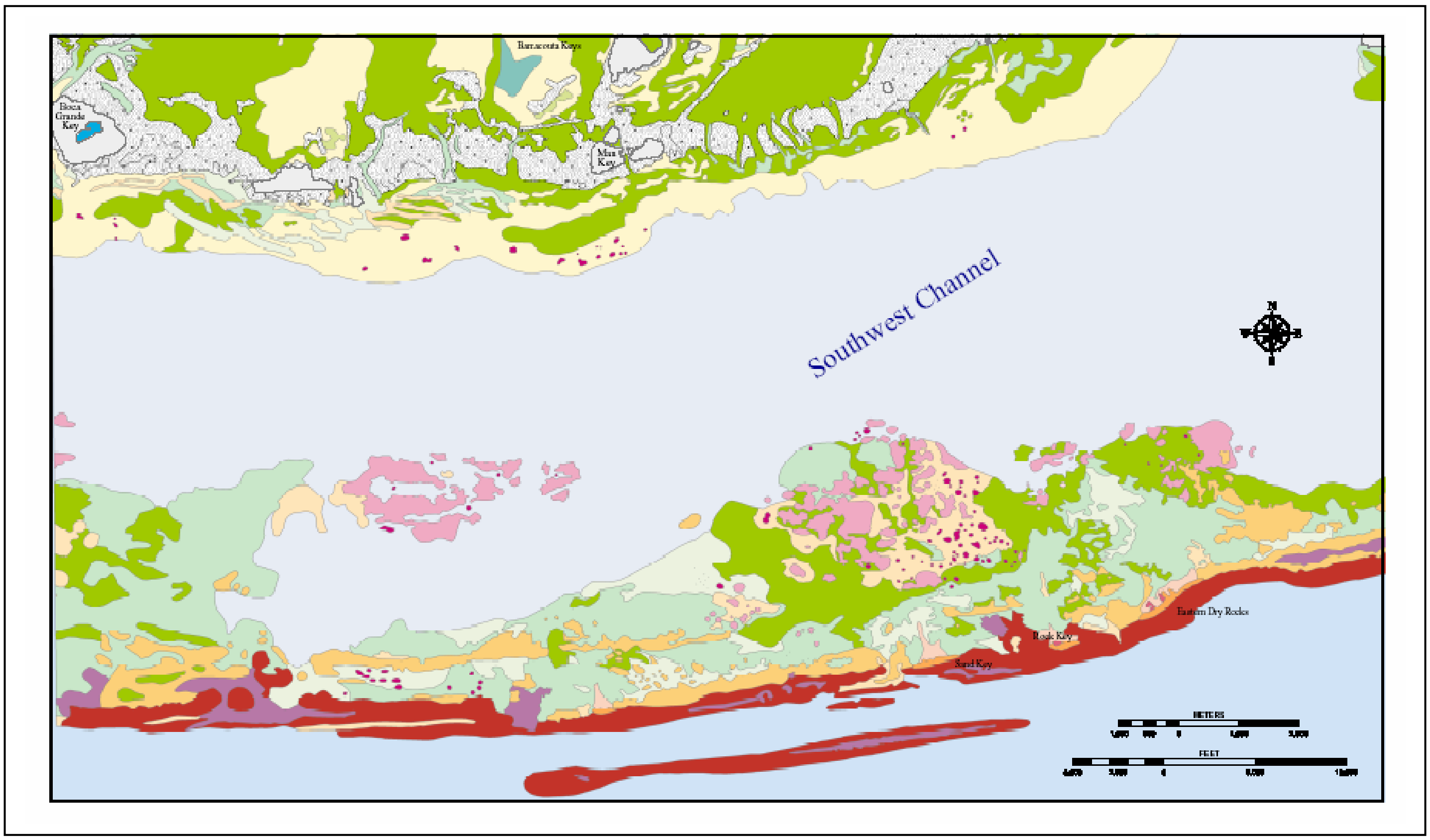


Figure 3. Middle Florida Keys, FMRI Tile #14 showing data for benthic habitats re-classified and mapped according to the national classification standard. See Figure 1 for legend.

Figure 4. Lower Florida Keys, FMRI Tile #26 showing data for benthic habitats re-classified and mapped according to the national classification standard. See Figure 1 for legend.



Coastal Marine Ecological Classification Standard
Pilot Project Information Template

PILOT PROJECT #2: South Atlantic Bight

Project Name: SEAMAP Project

Information Source: Distribution of Bottom Habitats on the Continental Shelf from North Carolina through the Florida Keys, April 2001.

Original Collection Contact: Robert VanDolah, South Carolina, DNR
Gary White
Atlantic States Marine Fisheries Commission
1444 Eye Street NW
6th Flr
Washington DC 20005
202-289-6400

Area: US South Atlantic Bight from coast to a depth of 200 m

Bounds: Coastal Atlantic from North Carolina to Florida

Data Collection Period: New data collected and existing data analyzed 1985-1995 but data go back to the 1970s.

Spatial Units: grid 1 minute latitude x 1 minute longitude

Map Scale:

Methodology: Bottom assessment using sonar, video, diver observation, combined trawl data

Additional Variables: ancillary trawl, physico-chemical, biological data

Bathymetry: acquired in diverse formats

South Atlantic Bight SEAMAP Benthic System

Re-Classification in National Coastal/Marine Classification system
Level 1: Gulf Stream Region, Carolinian Region and parts of the Floridian/Bahamian Region
Level 2: Estuarine, Nearshore Marine, Neritic
Level 3: Reef, Bank, Embayment and Open System
Level 4: Photic Subtidal Benthic, Aphotic Subtidal Benthic (water column not mapped)
Level 5: energy not measured
Level 6: Scarp, Ramp, Flat Low-Relief Hardbottom, Flat Low-Relief Softbottom, Reef
Level 7: Platform Reef, Patch Reef, Hardbottom, Softbottom, Sand Ripples, Sand Waves, Rock Outcrops, Mixed Hardbottom-Softbottom Complex
Level 8: Hardbottom Community, Softbottom Community

Figure 5. Overview of SEAMAP survey zones in the South Atlantic

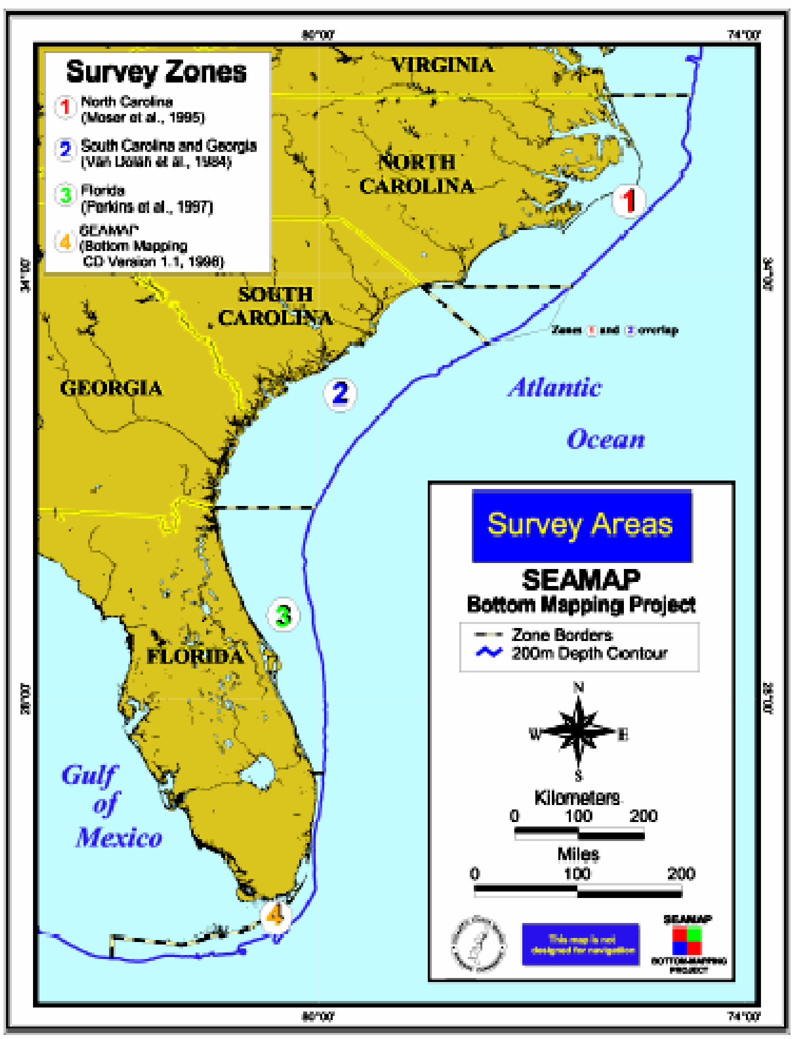
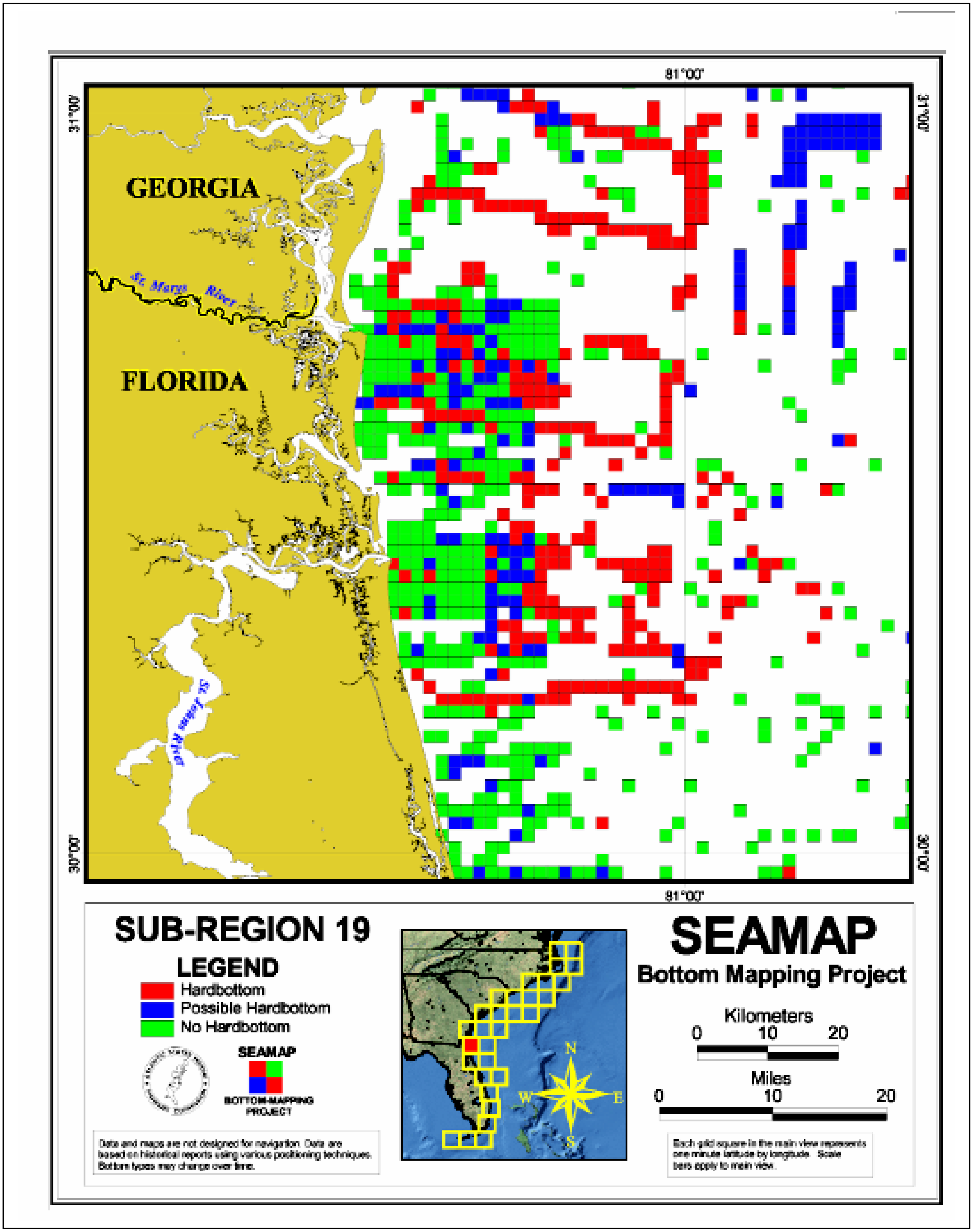


Figure 1 Survey areas for the three SEAMAP documents covering the South Atlantic Bight. Zone Four was included on the SEAMAP bottom mapping CD-ROM.

Figure 6. Example SEAMAP grid for Georgia-Florida with bottom type.



Introduction

The SEAMAP (Southeast Area Monitoring and Assessment Program) project was begun in 1985 with the objective of developing a regional database of hardbottom habitats in the South Atlantic Bight (Figure 5). The extensive database collected or compiled and analyzed over the ensuing decade provides managers with a comprehensive view of bottom type distributions and associated fisheries data from the coast to the shelf break for the states of North Carolina, South Carolina-Georgia, and the Atlantic coast of Florida (Figure 6).

Marine managers consider it particularly important to understand and protect hardbottom habitat as this resource is known to support commercially and ecologically important fish, shellfish and invertebrates. Benthic mapping of the study area was done largely by either seismic profiling, or by trawl data from which inference about habitat was made based on a standard criterion (frequency of occurrence of indicator species). To a lesser extent the area was sampled and ground-truthed by video and sonar.

Because the SEAMAP classification system was designed to focus exclusively on detecting and protecting hardbottom, the classification used to bin the benthic data was simple: a three-element classification: Hardbottom, Possible Hardbottom, No Hardbottom. This classification is of limited use for many other potential mapping and classification applications. However, inspection of the original data reveals that additional characteristics of the environment were recorded that are useful in developing a crosswalk to the national classification. Analysis of the geophysical data acquired by Moser et al. (1995) reveals several bottom features that could be classified into a finer scale 9-element classification system for bottom type from a scheme developed by Ross et al. (1987) as follows:

Tertiary Outcrop
Quaternary Sand
Subbottom Channel
Hardbottom Flats
Hardbottom Flats cored by Subbottom Channel
Low-Relief Scarp (<0.5m)
Moderate-Relief Scarp (0.5-2m)
High-Relief Scarp (>2m)
Ramp

For the SEAMAP project, these types were reduced to the three class types mentioned, with the following designations indicated in the legend in Figure 6: Hardbottom (HB) where clear evidence of hardbottom was shown or three or more hardbottom indicator species were trawled; Possible Hardbottom (PH) where a combination of soft and hardbottom seismic returns were recorded, or where two indicator species were trawled; and No Hardbottom (NH) where clear evidence of softbottom was observed. For SEAMAP, the nine elements from the North Carolina data were converted to this simple scheme according to the following criteria: Flats and Scarps and some Ramps were re- classified as HB if evidence of rock-rubble existed from side-scan sonar; Ramps showing winnowed sands were re-classified as PH; Tertiary outcrops, Quarternary sands and Subbottom channels were re-classified as NH. For the national classification pilot study, the nine classes of bottom type were resolved and translated into the national classification equivalents using the crosswalk in Table 2. The No Hardbottom category is renamed soft bottom.

In addition to the finer resolution of classification afforded by the seismic data, photographic information indicates the kinds of soft bottom encountered in some of the North Carolina transects (Moser et al. 1995) (Figure 7) and hardbottoms encountered in Florida transects (Perkins et al. 1997). While not classified in the original SEAMAP source report as anything other than No Hardbottom and Hardbottom, respectively, the photographs are classified according to finer resolution structure in terms provided by the national classification (Table 2).

Table 2. Translation look-up table relating FMRI classification to equivalent units in the National Coastal/Marine Classification. Note that trawl data did not provide sufficient information to develop biotope or species association relationships to the habitat information reported.

Translation Table:	**NatureServe/NOAA Coastal Marine Classification System**		
NORTH CAROLINA seismic			
SEAMAP DATA NC	**GEOMORPHIC STRUCTURE LEVEL 6**	**HABITAT LEVEL 7**	**BIOTOPE LEVEL 8**
	HARDBOTTOM		
Hardbottom flat	HARDBOTTOM, rock mesa, high profile, low relief	HARDBOTTOM, rock mesa, high profile, low relief	no information
Hardbottom flat cored by subbottom channel	HARDBOTTOM-Sand complex, moderate relief, low profile	HARDBOTTOM-Sand complex, moderate relief, low profile	no information
Low-relief scarp (<0.5m)	HARDBOTTOM, rock scarp, low profile, low relief	HARDBOTTOM, rock scarp, low profile, low relief	no information
Moderate relief scarp (0.5-2m)	HARDBOTTOM, rock scarp, moderate profile, moderate relief	HARDBOTTOM, rock scarp, moderate profile, moderate relief	no information
high-relief scarp (>2m)	HARDBOTTOM, rock scarp, high profile, moderate relief	HARDBOTTOM, rock scarp, high profile, moderate relief	
Ramp	HARDBOTTOM, rock outcrop-rubble complex, ramp, moderate profile, low relief	HARDBOTTOM, rock outcrop-rubble complex, ramp, moderate profile, low relief	
	SOFTBOTTOM		
tertiary outcrop	SOFTBOTTOM, sand outcrop, moderate relief, low profile	SOFTBOTTOM, sand outcrop, moderate relief, low profile	no information
Ramp	SOFTBOTTOM, rock outcrop-sand complex, ramp, moderate profile, low relief	SOFTBOTTOM, rock outcrop-sand complex, ramp, moderate profile, low relief	no information
Quarternary sand	SOFTBOTTOM, sand, flat	SOFTBOTTOM, sand, flat	no information
Subbottom channel	SOFTBOTTOM, sand-silt complex	SOFTBOTTOM, sand-silt complex	no information
NORTH CAROLINA Photographic			
SEAMAP DATA NC			
Figure 72	HARDBOTTOM, flat relief, low profile	HARDBOTTOM-Sand complex, rocky outcrop inclusions, colonized	no information
Figure 73	HARDBOTTOM, flat relief, low profile	HARDBOTTOM, flat relief, low profile, colonized	no information
Figure 74	HARDBOTTOM, flat relief, low profile	HARDBOTTOM, flat relief, low profile, colonized	no information
Figure 75	SOFTBOTTOM, flat relief, low profile	SOFTBOTTOM, flat relief, low profile	no information
Figure 76	SOFTBOTTOM-sand, undulating,	SOFTBOTTOM-sand, undulating,	no information
Figure 77	SOFTBOTTOM, sand-shell hash complex, ripple, flat	SOFTBOTTOM, sand-shell hash complex, ripple, flat	no information
FLORIDA Photographic			
SEAMAP DATA FL	**GEOMORPHIC STRUCTURE LEVEL 6**		
Figure 87	HARDBOTTOM-REEF	HARDBOTTOM-Coral complex, colonized	scleractinian coral octocoral hydrozoan polychaete
Figure 98	REEF	REEF, worm, vegetated, colonized	sebellaridae, macroalga
Figure 99	PINNACLE	REEF, worm, pinnacle inclusion in sand matrix, vegetated, colonized	Oculina varicosa, hardbottom reef fishes
Figure 100	REEF	REEF, worm, Intertidal sabbillarriid reef habitat	sebellaridae, macroalga

Figure 7. Photographs of bottom types in North Carolina SEAMAP transects (Moser et al. 1995)

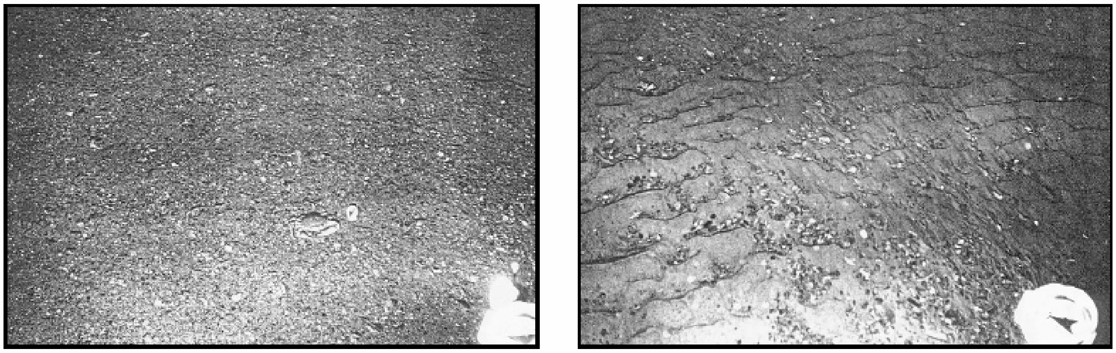


Figure 75 *Representative photographs of sand bottom (NH) taken with an underwater drop camera at station 22223 (left panel) and station 22225 (right panel) in 119 m and 132 m water depths, respectively..*

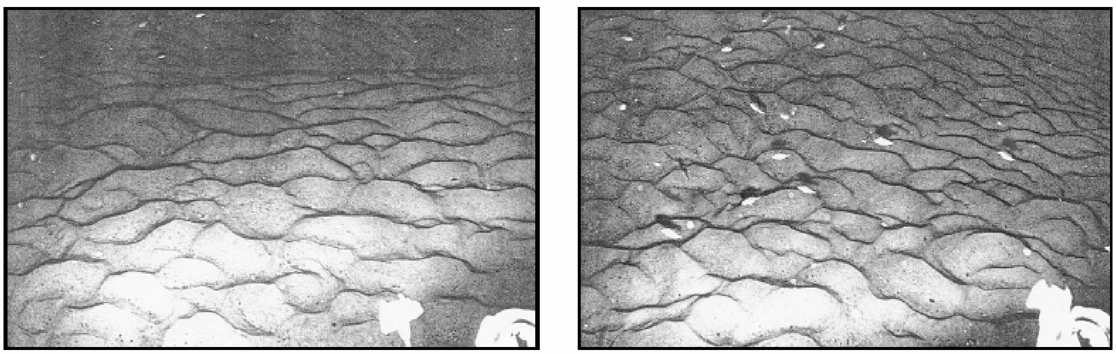


Figure 76 *Representative photographs of sand bottom (NH) taken with an underwater drop camera at station 22229 in 93 m water depth.*

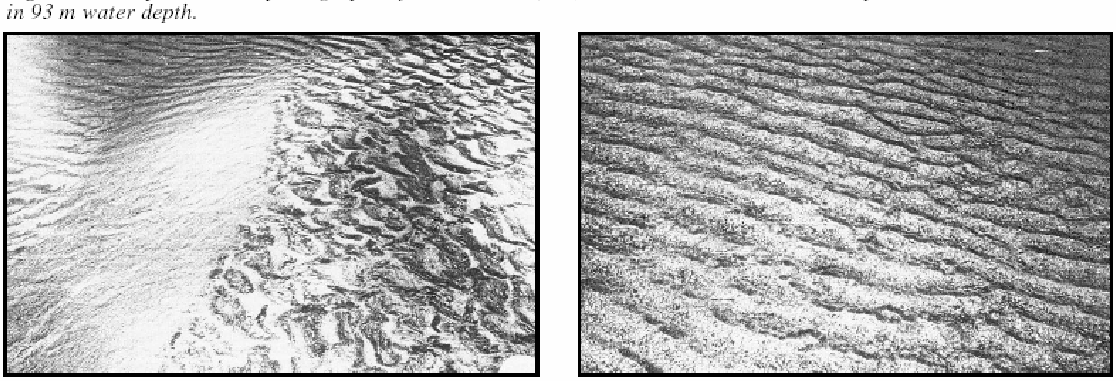


Figure 77 *Representative photographs of sand bottom (NH) taken with an underwater drop camera at station 13050 in water depth of 26 m.*

Analysis

The data gathered for SEAMAP were of a very different type and were much more extensive than for the Florida pilot. However, the SEAMAP data were focused narrowly on the determination of hardbottom areas, so less information was available concerning fine-scale structure of the bottom, water quality parameters and biological associations. SEAMAP data included no aerially remotely sensed images. Most of the study area was at great depth, rendering remote sensing inapplicable. Furthermore, depths often precluded direct observation and ground truthing of the in most of the area. Limited in this way by the tools at hand, the final presentation of the data provided only a narrow look at the distribution of hardbottom without regard to form or structure. Nonetheless, the information provided in the data and metadata afforded an opportunity to classify the region at a much greater degree than intended or attempted by the SEAMAP working group.

As with the Florida Keys pilot, the information presented in the SEAMAP report was first tested by insertion in the upper levels of the national classification to the extent possible. At Level 1 the study area encompasses the Carolinian, Gulf Stream and Floridian-Bahamian biogeographic regions. At Level 2, the area includes the Estuarine, Nearshore Marine, and Neritic Systems. Level 3 large geographic features were within the range and scale of the SEAMAP methodology, but mapping them was not within the scope of the project and large geographic features were not identified in the data. Insufficient continuous data were gathered by SONAR or video to directly characterize large geographic features on the bottom, such as seamounts, etc. And according to SEAMAP protocols, trawl transects were purposefully kept short (15 min) to avoid "smearing" the catch data relative to their position when taken. In existing data, trawls longer than 1 hr were not used at all due to the extreme positional bias introduced by long trawls into fisheries data, so by definition larger geographic features were often not recorded. However, from existing maps and knowledge of the exact positions of the SEAMAP transects, it is possible and would be a relatively simple matter to superimpose major geographic features on the sampled areas, as well as to obtain hydrographic features such as the Gulf Stream current, from existing maps and known data.

The vertical zone, Level 4 is known, since the project is a benthic mapping enterprise, and the littoral and benthic zones were directly mapped. As in the Florida study, the water column was a component of the area sampled, but no direct parameters of the water column (currents, temperature, transparency) were measured as part of this project. It can be assumed that both photic and aphotic bottom were measured in the course of the transects, but no data were provided that indicated where the zones were, or which features or biology were within each zone. The energy regime, Level 5, as in the Florida Keys pilot, was the only level that was not measured or in any way inferable from the data gathered and presented from the original project.

The level on which the original data of the SEAMAP study was almost exclusively focussed was geomorphic structure, Level 6 in the national classification. The parts of the study conducted by side-scan SONAR, uniboom, video and observation gathered data that enabled classification of the bottom geomorphology. The position of these habitats could not be determined SEAMAP report because that information was not included with the SEAMAP data, although it would be obtainable from the original raw data. The SEAMAP classification is extremely coarse and did not discriminate individual geomorphic features, classing all of them "Hardbottom." But from data that was provided with the SEAMAP report and the ancillary classification of Ross et al. (1987) enabled a benthic habitat classification of bottom geomorphology (though not mapping) using a subset of the data. The geomorphic types in the Ross study corresponded to types in the national classification and were nearly identical to (but fewer in number than) several of the sea-floor types developed by Greene et al. (1999), the source material for Level 6 of the national classification.

This pilot exercise emphasizes that habitat can occur at different levels of the hierarchy at different scales, depending on the biota being considered. The habitats reported in this pilot were completely within Level 6 of the national classification, being based solely on geomorphology, rather than the finer scale of the "habitat" level 7 or "biotope" level 8. Very little additional modifier data was included. Yet, the data and metadata were sufficient to enable characterization of the area within the hierarchy of the national coastal/marine classification, yielding useful value-added information about the habitat from the upper levels. Although at a coarse level, the data presented in Pilot #2 are sufficient for characterizing bottom to a degree that is useful to managers seeking to relate hardbottom habitat to living resources and to make decisions about how to manage and conserve such areas.

Literature Cited (Appendix 6)

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Ross, S. W. E. K. Barber, R. B. Searles, and S. R. Riggs. 1987. An evaluation of methods for mapping hardbottoms in the South Atlantic Bight. Compilation Report S.E. Area Monitoring Assess. Prog. Project SM-11 122.pp.

SEAMAP. 2001. Southeast area monitoring and assessment program- South Atlantic (SEAMAP-SA). 2001. Distribution of bottom habitats on the continental shelf from North Carolina through the Florida Keys. SEAMAP-SA Bottom Mapping Workgroup, Atlantic States Marine Fisheries Commission, Washington D.C. 166 p.

Appendix 7: CMECS: Habitat Classification Framework

This appendix presents the framework of the Coastal Marine Ecological Classification Standard. It depicts the eight levels of the system plus a column that includes biological types that are reported to be associated with each habitat type.

Level 1 Ecoregion have not been included in this table for simplicity as they are listed in the main text of this report, but the classification as depicted can be viewed as fitting into each of the ecological regions. **Level 2 Regime** is listed in column 1, dividing systems influenced by fresh water from those that are truly marine. **Level 3 System** separates those fresh systems that are true estuaries, morphologically, from those open water systems that receive some input of fresh water flow from land but are not considered estuaries. The marine regime is divided into three systems based on depth and relation to the shelf break.

Level 4 Geoform/Hydroform breaks down each of the systems into its major structural components. **Level 5 Zone** introduces the distinction between water column, littoral and bottom components in each Geoform and Hydroform. These are listed in a notation that describes both the zone (W=water column; L=littoral; B=bottom) and the subzone (for W, U=upper layer; B=bottom layer; for L, I=intertidal; S=Supratidal; subzones for the bottom are not listed). It can be noted that not every form in column 3 has a complete set of zones. Hydroforms tend to have only water column components, and some geoforms have only bottom components (e.g., seamount). Some geoforms, such as lagoons have all three zones.

Level 6 Macrohabitat lists the finer structural components within the larger geoform and zone. If there is a littoral component and a water column component for a macrohabitat, they are listed as separate macrohabitats. **Level 7 Habitat** represents distinct physical subunits of every macrohabitat. These units are determined through application of standard modifiers that are listed in Appendix 2 (e.g., energy, salinity, substrate), or separation of biophysical units (e.g., reef crest from fore reef). These habitats are identified by extensive use of the local classifications and literature review. The current list represents types recognized by many current classifications. As the CMECS classification is applied and refined, additional habitat units will be formally identified and included.

Level 7 Biotope will similarly be expanded and refined through use of the classification. The biotope is the basic unit of classification of the biota. It represents the conjunction of a habitat and the dominant fixed biological species associated, and will be expressed as a habitat-biota combination (e.g., nearshore marine bottom vegetated carbonate softbottom-mixed *Thalassia testudinum/Halodule wrightii*). A nomenclature and rules set for identifying and accepting units as biotopes in under development and will be completed as an extension of this work. Pending the formulation of biotopes, biological information associated with the habitats has been included in the final column. This information represents a variety of biological associations, along with lists of dominant species, diagnostic species, and common species. This growing body of information will form the basis for formally naming the biotopes.

An extensive set of biotopes has been identified locally for the British Isles (Costello 1995; Costello 2003). The rules and nomenclature for them are described in Picton and Costello (1998) and widely available via the Biotope Viewer, (www.ecoserve.ie/biomar/viewer.html) and the Ocean Biogeographic Information System (OBIS, Zhang and Grassle 2003). It is expected that the comprehensive biotope list for the coastal and marine habitats of the U.S. will be similar.

Ultimately, it is expected that the CMECS habitat and biotope catalog will bridge to all existing systems and will become a global standard for habitat classification under OBIS.

Literature Cited (Appendix 7)

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Zhang, Y. and J. F. Grassle. 2003. A portal for the Ocean Biogeographic Information System. Oceanologica 25: 193-197.

Appendix 7: COASTAL MARINE ECOLOGICAL CLASSIFICATION STANDARD (CMECS): HABITAT CLASSIFICATION FRAMEWORK
Madden and Grossman 2004

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
I- Fresh Influenced	A. Estuarine	1. Lagoon	WU- Water Col. (upper layer)	a. estuarine water column	estuarine turbidity maximum		
					pycnocline		
					upper water column		
					small fresh water lens		
					hyperhaline estuarine water column		
					phytoplankton bloom		
					epipelagic zone		
					floating vegetation mat		
					tributary discharge zone		
					counter current		
I- Fresh Influenced	A. Estuarine	1. Lagoon	WB- Water Col.		anoxic bottom water		
			(bottom layer)		oxic bottom water		
					salt wedge		
					groundwater seep		
					benthic boundary layer		
I- Fresh Influenced	A. Estuarine	1. Lagoon	LS-Littoral Supratidal	a. unconsolidated sediments	bare organic mud		
					bare carbonate sediment		
					bare carbonate mud		
					bare carbonate sand		
					bare mixed-coarse sediment softbottom		
					vegetated mineral sediments		
					vegetated organic sediments		
				b. rocky shore	bedrock shore		*Littorina*
					hardpan shore		Balanus, boring polychaete
					boulder shore		

Appendix 7: COASTAL MARINE ECOLOGICAL CLASSIFICATION STANDARD (CMECS): HABITAT CLASSIFICATION FRAMEWORK
Madden and Grossman 2004

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					cobble shore		
					sand-bedrock shore		
				c. dune system	foredune		*Uniola, ammophila, hudsonia*
					dune crest		*Uniola, ammophila, hudsonia*
					backdune		*Uniola, ammophila, hudsonia*
				d. cliff	cliff notch		
					cliff bioerosion notch		
					cliff cave		
					cliff fracture		
					cliff rubble zone		
				e. mangrove swamp	prop root zone		*Rhizophora*
					basin swamp		*Laguncularia*
					buttonwood ridge		*Conocarpus*
					pneumatophore zone		*Avicennia*
					swamp creek		mixed scrub mangrove
I- Fresh Influenced	A. Estuarine	1. Lagoon	LI- Littoral Intertidal	a. unconsolidated sediments	bare organic mud softbottom		
					bare carbonate sediment softbottom		
					bare carbonate mud softbottom		
					bare carbonate sand softbottom		
					bare mixed-coarse sediment softbottom		isopods, polychaetes
					vegetated softbottom- holdfast (macroalgae bed)		Green ulvoid algae, Macoma
					vegetated softbottom- rooted (seagrass bed)		*Thalassia, Zostera, Halodule, Syringodium*
					vegetated organic softbottom		*Salicornia, Distichlis, Typha,Deschampsia, Juncus*
				b. mudflat	fringing vegetated brackish mudflat		*Juncus, Eleocharis, Spartina patens*
					fringing vegetated saline mudflat		*Ranunculus, Spartina*
					bare brackish mudflat		benthic microalgae, Limulus, Ilyanassa
					bare saline mudflat		benthic microalgae, Limulus, Ilyanassa
				c. saline fringing wetland (marsh)	saline fringing wetland tidal pass		
					saline fringing wetland tidal creek		
					saline fringing wetland tidal creek bank		*Spartina alterniflora, Distichlis*
					saline wetland hammock		
					saline wetland inland basin marsh		

Appendix 7: COASTAL MARINE ECOLOGICAL CLASSIFICATION STANDARD (CMECS): HABITAT CLASSIFICATION FRAMEWORK
Madden and Grossman 2004

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					saline wetland streamside marsh		
				d. brackish fringing wetland (marsh)	brackish fringing wetland tidal pass		
					brackish fringing wetland tidal creek		*Crassostrea virginica, C. rhizophora*
					brackish fringing wetland tidal creek bank		*Eleocharis, Juncus, Spartina patens*
					brackish wetland hammock		*Salix*
					brackish wetland inland basin marsh		*Juncus*
					brackish wetland streamside marsh		*Spartina Cynoseroides*
				e. hardbottom	bare gravel hardbottom		*Fucus*
					bare limestone pavement hardbottom		
					bare bedrock hardbottom		
				f. cliff	notch		
					bioerosion notch		
					cave		
					fracture		
					rubble zone		
				g. mangrove swamp	prop root zone		*Rhizophora*
					basin swamp		*Laguncularia*
					buttonwood ridge		*Conocarpus erectus, Crabs Uca pugnax, Callinectes sapidus*
					pneumatophore zone		*Avicennia*
					swamp creek		mixed scrub mangrove
					basin pond		scrub black mangrove (Avicennia)
				h. coastal beach	sand beach		
					mixed-fine sediment beach		*Scirpis, Carex*
					mixed-fine sand and mud beach		*Macoma*
					mud beach		*Macoma*
					rock and boulder beach		*Zostera, Gracilaria, Macoma*
					cobble beach		*Salicornia, Distichlis*
					mixed-coarse sediment beach		*Salicornia, Distichlis, Carex*
					gravel beach		*Zostera*

Appendix 7: COASTAL MARINE ECOLOGICAL CLASSIFICATION STANDARD (CMECS): HABITAT CLASSIFICATION FRAMEWORK
Madden and Grossman 2004

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
				i. rocky shore	bedrock shore		*Littorina, Fucus, Ascophyllum*
					hardpan shore		*Balanus, boring polychaete*
					boulder shore		
					cobble shore		
					sand-bedrock shore		
I- Fresh Influenced	A. Estuarine	1. Lagoon	B- Bottom	a. oyster reef	live oyster reef		*Crassostrea virginica*
					relict oyster reef		
					submerged oyster reef		*Crassostrea virginica*
					periodically emergent oyster reef		*Crassostrea virginica*
					oyster shell midden		
				b. worm reef	live worm reef		*Sabellaria*
					relict worm reef		
					live mussel reef		
					relict mussel reef		
				c. unconsolidated sediments	bare sandy softbottom		
					bare mineral mud softbottom		
					bare organic mud softbottom		
					bare carbonate mud-shell hash softbottom		
					bare carbonate mud softbottom		
					bare carbonate sand softbottom		
					bare mixed-coarse sediment softbottom		
					colonized mixed-fine softbottom		bivalves Psephidia, Mysella
					vegetated mud and mixed-fine softbottom		*Zostera, Red algae*
					bare gravel softbottom		isopods, polychaetes
					vegetated softbottom		*Thalassia, Zostera, Halodule, Syringodium*
					colonized softbottom		
					vegetated colonized softbottom		*surfgrass, Zostera, Macoma*
				d. hardbottom	bare limestone pavement hardbottom		

Appendix 7: COASTAL MARINE ECOLOGICAL CLASSIFICATION STANDARD (CMECS): HABITAT CLASSIFICATION FRAMEWORK
Madden and Grossman 2004

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					vegetated rock and boulder hardbottom		*Macrocystis*
					cobble hardbottom		horse mussel (Modiolus), Balanus
					gravel hardbottom		polychaetes, isopods
					boulder hardbottom		
					bedrock hardbottom		
					colonized tidal creek bottom		*Crassostrea virginica*
I- Fresh Influenced	A. Estuarine	2- Embayment	WU- Water Col.	a. estuarine water column	estuarine turbidity maximum		
			(upper layer)		pycnocline		phytoplankton maximum, Acartia
					upper water column		
					small fresh water lens		
					hyperhaline estuarine water column		
					phytoplankton bloom		
					epipelagic zone		
					floating vegetation mat		*Eichornia*
					tributary discharge zone		
I- Fresh Influenced	A. Estuarine	2- Embayment	WB- Water Col.		counter current		Sheepshead minnow
			(bottom layer)		anoxic bottom water		
					oxic bottom water		
					salt wedge		Pink shrimp
					groundwater seep		
					benthic boundary layer		
I- Fresh Influenced	A. Estuarine	2- Embayment	LS-Littoral Supratidal	a. unconsolidated sediments	bare organic mud		
					bare carbonate sediment		
					bare carbonate mud		
					bare carbonate sand		
					bare mixed-coarse sediment softbottom		
					vegetated mineral sediments		
					vegetated organic sediments		

Appendix 7: COASTAL MARINE ECOLOGICAL CLASSIFICATION STANDARD (CMECS): HABITAT CLASSIFICATION FRAMEWORK
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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
				b. rocky shore	bedrock shore		*Littorina*
					hardpan shore		Balanus, boring polychaete
					boulder shore		
					cobble shore		
					sand-bedrock shore		
				c. dune system	foredune		
					dune crest		
					backdune		
				d. cliff	cliff notch		
					cliff bioerosion notch		
					cliff cave		
					cliff fracture		
					cliff rubble zone		
				e. mangrove swamp	prop root zone		*Rhizophora*
					basin swamp		*Laguncularia*
					buttonwood ridge		*Conocarpus*
					pneumatophore zone		*Avicennia*
					swamp creek		mixed scrub mangrove
I- Fresh Influenced	A. Estuarine	2- Embayment	LI- Littoral Intertidal	a. unconsolidated sediments	bare organic mud softbottom		
					bare carbonate sediment softbottom		
					bare carbonate mud softbottom		
					bare carbonate sand softbottom		
					bare mixed-coarse sediment softbottom		isopods, polychaetes
					vegetated softbottom- holdfast (macroalgae bed)		Green ulvoid algae, Macoma
					vegetated softbottom- rooted (seagrass bed)		*Thalassia, Zostera, Halodule, Syringodium*
					vegetated organic softbottom		*Salicornia, Distichlis, Typha,Deschampsia, Juncus*
				b. mudflat	fringing vegetated brackish mudflat		*Juncus, Eleocharis, Spartina patens*
					fringing vegetated saline mudflat		*Ranunculus, Spartina*

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					bare brackish mudflat		benthic microalgae, Limulus, Ilyanassa
					bare saline mudflat		benthic microalgae, Limulus, Ilyanassa
				c. saline fringing wetland (marsh)	saline fringing wetland tidal pass		
					saline fringing wetland tidal creek		
					saline fringing wetland tidal creek bank		*Spartina alterniflora, Distichlis*
					saline wetland hammock		
					saline wetland inland basin marsh		
					saline wetland streamside marsh		
				d. brackish fringing wetland (marsh)	brackish fringing wetland tidal pass		
					brackish fringing wetland tidal creek		*Crassostrea virginica, C. rhizophora*
					brackish fringing wetland tidal creek bank		*Eleocharis, Juncus, Spartina patens*
					brackish wetland hammock		
					brackish wetland inland basin marsh		
					brackish wetland streamside marsh		
				e. hardbottom	bare gravel hardbottom		
					bare limestone pavement hardbottom		
					bare bedrock hardbottom		
				f. cliff	cliff notch		
					cliff bioerosion notch		
					cliff cave		
					cliff fracture		
					cliff rubble zone		
				g. mangrove swamp	prop root zone		*Rhizophora*
					basin swamp		*Laguncularia*
					buttonwood ridge		*Conocarpus*
					pneumatophore zone		*Avicennia*
					swamp creek		mixed scrub mangrove
					basin pond		scrub black mangrove (Avicennia)

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
				h. beach	sand beach		
					mixed-fine sediment beach		*Scirpis, Carex*
					mixed-fine sand and mud beach		*Macoma*
					mud beach		
					rock and boulder beach		*Zostera, Gracilaria, Macoma*
					cobble beach		*Salicornia, Distichlis*
					mixed-coarse sediment beach		*Salicornia, Distichlis, Carex*
					gravel beach		*Zostera*
				i. rocky shore	bedrock shore		*Littorina, Fucus, Ascophyllum*
					hardpan shore		Balanus, boring polychaete
					boulder shore		
					cobble shore		
					sand-bedrock shore		
					foredune		*Uniola, ammophila, hudsonia*
					dune crest		*Uniola, ammophila, hudsonia*
					backdune		*Uniola, ammophila, hudsonia*
I- Fresh Influenced	A. Estuarine	2- Embayment	B- Bottom	a. oyster reef	live oyster reef		*Crassostrea virginica*
					relict oyster reef		*Crassostrea virginica*
					submerged oyster reef		*Crassostrea virginica*
					periodically emergent oyster reef		*Crassostrea virginica*
					oyster shell midden		*Crassostrea virginica*
				b. worm reef	live worm reef		*Sabellaria*
					relict worm reef		*Sabellaria*
					live mussel reef		*Mytelis*
					relict mussel reef		*Mytelis*
				c. unconsolidated sediments	bare sandy softbottom		*Ptilosarcus guerneyi*
					bare mineral mud softbottom		
					bare organic mud softbottom		

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					bare carbonate mud-shell hash softbottom		
					bare carbonate mud softbottom		
					bare carbonate sand softbottom		
					bare mixed-coarse sediment softbottom		surfgrass, zostera
					colonized mixed-fine softbottom		bivalves Psephidia, Mysella
					vegetated mud and mixed-fine softbottom		*Zostera marina*
					bare gravel softbottom		isopods, polychaetes
					vegetated softbottom		*Thalassia, Zostera, Halodule, Syringodium*
					colonized softbottom		
					vegetated colonized softbottom		
				d. hardbottom	bare limestone pavement hardbottom		
					vegetated rock and boulder hardbottom		kemp (Macrocystis)
					cobble hardbottom		horse mussel (Modiolus), Balanus
					gravel hardbottom		polychaetes, isopods
					boulder hardbottom		
					bedrock hardbottom		
					colonized tidal creek bottom		*Crassostrea virginica*
I- Fresh Influenced	A. Estuarine	3. Open Shoreline	WC	a. estuarine water column	sea surface		
					surf zone		
				a. wave zone			
		3. Open Shoreline	LI- Littoral Intertidal	a. unconsolidated sediments			
				b. rocky shore			
				c. dune system			
				d. mangrove swamp			
				e. fringing marsh			
		3. Open Shoreline	B	a. unconsolidated sediments			
				b. hardbottom			
				c. reef	worm reef		

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					mussel reef		
I- Fresh Influenced	A. Estuarine	4. Surface channel (River)	WC	a. river current	turbid upper water column		
					clear upper water column		
		4. Surface channel (River)	L	a. riverbank	vegetated		
					mud		
					rocky		
		4. Surface channel (River)	B	a. riverbed	softbottom		
					hardbottom		
					scour hole		
					organic deposition zone		
I- Fresh Influenced	A. Estuarine	5. Island	L	a. rocky shore			
				b. unconsolidated sediments			
				c. reef	worm reef bed		
					mussel bed		
					coral head		
		5. Island	B				
I- Fresh Influenced	A. Estuarine	6. Delta	WC	a. interlobe pass			
		6. Delta	L	a. deltaic mudflat			
		6. Delta	B	a. deltaic chenier			
			B	b. deltaic unconsolidated sediments			
I- Fresh Influenced	A. Estuarine	7. Wetland	WC	a. deeply flooded wetland water column	deeply flooded wetland water column		
		7. Wetland	LI- Littoral Intertidal	a. brackish fringing wetland (marsh)			
				b. saline fringing wetland (marsh)			
			B				
I- Fresh Influenced	A. Estuarine	8. Bank	B				
I- Fresh Influenced	A. Estuarine	9. Slough	LI- Littoral Intertidal				
I- Fresh Influenced	B. Estuarine-Influenced	1. Estuarine plume	WU- Water Col.	a. turbid estuarine water column	phytoplankton bloom floating mat		
		2. Fresh water lens	WU-Water Col.		phytoplankton bloom		

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					floating mat		
		3. Open shoreline	WU- Water Col.				
			LI- Littoral Intertidal				
			B				
		4. Chenier	LS-Littoral Supratidal	a. dune			
				b. hammock			
				c. pool			
		5. Island	LI- Littoral Intertidal				
			LS-Littoral Supratidal				
I- Fresh Influenced	A. Estuarine	6. Shoal	B				
I- Fresh Influenced	A. Estuarine	7. Subsurface Channel	B				
I- Fresh Influenced	A. Estuarine	8. Reef	LI- Littoral Intertidal	a. intertidal oyster reef			
		9. Reef	B	b. subtidal oyster reef			
				c. coral reef	relict coral		
I- Fresh Influenced	A. Estuarine	10. Current system	WC	a. estuarine water column			
I- Fresh Influenced	A. Estuarine	11. Open Water	WC	a. estuarine water column			
I- Fresh Influenced	A. Estuarine	12. Downwelling	WC	a. divergence zone			
I- Fresh Influenced	A. Estuarine	13. Upwelling	WC	a. convergence zone			
I- Fresh Influenced	A. Estuarine	14. Wave zone	WC	a. wave zone			
			B	a. infratidal wave zone			
I- Fresh Influenced	A. Estuarine	15. Ice	LI- Littoral Intertidal				
I- Fresh Influenced	A. Estuarine	16. River plume	WC	a. estuarine water column	phytoplankton bloom		
I- Fresh Influenced	A. Estuarine	17. Deposition site	B	a. unconsolidated sediments			
I- Fresh Influenced	A. Estuarine	18. Turbidity current	WC	a. turbid water column			
I- Fresh Influenced	A. Estuarine	19. Coastal water mass	WC	b. turbid water column			
				a. clear water column			
I- Fresh Influenced	A. Estuarine	20. Submarine slump	B	a. unconsolidated sediments			
II. Marine	A. Nearshore Marine	1. Lagoon	WU- Water Col. (upper layer)	a. marine water column	upper water column pycnocline		

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					hyperhaline water column		
					phytoplankton bloom		
					epipelagic zone		
					floating vegetation mat		
					counter current		
					surf zone		
					sea surface		
II. Marine	A. Nearshore Marine	1. Lagoon	WB- Water Col.		anoxic bottom water		
			(bottom layer)		oxic bottom water		
					salt wedge		
					groundwater seep		
					benthic boundary layer		
II. Marine	A. Nearshore Marine	1. Lagoon	LS-Littoral Supratidal	a. unconsolidated sediments	bare organic mud		
					bare carbonate sediment		
					bare carbonate mud		
					bare carbonate sand		
					bare mixed-coarse sediment softbottom		
					vegetated mineral sediments		
					vegetated organic sediments		
				b. rocky shore	bedrock shore		*Littorina*
					hardpan shore		Balanus, boring polychaete
					boulder shore		
					cobble shore		
					sand-bedrock shore		
				c. dune system	foredune		*Uniola, ammophila, hudsonia*
					dune crest		*Uniola, ammophila, hudsonia*
					backdune		*Uniola, ammophila, hudsonia*
				d. cliff	cliff notch		

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					cliff bioerosion notch		
					cliff cave		
					cliff fracture		
					cliff rubble zone		
				e. mangrove swamp	prop root zone		*Rhizophora*
					basin swamp		*Laguncularia*
					buttonwood ridge		*Conocarpus*
					pneumatophore zone		*Avicennia*
					swamp creek		mixed scrub mangrove
II. Marine	A. Nearshore Marine	1. Lagoon	LI- Littoral Intertidal	a. unconsolidated sediments	bare organic mud softbottom		
					bare carbonate sediment softbottom		
					bare carbonate mud softbottom		
					bare carbonate sand softbottom		
					bare mixed-coarse sediment softbottom		isopods, polychaetes
					vegetated softbottom- holdfast (macroalgae bed)		Green ulvoid algae, Macoma
					vegetated softbottom- rooted (seagrass bed)		*Thalassia, Zostera, Halodule, Syringodium*
					vegetated organic softbottom		*Salicornia, Distichlis, Typha,Deschampsia, Juncus*
				b. mudflat	fringing vegetated brackish mudflat		*Juncus, Eleocharis, Spartina patens*
					fringing vegetated saline mudflat		*Ranunculus, Spartina*
					bare brackish mudflat		benthic microalgae, Limulus, Ilyanassa
					bare saline mudflat		benthic microalgae, Limulus, Ilyanassa
				c. saline fringing wetland (marsh)	saline fringing wetland tidal pass		
					saline fringing wetland tidal creek		
					saline fringing wetland tidal creek bank		*Spartina alterniflora, Distichlis*
					saline wetland hammock		
					saline wetland inland basin marsh		
					saline wetland streamside marsh		
				d. brackish fringing wetland (marsh)	brackish fringing wetland tidal pass		

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					brackish fringing wetland tidal creek		*Crassostrea virginica, C. rhizophora*
					brackish fringing wetland tidal creek bank		*Eleocharis, Juncus, Spartina patens*
					brackish wetland hammock		*Salix*
					brackish wetland inland basin marsh		*Juncus*
					brackish wetland streamside marsh		*Spartina Cynoseroides*
				e. hardbottom	bare gravel hardbottom		*Fucus*
					bare limestone pavement hardbottom		
					bare bedrock hardbottom		
				f. cliff	notch		
					bioerosion notch		
					cave		
					fracture		
					rubble zone		
				g. mangrove swamp	prop root zone		*Rhizophora*
					basin swamp		*Laguncularia*
					buttonwood ridge		*Conocarpus erectus, Crabs Uca pugnax, Callinectes sapidus*
					pneumatophore zone		*Avicennia*
					swamp creek		mixed scrub mangrove
					basin pond		scrub black mangrove (Avicennia)
				h. beach	sand beach		
					mixed-fine sediment beach		*Scirpis, Carex*
					mixed-fine sand and mud beach		*Macoma*
					mud beach		*Macoma*
					rock and boulder beach		*Zostera, Gracilaria, Macoma*
					cobble beach		*Salicornia, Distichlis*
					mixed-coarse sediment beach		*Salicornia, Distichlis, Carex*
					gravel beach		*Zostera*
				i. rocky shore	bedrock shore		*Littorina, Fucus, Ascophyllum*

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					hardpan shore		*Balanus, boring polychaete*
					boulder shore		
					cobble shore		
					sand-bedrock shore		
				j. oyster reef	live oyster reef		*Crassostrea virginica*
					relict oyster reef		
					submerged oyster reef		*Crassostrea virginica*
					periodically emergent oyster reef		*Crassostrea virginica*
					oyster shell midden		
				k. mussel reef	live mussel reef		
					relict mussel reef		
				l. coral reef	relict coral reef		
				k. worm reef	live worm reef		*Sabellaria*
					relict worm reef		
II. Marine	A. Nearshore Marine	2. Embayment	WU- Water Col.	a. marine water column	upper water column		
			(upper layer)		pycnocline		
					hyperhaline water column		
					phytoplankton bloom		
					epipelagic zone		
					floating vegetation mat		
					counter current		
			WB- Water Col.		anoxic bottom water		
			(bottom layer)		oxic bottom water		
					salt wedge		
					groundwater seep		
					benthic boundary layer		
II. Marine	A. Nearshore Marine	3. Open shoreline	WU- Water Col.	a. marine water column			
II. Marine	A. Nearshore Marine	3. Open shoreline	LI	a.unconsolidated sediments			

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
				b. mudflat			
				c. saline fringing wetland (marsh)			
				d. brackish fringing wetland (marsh)			
				e. hardbottom			
				f. cliff			
				g. mangrove swamp			
II. Marine	A. Nearshore Marine	3. Open shoreline	B	a. unconsolidated sediments			
				b. rocky shore			
II. Marine	A. Nearshore Marine	4. Surface channel	W	a. river current			
			L	b. riverbank			
			B	c. riverbed			
II. Marine	A. Nearshore Marine	5. Island	W				
			L				
			B				
II. Marine	A. Nearshore Marine	6. Marine Delta	W	a. interlobe pass			
			L	b. deltaic mudflat			
			B	c. deltaic chenier			
			B	d. deltaic unconsolidated sediments			
II. Marine	A. Nearshore Marine	7. Wetland	W				
			L				
			B				
II. Marine	A. Nearshore Marine	8. Bank	B				
II. Marine	A. Nearshore Marine	9. Shoal	B				
II. Marine	A. Nearshore Marine	10. Subsurface Channel	B				
II. Marine	A. Nearshore Marine	11. Reef	L	a. oyster reef			
			B				
				b. coral reef	forereef		
					backreef		

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					spur and groove		
					reef halo		
					reef remnant		
					sand channel		
					patch reef		
					aggregated patch reefs		
					pinnacle		
					fringe reef		
					linear reef		
					platform		
					individual coral head		
					reef rubble		
		12. Current system	W				
		13. Open Water	W				
		14. Downwelling	W				
		15. Upwelling	W				
		16. Wave zone	W				
			B				
		17. Ice	W				
			L				
			W				
		19. Anchialine Lake	W				
			L				
			B				
		20. Deposition site	B	a. unconsolidated sediments			
		21. Major turbidity current	W	a. turbid water column			
		22. Coastal water mass	W				

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
		23. Submarine slump	B				
II. Marine	B. Neritic	1. Island	WC-U	see classes for Nearshore Marine Lagoon WC-U			
			LI	a. unconsolidated sediments			
				b. basalt pinnacle/rock/stack			
				c. low coral islet			
				d. high basalt island			
				e. high limestone island			
			B				
		2. Island arc	WC-U	a. inter-island pass	clear water column		
			LI		turbid water column		
			B				
		3. Atoll	WC-U	a. interior lagoon	clear water column		
			B	b. coral reef	bare carbonate sand softbottom		
					patch reef		
					patch reef with halo		
					forereef		
					backreef		
					spur and groove		
					reef halo		
					reef remnant		
					sand channel		
					patch reef		
					aggregated patch reefs		
					pinnacle		
					fringe reef		
					linear reef		
					platform		
					individual coral head		

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					reef rubble		
				c. hardbottom	bare limestone pavement hardbottom		
				d. unconsolidated sediments	carbonate sediments		
					bare mineral mud softbottom		
					bare organic mud softbottom		
					bare carbonate mud-shell hash softbottom		
					bare carbonate mud softbottom		
		4. Iceberg	WC				
			L				
		5. Mixed layer	WC				
		6. Frontal boundary	WC				
		7. Plunging current	WC				
		8. Density current	WC				
		9. Upwelling	WC				
		10. Downwelling	WC				
		11. Current system	WC				
		12. Mesoscale eddy	WC				
		13. Ice	WC				
		14. Stratified layer	WC				
		15. Open Water	WC				
		16. Benthic boundary layer	WC				
		17. Sea surface	WC				
		18. Vent					
		17. Trench	B				
		18. Plain	B	a. lava field	compression ridge		
					lava tube		
					crater		
					lava flow		

Appendix 7: COASTAL MARINE ECOLOGICAL CLASSIFICATION STANDARD (CMECS): HABITAT CLASSIFICATION FRAMEWORK
Madden and Grossman 2004

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
				b. sediment wave	organic debris		
					mud		
					sand		
				c. bar	mud		
					sand		
					hardbottom		
				d. moraine	gravel		
					pebble		
					cobble		
					boulder		
					mixed		
					bedrock		
				e. cave	bedrock		
					coral		
					lava		
				f. crevice	bedrock		
					coral		
					lava		
				g. sink	hardbottom		
				h. debris field	gravel		
					pebble		
					cobble		
					boulder		
					mixed		
					bedrock		
				i. groove	bedrock		
					coral		
				j. channel	bedrock		

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
					coral		
				k. ledge	bedrock		
					coral		
				l. wall	bedrock		
					coral		
				m. pinnacle	coral		
				n. mound			
				o. slabs			
				p. terrace			
				q. vent			
		19. Ridge	B				
		20. Seep	B				
		21. Fissure	B				
		22. Seabed	B				
		23. Bank	B				
		24. Submarine canyon	B	a. head			
				b. upper			
				c. middle			
				d. lower			
		25. Artificial structure		a. wreck			
				b. breakwater			
				c. pier			
		26. Deepwater Reef	B				
		27. Ice	W				
		28. Turbidity current	W				
		29. Coastal water mass	W				
		30. Submarine slump	B				
		31. Deposition site	B				

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II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
		32. Wave zone	W				
II. Marine	Oceanic	1. Island	L	see classes for Nearshore Marine Lagoon LI			
			B	see classes for Nearshore Marine Lagoon B			
		2. Island arc	WC				
			L				
			B				
		3. Atoll	WC	a. interior lagoon	clear water column		
			B	b. coral reef	bare carbonate sand softbottom		
					patch reef		
					patch reef with halo		
					bare limestone pavement hardbottom		
					carbonate sediments		
					bare mineral mud softbottom		
					bare organic mud softbottom		
					bare carbonate mud-shell hash softbottom		
					bare carbonate mud softbottom		
		4. Iceberg	WC				
			L				
		5. Mixed layer	WC				
		6. Frontal boundary	WC				
		7. Plunging current	WC				
		8. Density current	WC				
		9. Upwelling	WC				
		10. Downwelling	WC				
		11. Current system	WC				
		12. Mesoscale eddy	WC				
		13. Gyre	WC				
		14. Stratified layer	WC				

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
		15. Open Water	WC				
		16. Benthic boundary layer	WC				
		17. Sea surface	WC				
		18. Vent	B				
		17. Trench	B				
		18. Plain	B	a. lava field	compression ridge		
					lava tube		
					crater		
					lava flow		
				b. sediment wave	organic debris		
					mud		
					sand		
				c. bar	mud		
					sand		
					hardbottom		
				d. moraine	gravel		
					pebble		
					cobble		
					boulder		
					mixed		
					bedrock		
				e. cave	bedrock		
					coral		
					lava		
				e. crevice	bedrock		
					coral		
					lava		
				f. sink	hardbottom		

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
				g. debris field	gravel		
					pebble		
					cobble		
					boulder		
					mixed		
					bedrock		
				h. groove	bedrock		
					coral		
				I. channel	bedrock		
					coral		
				j. ledge	bedrock		
					coral		
				k. wall	bedrock		
					coral		
				l. pinnacle			
				m. mound			
				n. slabs			
				o. terrace			
				p. vent			
		19. Midocean Ridge	B				
		20. Seep	B				
		21. Fissure	B				
		22. Seabed	B				
		23. Bank	B				
		24. Submarine canyon	B	a. head			
				b. upper			
				c. middle			
				d. lower			

Appendix 7: COASTAL MARINE ECOLOGICAL CLASSIFICATION STANDARD (CMECS): HABITAT CLASSIFICATION FRAMEWORK
Madden and Grossman 2004

II. Regime	III. System	IV. Geoform/Hydroform	V. Zone	VI. Macrohabitat	VII. Habitat (under development)	VIII. Biotope (to be developed)	Associated Biology
		25. Seamount	B	a. top			
			B	b. flank			
			B	c. base			
		26. Deepwater Reef	B				
		27. Ice	WC				
		28. Turbidity current	WC				
		29. Coastal water mass	WC				
		30. Submarine slump	B				
		31. Deposition site	B				
		32. Wave zone	WC				