

# **The Coastal and Marine Ecological Classification Standard (CMECS)**

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## **Introduction**

This document contains the Coastal and Marine Ecological Classification Standard (CMECS) Catalog Version 1.1.0. This version includes changes to the Substrate Component, where units were added, deprecated and re-arranged, definitions were revised, and implementation guidance was added or clarified; and addition of modifiers for Mineral Precipitates and Substrate Descriptors.

All other Settings, Components, Modifiers and units remain unchanged from the Coastal and Marine Ecological Classification Standard (FGDC-STD-018-2012) document. All mentions of page numbers, section numbers, figures, and tables in the CMECS Catalog are references to the CMECS FGDC-STD-018-2012 document, unless otherwise noted.

## **Biogeographic Setting**

The CMECS Biogeographic Setting is adopted from the Marine Ecoregions of the World (MEOW) technique (Spalding et al, 2007) for characterizing bioregions of marine coastal and shelf environments. MEOW provides global coverage with a nested, three-tiered system of realms, provinces, and ecoregions (moving from larger-scale to smaller-scale units). CMECS proposes to use the MEOW realms, provinces, and ecoregions for describing biogeographic elements of the Estuarine System and the Marine Nearshore and Offshore Subsystems.

### **Arctic Realm**

#### **Arctic Province**

##### **Beaufort Sea Continental Coast and Shelf Ecoregion**

#### **Cold Temperate Northern Atlantic Province**

##### **Scotian Shelf Ecoregion**

##### **Gulf of Maine/Bay of Fundy Ecoregion**

##### **Virginian Ecoregion**

#### **Warm Temperate Northern Atlantic Province**

##### **Carolinian Ecoregion**

##### **Northern Gulf of Mexico Ecoregion**

### **Temperate Northern Pacific Realm**

#### **Cold Temperate Northeast Pacific Province**

##### **Aleutian Islands Ecoregion**

##### **Gulf of Alaska Ecoregion**

##### **North American Pacific Fjordland Ecoregion**

##### **Puget Trough/Georgia Basin Ecoregion**

**Oregon, Washington, Vancouver Coast and Shelf Ecoregion**  
**Northern California Ecoregion**  
**Southern California Bight Ecoregion**

## **Tropical Atlantic Realm**

### **Tropical Northwestern Atlantic Province**

**Eastern Caribbean Ecoregion**  
**Greater Antilles Ecoregion**  
**Southwestern Caribbean Ecoregion**  
**Floridian Ecoregion**

## **Central Indo-Pacific Realm**

### **Tropical Northwestern Pacific Province**

**Mariana Islands Ecoregion**

## **Eastern Indo-Pacific Realm**

### **Hawaii Province**

### **Marshall, Gilbert, and Ellis Islands Province**

**Marshall Islands Ecoregion**

### **Central Polynesia Province**

**Line Islands Ecoregion**  
**Phoenix/Tokelau/Northern Cook Islands Ecoregion**  
**Samoa Islands Ecoregion**

## **Aquatic Setting**

The Aquatic Setting (AS) is comprised of three hierarchical levels (System, Subsystem and Tidal Zone) and provides the context for all CMECS components. It distinguishes oceans, estuaries and lakes, deep and shallow waters and submerged and intertidal environments within which more refined classification of geological, physicochemical, and biological information can be organized.

### *System*

The CMECS Systems—Lacustrine, Estuarine, and Marine—are based on salinity and geomorphological characteristics of the setting. System (as defined in CMECS) is equivalent in concept to system as defined in *Classification of Wetlands and Deepwater Habitats in the United States*, FGDC-STD-004 (FGDC 1996b). The definition and units of the Lacustrine System are similar to the analogous system of FGDC-STD-004. The Great Lakes are classified as a Lacustrine System in CMECS and coincide with the definitions and concepts of FGDC-STD-004.

The Estuarine System has basic similarity with FGDC-STD-004, but includes the tidal freshwater portion of the Riverine System as defined in FGDC-STD-004. This is done to unify the tidal fresh and low-salinity portions of estuaries within the CMECS Estuarine System umbrella. The Marine System has been elaborated significantly in CMECS, to include the ocean environments and habitats.

### *Subsystem*

Each system is divided into subsystems based on depth and position relative to the shoreline. Lacustrine Systems include the Subsystems Littoral and Limnetic, conforming, respectively to shoreline and deepwater habitats. The Estuarine System has four Subsystems: Coastal, Open Water, Tidal Riverine Coastal and Tidal Riverine Open Water. The Marine System is comprised of three Subsystems: Nearshore, Offshore, and Oceanic, distinguished by total water depth.

### *Tidal Zone*

Tidal zone is an important determinant of biological and abiotic processes in the environment. Habitats in the littoral zone support life forms that can tolerate the sometimes highly energetic physical processes of tide, wave and current action. Biota in these areas are also subjected to alternate submergence and drying/desiccation. Temperatures in littoral and intertidal habitats are more extreme than in the buffered subaqueous environment, and excessive light and radiant energy can present a challenge for some biota. Evaporation, drying and concentration of salts creates sometimes harsh conditions for vegetation and fauna at the land-sea margin and the high energy of coastal situations increases erosional depositional forces.

Subtidal environments are presented with a different set of challenges in that oxygen, light, nutrients and temperature are often reduced with respect to biological requirements and species and communities have developed characteristic strategies to optimize access to resources in these environments. In CMECS each Subsystem in the Estuarine and Marine System is distinguished by tidal zone (Figure 4.1).

## **Lacustrine System**

The CMECS Lacustrine System includes (a) all deepwater areas of the Great Lakes and (b) shoreline areas of the Great Lakes with less than 30 percent areal coverage by trees, shrubs, and persistent emergents. In areas with a greater percentage of vegetative cover, the appropriate Palustrine FGDC-STD-004 should be used for classification. Where a river enters or leaves a lake, the extension of the lacustrine shoreline forms the riverine-lacustrine boundary.

### **Subsystem: Lacustrine Littoral**

The Littoral Subsystem includes shallow habitats in the Lacustrine System. The shoreward boundary of this subsystem extends to the landward limit of non-persistent emergents. The lakeward boundary includes all waters to a depth of 2 meters below Mean Lower Low Water (MLLW), or to the maximum extent of non-persistent emergents, whichever depth is greater.

### **Subsystem: Lacustrine Limnetic**

The Limnetic Subsystem includes all deepwater habitats within the Lacustrine System.

“Deepwater habitats” are those that occur at depths greater than 2 meters below MLLW—unless there are non-persistent emergents in those areas. In which case, “deepwater habits”

are those beyond the limit of occurrence of non-persistent emergents.

## **Estuarine System**

The Estuarine System is defined by salinity and geomorphology. This System includes tidally influenced waters that (a) have an open-surface connection to the sea, (b) are regularly diluted by freshwater runoff from land, and (c) exhibit some degree of land enclosure.

The Estuarine System extends upstream to the head of tide and seaward to the mouth of the estuary. Head of tide is identified in accordance with the *Metadata Profile for Shoreline Data*, FGDC-STD-001.2-2001 (FGDC 2001) as the inland or upstream limit of water affected by a tide of at least 0.2-foot (0.06 meter) amplitude. The mouth of the estuary is defined by an imaginary line connecting the seaward-most points of land that enclose the estuarine water mass at MLLW. Islands are included as headlands if they contribute significantly to the enclosure.

Estuaries occur on continents or on islands and include waters of any depth. In CMECS they are defined as waters bounded by significant enclosure by land, having a direct connection to the sea and receiving measurable freshwater input to some part of the enclosed system during an average year. Salinity, a dimensionless conductivity ratio as measured on the practical salinity scale (PSS), was established by the IAPSO (International Association for the Physical Sciences of the Oceans) in 1978 (UNESCO 1981), and is of prime importance in distinguishing freshwater from saline estuarine environments and differentiating among estuarine and marine environments of differing salinity. The range of salinity considered in the CMECS classification extends from zero to hyperhaline (>40). Oceanic salinities normally encountered throughout the world range from 30-40 on the PSS scale. Highly saline negative estuaries such as Laguna Madre and Florida Bay may experience salinity as high as 70-80. Extreme environments like the Dead Sea have salinity near 300.

The tidally influenced part of the estuary may occur in a fresh reach where salinity is < 0.5. According to FGDC-STD-004, this area would be classified within the Riverine System. However, in CMECS, the Tidal Riverine area is considered to be an integral part of the ecology of the estuarine ecosystem, so it is classified within the Estuarine System instead.

The Estuarine System has four subsystems: Coastal, Open Water, Tidal Riverine Coastal, and Tidal Riverine Open Water.

### **Subsystem: Estuarine Coastal**

The Estuarine Coastal Subsystem extends from the supratidal zone at the land margin up to the 4-meter depth contour in waters that have salinity greater than 0.5 (during the period of average annual low flow). The Estuarine Coastal Subsystem would be considered the shallow perimeter in a deeper estuary, although many estuaries may be entirely less than 4 meters deep and be classified as completely in the Coastal Subsystem. The 4-meter contour was selected as a cutoff between “coastal” and “offshore” estuarine waters because it identifies (somewhat arbitrarily) a region that is both shallow and generally in close proximity to the shore, making the substrate-to-water volume ratio here the highest in the entire estuary. A convening of experts delineated this 4-meter contour as described in Reilly, Spagnolo, and Ambrogio (1999) as important in both an ecological and a regulatory sense in estuarine systems

and CMECS has adopted it to emphasize the significant human and natural processes that occur there.

The high wetland-water ration and pelagic-benthic connectivity makes the Estuarine Coastal Subsystem an extremely dynamic and active area in terms of hydrodynamics, geology, and biology. It is this area in shallow coastal waters where maximum interaction between estuarine waters, and adjacent wetlands or developed shoreline occurs and often where intense juxtaposition of human activity and the natural system occurs. Watershed, point and non-point inputs to the estuary are often maximal in this shallow zone.

Because the Coastal Subsystem tends to receive an abundance of light, these waters and bottom areas are usually sites of high primary production. In water columns, shallow waters typically support high phytoplankton productivity while shallow water bottoms are covered in highly productive microphytobenthos, macroalgae and/or rooted macrophytes and their attached epiphytic communities. As regions of high primary production, shallow waters attract an abundance of higher trophic level organisms that feed on plants and on their grazer communities. Strong physical subsidies from flowing waters and wind stresses create waves and currents that generally maintain the shallow waters in a well-oxidized state. Surface waters of the Coastal Subsystem tend to be well-mixed and are affected by strong physical processes that impact the bottom: resuspending sediments, reducing light and altering spectral characteristics of the light climate. The estuarine bottom in shallow waters is also subject to frequent wind-induced reworking and transport of sediments and dynamic bedforms.

The Estuarine Coastal Subsystem is divided in three zones based on tidal action:

**Tidal Zone: Estuarine Coastal Subtidal**

The substrate is generally continuously submerged in this zone and includes those areas below MLLW.

**Tidal Zone: Estuarine Coastal Intertidal**

The substrate in this zone is regularly and periodically exposed and flooded by tides. This zone extends from MLLW to Mean Higher High Water (MHHW). The Coastal Intertidal is exposed regularly to the air by tidal action.

**Tidal Zone: Estuarine Coastal Supratidal**

This zone includes areas above MHHW; areas in this zone are affected by wave splash and overwash. It does not include areas affected only by wind-driven spray, which may extend further inland.

**Subsystem: Estuarine Open Water**

The Estuarine Open Water Subsystem includes all waters of the Estuarine System with a total depth greater than 4 meters, exclusive of those waters designated Tidal Riverine Open Water.

The Open Water Subsystem is subject to a number of physical factors that make it distinct from the Coastal Subsystem, including reduced air-water exchange, potentially reduced light at depth, reduced physical impact from waves and surface currents and reduced interaction between the water column and the bottom. Moreover, because of the formation of stratified layers in the Estuarine System, the Open Water Subsystem is often “capped” by a relatively

strong density or stability gradient that distinctly separates the lower water column from the upper water column, separated by a zone of transition (such as a pycnocline, halocline, or thermocline).

The Open Water Subsystem may be heterotrophic, because it often acts as a receiving basin for organic material settling from the shallower, better lit surface waters, especially when the waters are stratified and form shallow flanks of the water body. At times, this role as a heterotrophic zone may support high rates of respiration (relative to production) and therefore consume much of the available oxygen and lead to the formation of hypoxic or anoxic zones, generally in the deeper parts of these waters. Additionally, stratification and the mechanics of estuarine circulation often promote the formation of a salt wedge intrusion (from the marine environment) that renders the bottom waters more saline than waters in the surface layer above.

**Tidal Zone: Estuarine Open Water Subtidal**

The substrate is generally continuously submerged in this zone and includes those areas below MLLW.

**Subsystem: Estuarine Tidal Riverine Coastal**

The Estuarine Tidal Riverine Coastal Subsystem includes the most upstream region of the estuary, in those areas between MHHW to the 4-meter depth contour below MLLW in waters that (a) can be regularly influenced by tides and (b) where salinity is below 0.5 during the period of annual low flow. The areas with this salinity may extend upriver to the head of tide, which is identified as the point where the mean tidal range becomes less than 0.2 feet (0.06 meters) (FGDC 2001).

The Tidal Riverine Coastal Subsystem includes upstream areas that are influenced by ocean tides, but do not experience significant salinity. The hydraulic gradient is low and water stage and velocity fluctuate under tidal influence. Water is always present and is confined within a channel, and is usually flowing. The Tidal Riverine Coastal Subsystem is a critical part of the ecology and habitat of the estuary. This area is the site of significant ecological activity and a number of estuarine and coastal species depend on Tidal Riverine Coastal areas for breeding habitats, nursery habitats, and migratory pathways (e.g., striped bass, wading birds, and anadromous fishes). The Tidal Riverine Coastal Subsystem also supports unique hydrological features, for example the Estuarine Turbidity Maximum, tidal bores and Coriolis deflections.

**Tidal Zone: Estuarine Tidal Riverine Coastal Subtidal**

The substrate is generally continuously submerged in this zone and includes those areas below MLLW.

**Tidal Zone: Estuarine Tidal Riverine Coastal Intertidal**

The substrate in this zone is regularly and periodically exposed and flooded by tides. This zone extends from MLLW to the extent of tidal inundation, i.e., the extreme high water of spring tides. The Coastal Intertidal is exposed regularly to the air by tidal action.

**Subsystem: Estuarine Tidal Riverine Open Water**

The Estuarine Tidal Riverine Open Water Subsystem includes tidal freshwater areas with a salinity of <0.5 and a depth of greater than 4 meters at MLLW.

The Estuarine Tidal Riverine Open Water Subsystem is the most upstream portion of the estuary and subject to river and watershed influences, including high nutrient and sediment loads and low salinity. Similar to the Estuarine Open Water Subsystem, physical impact from waves and surface currents is reduced interaction at depth. This zone may be the site of the upper limit of the salt wedge and of a turbidity maximum zone, important as feeding and aggregation sites for plankton and benthic species. This zone is also potentially subject to high organic loading and formation of hypoxic waters. Primary production is often low, due to high turbidity and deep, dimly lighted water columns, especially in the river channel. For this reason, the Tidal Riverine Open Water Subsystem may be heterotrophic with net negative metabolic rates.

**Tidal Zone: Estuarine Tidal Riverine Open Water Subtidal**

The substrate is generally continuously submerged in this zone and includes those areas below MLLW.

## **Marine System**

The Marine System is defined by salinity, which is typically about 35, although salinity can measure as low as 0.5 during the period of average annual low flow near fresh outflows. This system has little or no significant dilution from fresh water except near the mouths of estuaries and rivers. The Marine System includes all non-estuarine waters from the coastline to the central oceans. The landward boundary of this system is either the linear boundary across the mouth of an estuary or the limit of the supratidal splash zone affected by breaking waves. Seaward, the Marine System includes all ocean waters.

The Marine System is typified by waves, currents and coastal water regimes determined by oceanic tides. Coastal indentations and bays that do not receive appreciable and regular freshwater inflow are part of the Marine System. Areas where river plumes discharge directly into marine waters without geomorphological enclosure are also part of the Marine System. In such areas, (e.g., Mississippi River plume, Chesapeake Bay plume), low salinity water and fresh plumes may discharge from the seaward boundary of the estuary, extending far into the Marine System beyond the enclosed part of the estuary. These freshwater features are considered to be Hydroforms within the Marine System (see Section 5).

The Marine System has three subsystems (which are defined by depth): Nearshore, Offshore, and Oceanic.

**Subsystem: Marine Nearshore**

The Marine Nearshore Subsystem extends from the landward limit of the Marine System to the 30-meter depth contour. The 30-meter depth contour was selected as a useful cutoff between shallower nearshore and deeper offshore waters. It is intended to represent an ecologically significant depth to which water column and benthic processes are strongly coupled in the Nearshore Subsystem. Surface currents and waves impinge the bottom at the storm wave base (Keen and Holland 2010) and vertical circulation generally distributes nutrients and sediments throughout the water column. The photic zone extends through the entire water column except in extreme cases (Kleypas, McManus and Menez 1999). The presence of nutrients and light

support the growth of vegetation on the bottom including seagrass and macroalgal beds and 30 meters generally represents the depth to which most living coral is found.

**Tidal Zone: Marine Nearshore Subtidal**

The substrate is generally continuously submerged in this zone and includes those areas below MLLW.

**Tidal Zone: Marine Nearshore Intertidal**

The substrate is regularly and periodically exposed and flooded by tidal action. This zone extends from MLLW to MHHW.

**Tidal Zone: Marine Nearshore Supratidal**

This zone includes areas above MHHW that are affected by wave splash and overwash but does not include areas affected only by wind-driven spray. This zone is subjected to periodic high wave energy, exposure to air, and often to variable salinity.

**Subsystem: Marine Offshore**

The Marine Offshore Subsystem extends from the 30-meter depth contour to the continental shelf break, as defined by the maximum slope discontinuity with a rapid change in gradient of 3° or greater at the outer edge of the continental shelf. This shelf break boundary generally occurs between 100 - 200 meters depth. In the case of steep-sided, oceanic islands, where a continental shelf is not present, the offshore boundary of the Offshore Subsystem is defined at a bottom slope discontinuity occurring between 100-200 meters, or at 200 meters if no such discontinuity exists.

The waters and benthos of the Offshore Subsystem are less coupled to each other and typically less influenced by terrigenous processes than in the Nearshore Subsystem. Distance from shore can vary greatly, depending on shelf morphology, and waters at the 30-meter isobath can be quite distant from the shore or may lie relatively close to land.

The Offshore Subsystem may be strongly influenced by open-ocean biogeochemistry and physical processes. Often distinct water layers at the surface and bottom may be present. Because Offshore Subsystem waters are less influenced by coastal inputs, they generally are less turbid than those of the Nearshore Subsystem. Light penetration in the Offshore Subsystem can extend to significant depths and often reach the ocean bottom.

**Tidal Zone: Marine Offshore Subtidal**

The substrate is subtidal and continuously submerged in this zone and includes those areas below MLLW.

**Subsystem: Marine Oceanic**

The Marine Oceanic Subsystem represents the open ocean, extending from the continental shelf break to the deep ocean. Oceanic waters typically have salinity levels of  $\geq 36$ . Water depths typically range from 100 -200 meters at their shallowest at the shelf break to over 11,000 meters at the deepest point in the ocean.

The great depth of the Oceanic Subsystem is responsible for many of its characteristics. The oceanic water column tends to be more stable physicochemically; undergoing changes in temperature and salinity relatively slowly. Greater depth also diminishes the influence of the



sea bottom on the overlying water column. Surface and bottom processes generally are poorly coupled and separated by great distances and thermocline layers. The waters of the Oceanic Subsystem receive little direct terrigenous input; the inputs from land typically occur indirectly, after passage through the substantial coastal water masses or atmospheric deposition.

Conditions in the Oceanic Subsystem are a function of the properties of the water column. For example, light penetration diminishes with depth (as sea water absorbs component wavelengths); thus, the quality and intensity of ambient light changes with depth. Little surface light penetrates below the photic zone (~200 meters). At greater depths, light is limited to that produced locally by bioluminescence. Water pressure also increases directly with depth because of the weight of the overlying water column, and water temperatures diminish with depth.

#### **Tidal Zone: Marine Oceanic Subtidal**

The substrate is subtidal and continuously submerged in this zone.

## **Water Column Component**

The Water Column Component (WC) describes the water column environment of estuaries and oceans. The water column presents unique challenges to classification and characterization—due to its three-dimensional structure; a high degree of temporal variability; a wide, dynamic range in environmental characteristics (across multiple spatial scales); and the inherent challenges of measuring the various parameters. The WC identifies the structures, patterns, properties, and processes, of the water column relevant to ecological relationships and habitat-organism interactions. This component extends from the land-sea margin to the deep oceans and vertically from the surface of the water to the benthic interface. The WC encompasses the Lacustrine, Estuarine, and Marine Systems. The water column component of the Lacustrine System will be fully addressed in a later document, while the latter two systems are described here.

Because the water column is highly variable in both time and space, it is difficult to assign structures or properties to a specific location or depth with certainty. The characteristics of the water continuously change over time. For example, in the clear waters of the open ocean, the well-lit zone of photosynthesis generally extends throughout the upper 200 meters of the water column. In estuaries and coastal waters, surface conditions and water constituents reduce the depth of the photic zone by orders of magnitude. Nearshore photic depths can be quite shallow and variable from place to place or over short time periods. In shallow waters, optical dynamics are compressed in the vertical dimension and their effects are amplified—strongly influencing biota in the water column and in the benthos.

The WC is designed to accommodate the high degree of spatio-temporal variability of the water column with a simple and flexible structure and a comprehensive array of units and modifiers. The WC provides a way to define and organize key information most commonly required to characterize the water column. Spatially, the WC can be applied to points or profiles within the water column, as well as to water masses, regions, entire water bodies and entire oceans.

The WC contains five subcomponents that can be used alone or in combination (Table 5.1):

Layer, Salinity, Temperature, Hydroform and Biogeochemical Feature. The Layer subcomponent indicates vertical position within the water column, using a set of defined layers associated with each subsystem and gives information about relative proximity to the atmosphere, mid-depth or benthos. Units in the Salinity and Temperature subcomponents describe the salinity and temperature characteristics of a water parcel within standard ranges. Hydroform Classes, their hydroforms, and hydroform types describe physical hydrographic features such as currents, waves, water masses, gyres, upwellings and fronts. The Biogeochemical Features subcomponent describes such phenomena as biofilm, thermocline and turbidity maximum—features of the water column that include properties and constituents beyond simple hydrodynamics. Modifiers can be selected from a comprehensive list and applied to any component to define additional characteristics such as trophic status, oxygen status, tide regime and energy regime.

## Water Column Layers Subcomponent

The Water Column Layer Subcomponent resolves the water column vertically into its major coherent layers based on position relative to the surface and to the pycnocline or mid-depth. These layers reflect ecologically important characteristics of the water column structure. The layers for all cross-shelf waters include Surface Layer, Upper Water Column, Pycnocline and Lower Water Column. In the Marine Oceanic Subsystem, additional divisions (described below) are based on depth in the water column. The Layer subcomponent works with the Subsystem of the Aquatic Setting described in Section 4 to define the estuarine and marine water column as a grid. The grid framework is composed of horizontal regions (x-y axes) divided on the basis of position relative to land and total water depth, and vertical layers (z-axis) defined by depth below the surface. This structural arrangement provides a fixed frame of reference for describing position within the water column and accommodates the variability in water column features, conditions and movements by applying additional subcomponents (Figure 5.1).

One set of Water Column Layers is defined for application to all Estuarine Subsystems and the two Marine Subsystems (Nearshore and Offshore) in cross shelf waters where the total water depth is relatively shallow.

For all subsystems (except the Marine Oceanic) the following Water Column Layers are defined:

*Surface Layer:* The interface between the water column and the atmosphere, extending to a depth of several centimeters, represents the surface of maximum exchange of atmospheric gases, heat and light. Surface films, floating vegetation and aggregations of materials or biota accumulate at this interface.

*Upper Water Column:* The area from just below the surface to the boundary of the pycnocline, if present. (If a pycnocline is not present or is not detected, the region above mid-depth in the water column is defined as the Upper Water Column.) The upper water column layer is in close contact with the atmosphere; usually oxygenated, well-mixed and well-lighted; and is generally marked by high rates of photosynthesis and net autotrophic production.

*Pycnocline:* The zone of maximum change of density of a particular physicochemical variable—normally salinity or temperature—that segregates two distinct layers, which are of relatively

homogeneous density. The presence of a pycnocline provides a barrier to vertical mixing between the upper and lower water columns, and this layer enhances the stability of the water column.

*Lower Water Column:* The area below the pycnocline (or, if absent, below mid-depth in the water column), the lower portion of the water column is often dimly or negligibly illuminated (particularly in estuaries) and can be heterotrophic. These deeper waters have limited contact with the atmosphere, may be reduced in oxygen content, and can have a high degree of interaction with bottom sediments. This layer receives organic and mineral material from upper waters and is frequently the site of anoxia. In estuaries, the salt wedge and counter current flow occur in this layer.

#### **Estuarine Coastal Surface Layer**

Estuarine waters between the shore and the 4-meter depth contour at the surface of the water column to a depth of a few centimeters.

#### **Estuarine Coastal Upper Water Column**

Estuarine waters above the pycnocline (or the mid-depth) between the shore and the 4-meter depth contour.

#### **Estuarine Coastal Pycnocline**

Estuarine waters within the pycnocline, between the shore and the 4-meter depth contour.

#### **Estuarine Coastal Lower Water Column**

Estuarine waters below the pycnocline (or mid-depth) and between the shore and the 4-meter depth contour.

#### **Estuarine Open Water Surface Layer**

Estuarine waters at the surface, at or beyond the 4-meter depth contour.

#### **Estuarine Open Water Upper Water Column**

Estuarine waters above the pycnocline (or mid-depth), at or beyond the 4-meter depth contour.

#### **Estuarine Open Water Pycnocline**

Estuarine waters within the pycnocline, at or beyond the 4-meter depth contour.

#### **Estuarine Open Water Lower Water Column**

Estuarine waters below the pycnocline (or mid-depth), at or beyond the 4-meter depth contour.

#### **Estuarine Tidal Riverine Coastal Surface Layer**

Tidal fresh waters at the surface, from the land-water interface up to the 4-meter depth contour.

#### **Estuarine Tidal Riverine Coastal Upper Water Column**

Tidal fresh waters above the pycnocline (or mid-depth), from the land-water interface up to the 4-meter depth contour.

#### **Estuarine Tidal Riverine Coastal Pycnocline**

Tidal fresh waters within the pycnocline, from the land-water interface up to the 4-meter depth contour.

**Estuarine Tidal Riverine Coastal Lower Water Column**

Tidal fresh waters below the pycnocline (or mid-depth), from the land-water interface up to the 4-meter depth contour.

**Estuarine Tidal Riverine Open Water Surface Layer**

Tidal fresh waters at the surface, at or beyond the 4-meter depth contour.

**Estuarine Tidal Riverine Open Water Upper Water Column**

Tidal fresh waters above the pycnocline (or mid-depth), at or beyond the 4-meter depth contour.

**Estuarine Tidal Riverine Open Water Pycnocline**

Tidal fresh waters within the pycnocline, at or beyond the 4-meter depth contour.

**Estuarine Tidal Riverine Open Water Lower Water Column**

Tidal fresh waters below the pycnocline (or mid-depth), at or beyond the 4-meter depth contour.

**Marine Nearshore Surface Layer**

Marine waters at the surface, from the land-water interface up to the 30-meter depth contour.

**Marine Nearshore Upper Water Column**

Marine waters above the pycnocline (or mid-depth), from the land-water interface up to the 30-meter depth contour.

**Marine Nearshore Pycnocline**

Marine waters within the pycnocline, from the land-water interface up to the 30-meter depth contour.

**Marine Nearshore Lower Water Column**

Marine waters below the pycnocline (or mid-depth), from the land-water interface up to the 30-meter depth contour.

**Marine Offshore Surface Layer**

Marine waters at the surface, between the 30-meter depth contour and the shelf break.

**Marine Offshore Upper Water Column**

Marine waters above the pycnocline (or mid-depth), between the 30-meter depth contour and the shelf break.

**Marine Offshore Pycnocline**

Marine waters within the pycnocline, between the 30-meter depth contour and the shelf break.

**Marine Offshore Lower Water Column**

Marine waters below the pycnocline (or mid-depth), between the 30-meter depth contour and the shelf break.

**Marine Oceanic Surface Layer**

The interface between the atmosphere and the water column, extending to a depth of several centimeters. Surface films, floating vegetation, and aggregations of materials or biota accumulate at the surface, which also represents the surface of maximum exchange of

atmospheric gases, heat, and light.

### **Marine Oceanic Epipelagic Upper Layer**

The Epipelagic Layer is the upper 200 meters of the oceanic water column. Within the Epipelagic, the Marine Oceanic Epipelagic Upper Layer is the region between the sea surface and the Epipelagic Pycnocline, if present, or mid-depth in the Epipelagic zone at 100 meters. This layer is generally well-mixed, well-lighted, and highly oxygenated, and supports photosynthesis largely throughout, although weakly in the lower depths. It has no contact with, and very minimal influence from land, and is very clear compared to coastal water masses. It is the zone of maximal productivity in the Oceanic Subsystem.

### **Marine Oceanic Epipelagic Pycnocline**

Within the Epipelagic Layer, the Marine Oceanic Epipelagic Pycnocline is the zone of maximum vertical change in density of the water normally due to a salinity or temperature gradient, which segregates the water column into two distinct layers that are of relatively homogeneous density. The presence of a pycnocline provides a barrier to mixing between the upper and lower water columns, and this layer enhances the stability of the water column preventing mixing to the bottom.

### **Marine Oceanic Epipelagic Lower Layer**

Within the Epipelagic Layer, the region below the Epipelagic pycnocline if present (or below mid-depth [100 meters]). Photosynthesis can generally occur through this layer although diminishing with depth to the critical depth for phytoplankton, which represents the point where production and respiration are in balance and no net productivity occurs. The lower bound of the Epipelagic Lower Layer is the bottom of the Epipelagic Layer at 200 meters.

### **Marine Oceanic Mesopelagic Layer**

The region where light is vertically attenuated to below the level required for photosynthesis, generally between 200 meters and 1,000 meters in depth. Oxygen declines rapidly to a minimum, corresponding with the lower limit of the Mesopelagic Zone—due to high bacterial respiration from settling organic material.

### **Marine Oceanic Bathypelagic Layer**

The region where light does not penetrate, rendering the water column totally dark except for bioluminescence, generally from 1,000 meters to 4,000 meters depth. Organisms at these depths are subjected to immense pressure; food webs depend on organic detritus rather than active photosynthetic production. Waters in this layer generally are composed of cold, bottom currents (from sinking water masses descending from polar latitudes).

### **Marine Oceanic Abyssopelagic Layer**

The region of the water column that is generally in contact with the abyssal seafloor, except in deep basins and trenches and represents the bottom layer of the ocean, generally from 4,000 meters to 6,000 meters depth. This layer is aphotic; it receives biogenic, detrital and mineral material descending from above and this layer acts as an accumulation zone. Oozes from tests of planktonic organisms form on the seafloor and fans of sedimentary material accumulate here. There are diverse and specialized faunal communities at these depths. Trophic webs are based on chemoautotrophic processes, hydrothermal vents, decomposition of organic matter

and bacterial production.

### **Marine Oceanic Hadalpelagic Layer**

The deepest waters of the globe occur in trenches and deep basins generally at depths greater than 6,000 meters. There is a high degree of tectonic and thermal activity in these areas.

Waters in this layer have unique characteristics of immense pressure, strong currents, accumulation of sediments and organic material; macrofauna that occur at these extreme depths have special feeding strategies and adaptations to intense pressure and total darkness.

### **Salinity Regime Subcomponent**

Salinity in seawater results from a concentration of salts including bromine, iodine, and (principally) sodium chloride. Salinity is measured as a dimensionless conductivity ratio on the practical salinity scale (PSS), which was established by the IAPSO (International Association for the Physical Sciences of the Oceans) in 1978 (UNESCO 1981). Most marine waters have salinities between 34 and 35, while in estuaries and coastal waters salinity can vary considerably from zero to hyperhaline (greater than or equal to 40). In estuaries, the salinity distribution is a function of direct precipitation, the influx of freshwater supplied by rivers, groundwater sources and runoff from the land and marine water supplied by exchange with the ocean as a function of tidal regime. Salinity is an indicator of the dynamic or conservative nature of mixing within the water body, and is one of the defining features of the structure of coastal waters. Most aquatic organisms function optimally within a narrow range of salinities, which has impact on the ecological balance and trophic structure of communities. Salinity categories and ranges for CMECS are provided in Table 5.2.

#### **Oligohaline Water**

Salinity (PSS) < 5

#### **Mesohaline Water**

Salinity (PSS) 5 to < 18

#### **Lower Polyhaline Water**

Salinity (PSS) 18 to < 25

#### **Upper Polyhaline Water**

Salinity (PSS) 25 to < 30

#### **Euhaline Water**

Salinity (PSS) 30 to < 40

#### **Hyperhaline Water**

Salinity (PSS) greater than or equal to 40

### **Temperature Regime Subcomponent**

Temperature is a measure of kinetic energy, and in most cases decreases with depth in the water column. The mean temperature of oceanic seawater, which by volume is principally at depth, is generally low, 0 – 5° C, but higher in the water column temperatures tend to converge toward air temperature at the surface. Marine waters are structured vertically with a mixed

surface layer having little gradient in temperature, a thermocline with a highly variable gradient, and underlying waters with little stratification. A thermocline is established between an upper layer of one temperature and a lower layer of another and can be seasonal or permanent depending on the circulation and weather patterns. Pronounced thermoclines occur in the tropics, and essentially none occur in Polar Regions. In estuaries, temperatures are more variable because waters are shallower and under more influence of the temperature of inflowing freshwaters or of tidal marine waters. Temperature has a considerable impact on ecosystem functioning, affecting photosynthesis, growth, metabolism, and mobility of organisms. Rates of microbial processes of decomposition, nitrogen fixation and denitrification generally double with each increase of 10° C. Organisms tolerate a particular temperature range, and the temperature optimum range may span only a few degrees. The solubility of gases and pH are dependent on temperature, and temperature influences the ability of water to hold oxygen or oxic status.

Temperature categories are established in intervals of sufficient range and resolution to provide meaningful ecological differences yet yield a parsimonious number of categories. Temperature categories are based on the British Columbia Marine Ecological Classification for Canada (Howes, Harper, and Owens 1994, Zacharias et al. 1998, Resource Information Standards Committee 2002), modified to add the higher temperature ranges typical of the subtropics and tropics. Categories for water mass temperature are established in Table 5.3.

**Frozen/Superchilled Water**

0°C and below

**Very Cold Water**

0°C to < 5°C (liquid)

**Cold Water**

5°C to < 10°C

**Cool Water**

10°C to < 15°C

**Moderate Water**

15°C to < 20°C

**Warm Water**

20°C to < 25°C

**Very Warm Water**

25°C to < 30°C

**Hot Water**

30°C to < 35°C

**Very Hot Water**

Greater than or equal to 35°C

**Hydroform Subcomponent**

Hydroforms are physical entities that have a coherent, definable structure with identifiable boundaries and characteristic physical properties. The Hydroform Subcomponent is a hierarchy of three levels consisting of Hydroform Classes, Hydroforms and Hydroform Types. Hydroforms are ecologically important because they shape their environment by creating gradients, surfaces, barriers, compartments and energy vectors. They strongly influence the distribution and condition of biota and often act as habitat by creating a complex environmental structure, by facilitating and enhancing transport of materials and energy, cycling nutrients, providing refugia, aggregating food resources, and providing migration paths. They influence the transfer of heat, salts, oxygen, carbon dioxide, trace elements, momentum, predicted trajectory, temporal persistence and associated fauna. Hydroforms vary extensively in size, volume, areal extent, persistence, and ecological significance.

In this standard hydroforms are represented conceptually as the average expression of their defining characteristics. The boundaries of the hydroforms are to be determined by methodology, technology limits, user objectives and application and lie along a continuum. Implementation guidance will be developed to assist in determining quantitative cutoffs that define their boundaries.

### **Hydroform Class: Current**

Water that is undergoing coherent mass movement, either as laminar or turbulent flow, relative to surrounding waters and fixed structural, landform or geologic features. A directional, coherently flowing water mass. Currents operate on a wide range of temporal and spatial scales from huge ocean gyres and major surface and deep-water currents of the ocean operating on annual timescales to tidal currents that operate on sub daily timescales. However, all currents have features in common: the advective movement and transport of water, constituents (such as particulates and dissolved compounds), qualities (such as temperature and salinity) and biota (such as plankton, nekton, and megafauna). Currents are driven by gravity flow, geostrophic flow, density differences, hydraulic differential or energy input. They may be isolated from land and freely flowing in the water column as is the Gulf Stream, or they may be in channelized flow or long-shore flow. Currents that impact land also shape the littoral zone or sea bottom by winnowing sediments, physically mixing or shearing substrates and biota and creating geoforms such as sand ripples and bars.

### **Hydroform: Boundary Current**

The portion of an ocean gyre that moves along the continental boundary.

### **Hydroform Type: Eastern Boundary Current**

The eastern portion of the great ocean gyres circulating in the ocean basins against west continental coasts. They may be broad or narrow and meandering; they transport colder water into the tropics. EBCs are typically shallow and slow-flowing compared to the Western boundary currents. EBCs may be associated with upwellings and nutrient rich seas that can support very productive fisheries, such as in the Peruvian Upwelling.

### **Hydroform Type: Western Boundary Current**

The western portion of the great ocean gyre circulation, which moves along the



eastern coasts of the continents. These currents are deeper (up to 1,000 meters) and faster moving than eastern counterparts. The western intensification, due to Coriolis forces being stronger in the latitudes of the Westerlies that steer Western boundary currents, is responsible for the great speed and intensity of these currents. WBCs transport warmer tropical waters into the cold higher latitudes and have a great effect on both oceanic and terrestrial climate, water temperatures and distribution of biota.

**Hydroform: Buoyancy Flow**

Current flow created by discontinuity in buoyancy of two juxtaposed water masses of different density, causing one to flow relative to the other toward buoyancy equilibrium.

**Hydroform Type: Downwelling**

Downwardly-directed current caused by convergence of water masses.

**Hydroform Type: Upwelling**

Upwardly-directed current caused by divergence of water masses

**Hydroform: Current Meander**

A current that deviates from a straight-line flow, which is often the result of incursion by lateral currents or the presence of a physical or density barrier. Meanders can pinch off from the main current flow and form rings.

**Hydroform: Deep Boundary Current**

A current that connects high-latitude ocean waters (where deep water is formed) with upwelling regions. The core depths of these currents are between 1,500 meters and 4,000 meters. Western-located Deep Boundary Currents lie adjacent to continental slopes in all ocean basins.

**Hydroform: Deep Circulation**

The mass circulation of the oceans that carries cold polar surface water to depth, sinking due to higher density and wind forcing. The mass transport also carries salt, oxygen, and other properties. Deep circulation is wind driven, with a tidal mixing component. It cools the surface and evaporates water, which determines where deep convection occurs. Wind-driven turbulence in the deep ocean mixes cold water upward at lower latitudes. Deep circulation has relative slow current movements but transport of water is comparable to surface transport and is responsible for closing the Earth's heat budget and determining climate.

**Hydroform Type: Abyssal Deep Circulation**

Deep, slow circulation in the abyssal zone driven by horizontal differences in density of water masses. The vast majority of ocean circulation is of this type, initiating by the sinking of cold water in the high latitudes to the ocean bottom, and spreading throughout the abyssal plains of the ocean basins.

**Hydroform Type: Bathyl Deep Circulation**

Deep, slow circulation in the bathyl zone driven by horizontal differences in

density of water masses. Water sinks down the continental slope and through the bathyl zone as part of thermohaline ocean circulation.

**Hydroform: Deep Convection**

Large mass flows of water in the deep ocean that form critical parts (and return paths) of the great ocean circulation.

**Hydroform: Density Flow**

Flow caused by differential density between two convergent water masses- or by a parcel of denser water flowing along a sloping bottom under a column of less-dense water.

**Hydroform: Ekman Flow**

The flow of water at 90° to the direction of the wind, at steady state, due to Earth's rotational effect.

**Hydroform Type: Ekman Upwelling**

Upwardly-directed current resulting from either the divergence of water masses or from movement of surface water away from the coast. At the divergence of two water masses (or the wind-driven movement of water away from a coastline), continuity of mass flow will move water from depth to the surface as replacement. In the nearshore, the circulation will bring the water from the shallow bottom. In deeper waters, the upwelling will carry water from a variety of depths- from near the surface to depths to as great as 500 meters (below the pycnocline). Because the upwelled water is working against gravity, its maximum influence is not as great as downwelled water (which is aided by gravity); however, the upwelling can reach into the mesopelagic zone.

**Hydroform Type: Ekman Downwelling**

Downwardly-directed current, resulting from either the convergence of water masses or from the convergence of a water mass with a coastline. At this convergence, gravity will force water into a downwelling, which will carry surface water to greater depths. In the nearshore, the circulation will take the water to the shallow bottom and then move seaward. In deeper waters, the downwelling will carry water to a depth determined by energy dissipation and relative density considerations; the maximum downwelling depth can be into the abyssalpelagic zone.

**Hydroform: Inertial Current**

Currents that continue motion through inertia. Due to the rotation of the Earth, inertial currents tend to form circular gyres.

**Hydroform: Langmuir Circulation**

Rotational oscillatory motion of surface waters induced by wind and Coriolis deflection. This circulation is caused by the transport of a parcel of water obliquely to the direction of wind transport due to the apparent Coriolis force imparted by the rotation of the earth. In the Northern Hemisphere this vector is to the right of the wind direction, in the Southern Hemisphere, it is to the left. This causes a piling of water in cells lateral to the

direction of travel. The piled water sinks to balance forces, and it also circulates to create elongated tubular circulations of water at the surface. Langmuir cells are important to productivity by circulating water through the water column, and form fronts at the junction of two Langmuir cells that are important points of aggregation and feeding of plankton and higher trophic levels (Wetzel 2001).

**Hydroform: Mean Surface Current**

The time-averaged steady state ocean surface current pattern responsible for mean oceanic water motions.

**Hydroform Type: North Equatorial Surface Current**

The southern portion of the northern ocean gyres. This current flows westward, is maintained by the trade winds, and entrains some water from southern oceans into the northern oceans. It is accompanied by a weaker easterly-flowing counter current.

**Hydroform Type: South Equatorial Surface Current**

The counterpart to the North Equatorial current, also flows east to west, forming the northern limb of the Southern Ocean gyres.

**Hydroform: Mesoscale Eddy**

A rotational feature that (a) breaks off of an ocean gyre or large current (such as the Gulf Stream) and (b) persist autonomously for some period (from days to months) at sizes of 20 kilometers to 500 kilometers. These eddies play an important role in ocean mixing- and in sheltering and acting as nursery waters for biota. The most energetic eddies are at the smaller end of the spatial scale. The larger eddies (called mesoscale eddies) are slower moving, but they persist for many months and are ubiquitous in the global oceans. Mesoscale Eddies are most prevalent in the North Atlantic and North Pacific, but they can occur in all oceans.

**Hydroform Type: Cold Core Ring**

An eddy that forms when a boundary current meander pinches off and closes, trapping a parcel of colder water in a surrounding ring of warmer water. The ring measures up to 300 kilometers and extends to 4,000 meters depth or the ocean bottom. The colder water in the core tends to be higher in nutrients and more productive than that in the surrounding ring, so they become islands of biological activity as they move through the ocean. Rings form in all oceans and can persist for months to years.

**Hydroform Type: Warm Core Ring**

An eddy that form when a boundary current pinches off a parcel of warmer water. The ring measures 100-200 kilometers and extends to 1,500 meters depth. The warm water in the core tends to be less productive than the colder, nutrient rich waters in the ring.

**Hydroform: Residual Current**

Current movement resulting from asymmetry in tidal flow- notably within a partially enclosed estuary or embayment- that results in characteristic estuarine circulation

patterns.

**Hydroform Type: Fjord Circulation**

Circulation in estuaries that possess a sill at the seaward end, inhibiting inflow of seawater into the bottom waters. Seawater flows over the sill mixing into the intermediate water of the estuary, and sinking to the bottom. The estuary receives freshwater input in excess of evaporation and the resulting brackish mixture is exported across the sill into the ocean end-member. The limited exchange of bottom waters can promote hypoxic conditions in some fjord estuaries.

**Hydroform Type: Partially Mixed Domain**

An estuarine circulation with an intermediate level of advective and tidal energy, that can disrupt the density barrier between the fresher upper and salty lower water column of an estuary, entraining water in both directions. This results in a gradient of increasing salinity from top to bottom, with no barrier to mixing.

**Hydroform Type: Reverse Estuarine Flow**

An estuarine circulation where evaporation greatly exceeds freshwater input, as in hot dry climes, salinity is concentrated within the estuarine basin. This results in a salinity maximum in the estuary that can far exceed seawater salinity.

**Hydroform Type: Salt Wedge Domain**

Portions of estuaries that have an unimpeded connection of bottom waters to the sea develop a wedge-shaped formation of high-salinity water in the bottom, with lower salinity water from upstream freshwater loading in the upper water column. The wedge form is developed as hydrostatic pressure of river water pushes against the incoming seawater and, being less dense, rides over it. The difference in salinity and density is important in estuarine chemistry and biology as the density barrier between upper and lower water columns restrains mixing and transport across the transitional gradient, called the pycnocline. This leads to an upper, autotrophic and lower, generally heterotrophic portion of the water column.

**Hydroform Type: Well-mixed Domain**

Reaches of estuaries where the tidal flux and/or the river discharge is sufficient to overcome the salt-wedge structure, the water column becomes well-mixed and vertical homogeneous.

**Hydroform: Sub-mesoscale Eddy**

A reverse current with rotational movement created when fluid flows past an obstacle. Sub-mesoscale eddies are of size scale smaller than 20 kilometers.

**Hydroform: Thermohaline Eddy**

Eddy formation due to the interaction of temperature and salinity differences between two water masses initiating convective flow.

**Hydroform: Tidal Flow**

Advective flow resulting from of tidal movement, often amplified in velocity when moving through an inlet, pass or channel. Tides are important in mixing the water column and transporting water, salt, nutrients and biota, particularly weak-swimming larval or non-motile planktonic forms. The life cycles of many organisms depend on tidal transport for survival.

**Hydroform Type: Diurnal Tidal Flow**

Tidal ocean waters where, due to the geometry of the ocean basin and obstructions presented by land, a second daily tide is suppressed, resulting in a single or diurnal tide regime with one high and one low tide per day, as in the Gulf of Mexico.

**Hydroform Type: Mixed Semi-diurnal Tidal Flow**

Tidal ocean waters where the amplitudes of two semi-diurnal tides are unequal, resulting in a stronger and a weaker high and low tide each day.

**Hydroform Type: Semi-diurnal Tidal Flow**

Tidal ocean waters where the gravitational action of the sun and moon on Earth's oceans create two high and two low tides per day of relatively equal amplitude.

**Hydroform: Turbidity Flow**

A flow of water down slope carrying a dense suspension of fluid mud or unconsolidated material.

**Hydroform: Wave-driven Current**

Residual current caused by asymmetrical force created by wave motion.

**Hydroform Type: Longshore Current**

A current that moves parallel to or at an oblique angle to the shoreline, carrying water and often transporting soft sediments downstream. Prevailing wind and wave directions can persist in a longshore direction for long periods, and are commonly responsible for the formation of spits, bars and many barrier islands.

**Hydroform Type: Rip Current**

A formation of water flow in a seaward direction generated by wave action and local topography nearshore. Shallow depressions in the sea floor or breaks in a bar will channel receding water at high velocity away from shore and through the surf zone after onshore wave action.

**Hydroform Type: Undertow**

Seaward-directed current generated by water that is receding from the shoreline after wave run up.

**Hydroform: Wind-driven Current**

Current caused by wind shear as distinguished by those caused by density differences, which result in thermohaline circulation. Though only a portion of the oceans are exposed to wind energy, winds are responsible for the great ocean gyres, dominant features of ocean circulation.

### **Hydroform Class: Front**

Front Hydroforms are linear features formed at the conjunction of two or more water masses with different properties. Fronts are formed in many different ways when two water masses juxtapose. The front itself becomes a third water feature, and it has several distinctive properties of its own, including current speed and direction, physicochemical properties derived from the two merging water masses, sharp gradients in properties (such as salinity, temperature, nutrients and water clarity) and an accumulation of matter and biota. In estuaries, fronts can occur at the boundaries of horizontal layers between fresher upper layers and saltier bottom waters; in the ocean, fronts can occur between the upper mixed layer and lower layers.

#### **Hydroform: Coastal Upwelling Front**

A frontal interface where a nearshore upwelling occurs due to local turbulent mixing. The upwelling front develops between the upwelling water and the coastal water mass.

#### **Hydroform: Shelf-break Front**

Frontal formations where cross-shelf waters encounter slope waters from the deeper oceans, often associated with upwelling. The seasonally transitional features are sites of high temperature, salinity and density gradients and often of high productivity where deep upwelled water contributes high nutrients.

#### **Hydroform: Tidal Front**

A front created by the linear convergence of two water masses brought into juxtaposition by tidal action. Generally, the two masses will have differential characteristics such as temperature, density, and often of color and productivity. Fronts can be maintained as distinct due to these differences, which inhibit mixing across a density barrier. There is often strong vertical mixing on either side of the front, producing upwelling and aggregations of biota feeding on the material grown <in situ> or accumulated at the front.

### **Hydroform Class: Water Mass**

The Water Mass Hydroform Class refers to a parcel of water with homogeneous properties (e.g., chemical, physical). If no other Hydroform applies (or sufficient information is not available to classify the Hydroform), the default would be a water mass that describes the general properties of the parcel. Any physicochemical property (or properties) can define a water mass. Common water mass types are those of homogeneous salinity, temperature or density- or a combination of those properties. The properties of a water mass generally change relatively slowly, because the factors that created and constrain the homogeneity tend to be buffered by the inertial properties of water itself. Thermal mass of water, for example, means that the water temperature will change much more slowly than air temperature. Non-conservative properties (such as nutrient concentration or pH) can change much more quickly, because biological processes can alter them.

#### **Hydroform: Background Mesoscale Field**

A water mass characterized by organized ocean-surface currents formed by coupled eddies (at the mesoscale length scale); responsible for much of water movement on the

ocean surface.

**Hydroform: Fumarole Plume**

A plume of hot gases venting from the sea bottom associated with volcanic or tectonic activity from cracks in the Earth's crust; often a site of significant chemoautotrophic activity.

**Hydrothermal Plume**

A discharge of hot fluids from sea-bottom vents associated with volcanic or tectonic activity. The fluids are often laden with high concentrations of minerals, which impart either a dark- even black- color or a white color. These minerals precipitate readily out of supersaturation.

**Hydroform Type: Detached Hydrothermal Plume**

A parcel of hot, mineral rich water that has become detached from its source and forms a persistent lens within the water column.

**Hydroform: Ice**

Frozen form of water, which is less dense than liquid water; ice floats on the surface of liquid water, sometimes extending into deep water zones. This property drives a number of important biological and physical processes in the ocean, including preventing freezing of the ocean to the bottom. Ice either floats on- or forms a solid cover on- the underlying water, which isolates atmospheric input for the duration of cover. Nonetheless, strong circulation and water motion occurs in the aquatic system under the ice (driven by advection of adjacent water masses or thermal convection). Because freshwater freezes at a higher temperature than salt water, surface freezing of the ocean concentrates salt brine in the liquid water below the ice. Ice formation and ice cover maintenance is relatively stable in both spatial and temporal terms, determined by relative air and water temperatures, velocity of water movements, and geomorphology of the setting.

**Hydroform Type: Drift Ice**

Ice that floats freely on the sea surface.

**Hydroform Type: Fast Ice**

Ice that is attached to a land mass such as the coast or, in shallow water, the sea floor.

**Hydroform Type: Frazil or Grease Ice**

Ice formation that develops when super-cooled water is turbulently mixed, permitting development of small ice crystals which continually fragment and break up without forming ice cover. Over time a slushy suspension of increasing density forms on the surface of the water. In quiet conditions frazil crystals can freeze together to form a continuous thin sheet of young ice.

**Hydroform Type: Ice Field**

Expanse of ice greater in size than an ice floe (greater than or equal to 10 kilometers in any dimension).

**Hydroform Type: Ice Floe**

Large floating ice chunk less than 10 kilometers on its longest axis.

**Hydroform Type: Pack Ice**

Accumulation of drift ice into a large floating mass, often against a continental shoreline.

**Hydroform Type: Pancake Ice**

Thin plaques of compressed ice particles formed by wave action into plates several meters in diameter that float on the sea surface.

**Hydroform Type: Polnya**

An area of open, liquid seawater surrounded by ice.

**Hydroform: Mesoscale Lens**

A trapped, homogeneous parcel of water lying within (or atop) larger ocean fields due to density differences. These hydroforms are 30 - 300 kilometers in size.

**Hydroform Type: River/Estuary Plume**

Formation of water resulting from the discharge of low-salinity water into marine waters of the ocean, forming a distinct layer of water on top of the seawater due to its lower density. The plume can extend for many kilometers and persist for months after the freshwater flow has stopped before being entrained into the seawater. These plumes are typically higher in nutrients, turbidity and productivity than the surrounding seawater and can gradually deliver those water quality characteristics to the adjacent ocean water.

**Hydroform Type: Meddy**

A lens of water that enters the eastern Atlantic from the Mediterranean Sea, flows down the Continental slope and pinches off at the depth of neutral buoyancy, about 1,000 meters. The salty warm water rotates clockwise and travels slowly westward in the Atlantic, persisting for many months.

**Hydroform: Microscale Lens**

A homogeneous parcel of water on the order of meters to a few kilometers positioned within (or atop) a larger ocean fields of different density.

**Hydroform Type: Small Freshwater Plume**

Similar to a river plume but on smaller scale and can be initiated from variety of sources such as a groundwater seep, a non-point source or a transient discharge.

**Hydroform: Winter Water Mass**

The mass of water produced- and introduced to oceans- as a result of melting winter ice formations. These water masses tend to be fresher than surrounding waters, and they often flow over the denser salt water.

**Hydroform Class: Wave**

The Wave Hydroform Class is a propagation of energy that moves through the water, causing a vertical, oscillatory motion with characteristic wavelength, amplitude, and celerity. Waves are of several types: internal, standing, and surface. Each type of wave propagates energy and



impacts the waters, substrate, and biota that it contacts. Waves are initiated by an energy source (such as wind, landslides, earthquakes, or volcanic eruptions), and they can occur at any depth in the water column. Wave energy varies depending on type and intensity of energy input; the wave regime can change on hourly timescales.

**Hydroform: Anthropogenic Wave**

Boat wake or other wave caused by energy resulting from human activity.

**Hydroform: Coastally Trapped Wave**

A wave that moves along the coastal margin, which forms a trapping barrier.

**Hydroform Type: Internal Kelvin Wave**

Subsurface gravity wave with a rotational component propagated along a density interface against a vertical barrier such as a coast or the wall of a basin.

**Hydroform Type: External Kelvin Wave**

Surface gravity wave with a rotational component propagated along the sea surface against a vertical barrier such as a coast or the wall of a basin. Such Kelvin waves are important at the Equator in determining the presence and strength of El Nino/ENSO events.

**Hydroform Type: Shelf Wave**

A wind-induced wave guided by continental shelf topography.

**Hydroform Type: Topographic Wave**

A sub-basin scale wave that is driven by wind-stress from the passage of cyclones across or along the shelf, with long period ( $\sim 5$  days) and to which a vorticity is imparted by the apparent Coriolis effect.

**Hydroform: Edge Wave**

A wave that moves along a trapping barrier, such as the continental shelf, the continental margin or an inertial water mass.

**Hydroform: Equatorial Wave**

A wave that is trapped by and moves along the Equatorial water mass, which forms a density barrier.

**Hydroform: Non-Equatorial Wave**

A wave that is propagated along an edge or barrier, such as a continental margin, and that is not associated with an Equatorial water mass.

**Hydroform: Internal Wave**

A wave that propagates along a density surface within the water column, below the water's surface.

**Hydroform: Seiche**

A long-period, standing wave that creates an oscillatory sloshing of water within an enclosed water body. This is due to wind or pressure effects that cause water motions that resonate with the length scale of the water body.

**Hydroform: Storm Surge**

A propagation of water associated with intense meteorological and wind activity such as a tropical storm. The surge of water from deep into shallow waters and onto land is caused by wind forcing in the forward, shoreward direction and by pressure differential within a cyclonic storm that positions extreme low pressure over a section of ocean, permitting tides to rise above normal range.

**Hydroform: Surf Zone**

Zone with incipient wave breaks, which are the result of an increase in the steepness of the wave as the water depth decreases. The surf zone is the region extending from the seaward boundary of wave breaking to the limit of wave uprush. The surf zone is the specific subset of the wave hydroform where waves are breaking against a shoreline. This relatively narrow area occurs when waves encounter bottom friction and break, forming a region of high turbulence, mixing, and intense energy. This occurrence affects biota in the water column, as well as bottom and shore substrates and biota. The surf zone is highly variable temporally and spatially in extent, energy characteristics, and physicochemical properties; this variability is due to the tight coupling between the water column and the substrate it impacts. In areas of soft sediments, high turbidity can result. Benthic biota (such as diatom mats) can be mixed into the water column, imparting its photosynthetic parameters to the water column and elevating water-column productivity. Nutrients can also be mixed from disturbed sediments into the water column, elevating concentrations there.

**Hydroform: Surface Wave**

A wave generated by energy input from sources such as wind, landslides, tidal action, or current action, and that moves along the surface of the ocean.

**Hydroform: Surface Wind Wave**

A surface wave generated by direct wind action on the water's surface producing shear, piling up water in the direction of the wind and generating a wave.

**Hydroform: Surface Swell**

A surface gravity wave propagating into an area from a distant source of energy/disturbance and that is not caused by direct local action of the wind.

**Hydroform: Tsunami**

A large long-wavelength (tens or hundreds of kilometers) ocean wave that is generated by a powerful undersea disturbance such as a landslide, earthquake, or volcano. The wave is nearly imperceptible in the open ocean but as it approaches land, it can reach heights of many tens of meters. They can have enormous destructive impact on the coast (and inland), as well as the biology of the nearshore zone.

## **Biogeochemical Feature Subcomponent**

The Biogeochemical Feature more specifically defines the water column by identifying factors including constituent composition (e.g., chlorophyll maximum, turbidity maximum), physical energy (e.g., light, surface mixed layer,), and gradients (halocline, thermocline). The Biogeochemical Feature subcomponent provides information that conveys the structure and

the processes that form and sustain the feature, as well as its potential relationship with the biota. The feature integrates specific information, which may include ecoregion, climate zone, position in the water column, position relative to land and spatial scale that is ecologically relevant. The Biogeochemical Feature also conveys information about properties of the other water column subcomponents.

### **Benthic Boundary Layer**

The layer formed at the interface between the lower water column and the benthic substrate.

### **Boundary Layer**

Layer formed at the interface between water and another water mass (or solid interface) where frictional shear forces on water motion cause exponential damping of movement with proximity to the interface.

### **Chlorophyll Maximum**

A feature in deeper water columns (often in the ocean), where phytoplankton production is locally high at depths along a surface of nutrient (nitrate) entrainment from lower-water layers.

### **Chlorophyll Minimum**

A layer of low chlorophyll- and hence phytoplankton- concentration (relative to adjacent waters) due to highly concentrated grazing activity.

### **Drifting Fine Woody Debris**

Aggregations of floating or suspended fine woody material such as small tree branches, husks or fibrous seeds, with a median particle size < 64 millimeters.

### **Drifting Herbaceous Debris**

Floating or suspended detached, decaying herbaceous plant matter such as leaves, forbs or grasses, including deciduous leaves or needles, palm leaves, seagrass debris, Spartina debris.

### **Drifting Trees**

Floating or suspended large dead trees or very large branches, with a median particle size of greater than 4,096 millimeters.

### **Drifting Woody Debris**

Floating or suspended detached large branches with a median particle size of 64 millimeters to < 256 millimeters such as Mangrove branches, coconut rafts.

### **Euphotic Zone**

The zone of the water column that is sufficiently illuminated for photosynthesis to occur.

### **Halocline**

The zone of rapid salinity change with depth in the water column, often separating two layers of different, homogeneous salinity. As the density of water changes with salinity, the halocline presents a barrier to vertical circulation and enhances water column stability

### **Lens**

A homogeneous parcel of water that- by composition- maintains coherence within water of different properties. Often a freshwater lens will sit perched atop saline ocean waters for long periods.

**Lysocline**

The depth in the ocean at which calcium dissolution increases due to increased pressure. This depth is around 4,000 meters in the Pacific Ocean and 5,000 meters in the Atlantic Ocean, owing to differences in temperature and chemistry. Below this depth, the precipitation of calcium carbonate decreases rapidly to the point where no calcite is deposited.

**Marine Snow Aggregation**

A concentration of organic material in the ocean water column. Composed of a mix of mineral, dead organic materials, and- sometimes- a rich microbial community. In this feature small particles aggregate through attractive ionic forces and then begin to fall through the water column.

**Microlayer**

Any extremely thin layer of material, nutrients, organisms or specific properties that exists on or in the water column. The microlayer can be a surface film or at depth and often refers to a microbial film.

**Nepheloid Layer**

Layer of water that contains a high concentration of silt and sediment- usually at the benthic-water column interface. This layer can be nearly a fluid mud. In the deep oceans, the layer can be hundreds of meters thick; in shallower waters with less fine sediments, it can be much thinner (only a few centimeters in places) or absent. Thickness is determined by substrate composition and current shear.

**Neustonic Layer**

Layer of biota that lives at the surface of the water. These organisms are either positively buoyant, maintain position by taking advantage of surface tension, or live on other biotic or abiotic material. Epineuston floats atop the water, hyponeuston lives just under the surface.

**Nutrient Maximum**

A layer or region in the water column that has high concentrations of a particular nutrient or nutrients due either to biological transformation or to abiotic factors such as advection or entrainment from adjacent water masses.

**Nutrient Minimum**

A layer in the ocean where net nutrient accumulation is at a minimum, often due to a locus of high biological activity drawing down nutrient stocks.

**Nutricline**

The zone of rapid nutrient change with depth in the water column, often as a result of entrainment of water from a lower depth that is higher in concentration of a particular nutrient. The nutricline can be a rich source of a limiting nutrient and hence, the site of intense microbial or photosynthetic activity.

**Oxygen Maximum**

A layer in the ocean where oxygen concentration is at a minimum, often due to a locus of high respiratory activity, notably microbial.

**Oxygen Minimum**

Region in the water column where oxygen is reduced (relative to surrounding waters) due to high respiration rates, usually associated with high concentrations of organic matter.

### **Oxycline**

Zone in the water column where oxygen concentration changes rapidly with depth, often as a result of biological or abiotic processes that consume oxygen. Deep, bottom water that contains no photosynthetic organisms- yet receives much deposited organic matter- can generate both high respiration rates and extremely low oxygen concentrations. The transition layer between hypoxic bottom water and oxygenated surface water is the oxycline.

### **Sea Foam**

Sea foam is produced by turbulent mixing and agitation of surface waters, enhanced by high concentrations of dissolved organic matter (DOM).

### **Seep**

Area on the ocean bottom where fluid slowly emerges. Cold seeps are usually at the continental margins; waters in these seeps are often highly concentrated in minerals and dissolved gases, such as hydrogen sulfide, methane, and hydrogen. Cold-fluid seeps and oil seeps are sources of energy for chemoautotrophic communities of bacteria and archaea, which in turn support communities of clams, mussels and vestimentiferan tubeworms.

### **Surface Film**

Thin layer of materials and biota that exist on the surface of the water, often only a few microns thick. The surface film can contain a rich microbial community that consumes the material that concentrated in the film. Dissolved Organic Carbon (DOC) is concentrated up to five times in the surface microlayer. These films are often aggregated and concentrated at frontal convergences of two water masses and can lead to formation of a rich community that feeds on the material.

### **Surface Mixed Layer**

The layer of water at the ocean surface that is mixed by wind. Water of homogeneous density is easily mixed to a depth determined by the intensity of wind shear and density of the water. Often wind mixing of the surface occurs to the pycnocline depth where density increases rapidly. The mixed layer depth is an important determinant of the extent and intensity of photosynthetic production as plankton cells are mixed through the vertical light gradient.

### **Thermocline**

The zone of rapid temperature change with depth in the water column, often separating two layers of different, homogeneous temperature. As the density of water changes with temperature, the thermocline presents a barrier to vertical circulation and enhances water column stability.

### **Turbidity Maximum**

Region in an estuary where turbidity is high, due to concentration of particulates in the water column. This occurs as a result of the increasing ionic strength of the water from the introduction of salt in the downstream direction (generally at around areas with a salinity of 5), which causes particle aggregation. This process is enhanced by the mixing regime particular to this upper estuary region, in which countercurrent flows from the salt wedge are entrained into

the seaward-flowing, upper-water layer. As particles settle out of the upper layer, they are carried upstream in the lower layer and so circulate within a zone of maximum turbidity.

## Geoform Component

In CMECS, the geological context—and associated features of the landscape and seascape—are captured in the Geoform Component (GC), which describes the physical structure of the environment across multiple scales. The GC addresses five aspects of the coastal and seafloor morphology: tectonic setting, physiographic setting, geoform origin, geoform, and geoform type. The framework for the GC adopts most of the structures described by Greene et al. (2007) and the estuary types outlined in Madden et al. (2008), but expands the options to include a larger number of coastal and nearshore features.

The GC is not intended to be a geological classification per se. Rather, it provides a way to present the structural aspects of the physical environment that are relevant to—and drivers of—biological community distribution. This component does not include surface geology attributes [such as hardbottom, softbottom, sand, gravel, and cobble as in Greene et al. (2007)], because these attributes are included in the Substrate Component that describes the character and composition of the seafloor. Used together, geoform and substrate component units reflect the physical environment in which benthic/attached biota occurs.

The GC is organized into four subcomponents that occur along a spatial continuum (Table 6.1): tectonic setting and physiographic setting describe large, global features, while the level 1 and level 2 geoform subcomponents describe meso- and microscale units (extending down to features at the meter scale). Each subcomponent has a general scale range associated with it, but features within these categories will naturally overlap one another—because of the natural gradients and transitions between geologic units and processes. Similarly, regional differences in processes will cause units to respond differently on spatial and temporal scales (Harris et al. 2005).

There are no mapping scales explicitly associated with the geoform levels. Users should determine a spatial scale for their work based on (a) project objectives and (b) the observational technologies to be employed. Users should then apply the appropriate GC units based on that scale; they are free to use any subcomponent singly or in combination. Modifiers are available to further describe geoform features.

The GC features listed in this document are meant to be an initial list; they are subject to modification as the standard is applied over time. See Appendix D for a table of the GC units and Section 10 for more details on CMECS modifiers.

### Tectonic Setting Subcomponent

At the largest scales, the GC is divided into eight planetary features that reflect global tectonic processes (both past and present). Generally, these features are thousands of square kilometers or larger in size. They include both continental and oceanic crustal units, and the tectonic setting features form the context for all of the smaller-scale geoforms.

#### Tectonic Setting: Abyssal Plain

A flat region of the deep ocean floor (with a slope less than 1:1,000) that was formed by the deposition of pelagic and gravity-current sediments, which obscure the pre-existing topography. Vast areas of the ocean floor fall within this setting, which can be subdivided into smaller basins based on regional topography.

**Tectonic Setting: Convergent Active Continental Margin**

Intense areas of active magmatism, where the oceanic lithosphere is subducted beneath the continental lithosphere. This results in chains of volcanoes near the continental margin; the leading edge of the continental plate is usually studded with steep mountain ranges.

**Tectonic Setting: Divergent Active Continental Margin**

Areas where tensional tectonic forces result in the crustal rocks being stretched and—ultimately—split apart or rifted. These areas are marked by subsidence and a continental rise.

**Tectonic Setting: Fracture Zone**

An elongate zone of unusually irregular topography (on the deep seafloor) that often separates basins and regions of different depths; fracture zones commonly follow (and extend beyond) offsets of the mid-ocean ridge.

**Tectonic Setting: Spreading Center**

Spreading centers are areas where tectonic plates are moving apart, allowing new oceanic crust to reach the surface of the sea floor.

**Tectonic Setting: Mid-Ocean Ridge**

An extremely large, global spreading center. The mid-ocean ridge is a continuous, seismically active, median mountain range extending through the North Atlantic, South Atlantic, Indian, and South Pacific Oceans. It is a broad, fractured swell with a central rift valley and usually extremely rugged topography. The ridge is 1–3 kilometers in height, about 1,500 kilometers in width, and over 84,000 kilometers in length. Sections of this feature are sometimes named based on the ocean region in which this feature occur (for example, Mid-Atlantic Ridge).

**Tectonic Setting: Passive Continental Margin**

The transition between oceanic and continental crust that is not an active plate margin. This feature was constructed by sedimentation above an ancient rift, now marked by transitional crust. Major tectonic movement is broad, whereas regional vertical adjustment, Earthquakes, and volcanic activity are minor and local.

**Tectonic Setting: Transform Continental Margin**

A feature defined by the transform fault that develops during continental rifting. These margins differ from rifted or passive margins in two key ways; they have a narrow continental shelf (less than 30 kilometers) and a steep ocean-continent transition zone (Keary et al. 2009).

**Tectonic Setting: Tectonic Trench**

A narrow, elongate depression of the deep seafloor associated with a subduction zone. These can be oriented parallel to a volcanic arc and are commonly aligned with the edge of the adjacent continent, between the continental margin and the abyssal hills. Trenches are commonly greater than 2 kilometers deeper than the surrounding ocean floor, and they may be thousands of kilometers long.

## **Physiographic Setting Subcomponent**

Spatially nested within the tectonic settings, physiographic settings describe landscape-level geomorphological features from the coast to mid-ocean spreading centers. These large features—generally on the scale of hundreds of square kilometers—can cross tectonic settings, and they can be delineated at a scale of 1:1,000,000 (or greater) using bathymetric maps and other remote sensing data. Each setting will normally contain a wide variety of the smaller geoform features.

### **Physiographic Setting: Abyssal/Submarine Fan**

A low, outspread, relatively flat-to-gently sloping mass of loose material—shaped like an open fan or a segment of a cone—deposited by a flow of water at the place where it issues from a narrower or steeper-gradient area into a broader area, valley, flat, or other feature. Abyssal fans form at the mouths of submarine canyons, and fans are also the result of turbidities (that is, gravity-driven, underwater avalanches).

### **Physiographic Setting: Barrier Reef**

A long, narrow coral reef, roughly parallel to the shore and separated from it by a lagoon of considerable depth and width. This reef may enclose a volcanic island (either wholly or in part), or it may lie a great distance from a continental coast (such as the Great Barrier Reef). Generally, barrier reefs follow the coasts for long distances—often with short interruptions that are called passes or channels. Three principle examples of this type of feature are Australia's Great Barrier Reef, the New Caledonia Barrier Reef, and the Meso-American Barrier Reef system—although similar features exist elsewhere.

### **Physiographic Setting: Bight**

A broad bend or curve in a generally open coast. Examples include the South Atlantic Bight and the Southern California Bight. These are distinguished from Embayment/Bays by the shallower angle between the apex of the bight and the adjacent coasts, although the term *Bay* has been used to name these features (e.g., Bay of Campeche).

### **Physiographic Setting: Borderland**

An area of the continental margin (between the shoreline and the continental slope) that is topographically more complex than the continental shelf. This feature is characterized by ridges and basins, some of which are below the depth of the continental shelf.

### **Physiographic Setting: Continental/Island Rise**

An area that lies at the deepest part of a continental or island margin between the continental slope and the abyssal plain. The rise is a gentle incline (with slopes of 0.5° to 1°) and it has generally smooth topography—although it may bear submarine canyons.

### **Physiographic Setting: Continental/Island Shelf**

That part of the continental margin that is between the shoreline and the continental slope (or a depth of 200 meters when there is no noticeable continental slope); it is characterized by its very gentle slope of 0.1°. Island shelves are analogous to the continental shelves, but surround islands.

### **Physiographic Setting: Continental/Island Shore Complex**



This feature includes the land-water interface zone and contains geoforms across a diversity of scales. For CMECS, the supratidal zone forms the landward limit of geoforms found within the shore complex setting. This setting does not include the land-water interface along tidal rivers that may extend a considerable distance inland.

**Physiographic Setting: Continental/Island Slope**

That part of the continental margin that is between the continental shelf and the continental rise (if there is one); it is characterized by its relatively steep slope of 1.5 -6°. Island slopes are analogous to the continental slopes, but occur around islands.

**Physiographic Setting: Embayment/Bay**

A water body with some level of enclosure by land at different spatial scales. These can be wide, curving indentations in the coast, arms of the sea, or bodies of water almost surrounded by land. These features can be small—with considerable freshwater and terrestrial influence—or large and generally oceanic in character.

**Physiographic Setting: Fjord**

A long, narrow, glacially eroded inlet or arm of the sea. They are often U-shaped, steep-walled, and deep. Because of their depth, they tend to have low surface-area-to-volume ratios. They have moderate watershed-to-water-area ratios and low-to-moderate riverine inputs. Fjords often have a geologic sill formation at the seaward end caused by glacial action. This morphology—combined with a low exchange of bottom waters with the ocean—can result in formation of hypoxic bottom waters.

**Physiographic Setting: Inland/Enclosed Sea**

A large, water body almost completely surrounded by land. Salinities range from fresh through marine. The term *inland* is used to describe situations where the water body is connected to an adjacent large water body by a narrow strait, channel, canal, or river. Examples of this type of setting are the Mediterranean and Black Seas. The Great Lakes, due to their connectivity to the Atlantic Ocean via the St. Lawrence River also fall into this category.

**Physiographic Setting: Lagoonal Estuary**

This class of estuary tends to be shallow, highly enclosed, and have reduced exchange with the ocean. They often experience high evaporation, and they tend to be quiescent in terms of wind, current, and wave energy. Lagoonal estuaries usually have a very high surface-to-volume ratio, a low-to-moderate watershed-to-water-area ratio, and can have a high wetland-to-water ratio. The flushing times tend to be long relative to riverine estuaries and embayments because the restricted exchange with the marine-end member and the reduced river input lengthen residence times. As such, there tends to be more benthic-pelagic interaction, enhanced by generally shallow bathymetry. Additionally, exchange with surrounding landscapes (often riparian wetland and palustrine systems) tends to be enhanced and more highly coupled than in other types of estuaries. Occasionally, a lagoon may be produced by the temporary sealing of a river estuary by a barrier. Such lagoons are usually seasonal and exist until the river breaches the barrier; these lagoons occur in regions of low or sporadic rainfall.

**Physiographic Setting: Major River Delta**

The nearly flat, alluvial tract of land at the mouth of a river, which commonly forms a triangular

or fan-shaped plain. It is crossed by many distributaries, and the delta is the result of sediment accumulation from the river. Deltas are distinguished from alluvial fans by their flatter slope. Examples of this feature include the Mississippi Delta, the Nile Delta, and the Ganges Delta. All deltas are dynamic areas of mixed-water flow and salinity.

**Physiographic Setting: Marine Basin Floor**

Basin floors refer broadly to the areas of the seafloor between the base of the continental margin (usually the foot of the continental rise) and the mid-ocean ridge. Occasionally, this large region is subdivided into smaller basins based on local bathymetry.

**Physiographic Setting: Ocean Bank/Plateau**

A mound-like or ridge-like elevated area on the seafloor; it may have a modest-to-substantial extent. Although submerged, this feature can reach close to sea level (e.g., Bahama Banks).

**Physiographic Setting: Riverine Estuary**

This class of estuary tends to be linear and seasonally turbid (especially in upper reaches), and it can be subjected to high current speeds. These estuaries are sedimentary and depositional, so they may be associated with a delta, bar, barrier island, and other depositional features. These estuaries also tend to be highly flushed (with a wide and variable salinity range) and seasonally stratified. Riverine estuaries have moderate surface-to-volume ratios with a high watershed-to-water-area ratio—and they can have very high wetland-to-water area ratios as well. These estuaries are often characterized by a V-shaped channel configuration and a salt wedge.

High inputs of land drainage can promote increased primary productivity, which may be confined to the water column in the upper reach, due to low transparency in the water column. Surrounding wetlands may be extensive and healthy, given the sediment supply and nutrient input. This marsh perimeter may be important in taking up the excess nutrients that are introduced to the system. Physically, the system may tend to be stratified during periods of high riverine input, and the input of marine waters may be enhanced by countercurrent flow.

**Physiographic Setting: Shelf Basin**

Basins occurring on the continental shelf formed by offshore faulting activity.

**Physiographic Setting: Shelf Break**

The slope discontinuity (rapid change in gradient) of 3° or greater that occurs at the outer edge of the continental shelf. This boundary generally occurs at a depth between 100–200 meters and forms the boundary between the Marine Offshore and Oceanic Subsystems.

**Physiographic Setting: Sound**

(a) A relatively long, narrow waterway connecting two larger bodies of water (or two parts of the same water body), or an arm of the sea forming a channel between the mainland and an island (e.g., Puget Sound, WA). A sound is generally wider and more extensive than a strait. (b) A long, large, rather broad inlet of the ocean, which generally extends parallel to the coast (e.g., Long Island Sound, NY).

**Physiographic Setting: Submarine Canyon**

A general term for all linear, steep-sided valleys on the seafloor. These canyons can be associated with terrestrial or nearshore river inputs, such as in the Hudson or Mississippi

canyons.

### **Physiographic Setting: Trench**

Trenches in the physiographic setting subcomponent occur at a smaller spatial scale than the hemispheric-sized trenches in the tectonic setting. Both types of trenches share similar morphology, but physiographic setting Trenches are not necessarily associated with plate subduction.

## **Geoform Subcomponent**

Geoforms are physical, coastal and seafloor structures that are generally no larger than hundreds of square kilometers in size. This size determination may be an areal extent or a linear distance. Larger geoforms (Level 1) are generally larger than one square kilometer, and correspond to Megahabitats in the Greene et al. classification system (2007). These features can be defined using geologic or geomorphic maps and bathymetric images of the seafloor at map scales of 1:250,000 or less. Smaller geoforms (Level 2) are generally less than one square kilometer in size (or less than 1 kilometer in distance); and correspond to Meso- and Macro-habitats in the Greene et al. system. Level 2 geoforms (such as individual coral reefs, tide pools, and sand wave fields) can be identified through in-situ observational methods (such as underwater videography) or through low-altitude, high-resolution optical or acoustic remote sensing.

Level 1 and Level 2 geoforms are arranged as two separate subcomponents so that they can be used in tandem to describe complex spatial patterns of geoform structures. Level 2 geoforms normally occur as portions of—or smaller features contained (nesting) within—Level 1 geoforms, but are not hierarchically constrained by the Level 1 geoforms. It is possible for geoforms at either level to nest within other units within their same level (for example, a Level 2 pockmark may occur within a Level 2 shoal/bar as in Figure 6.1 below). Although Level 1 and Level 2 geoforms are considered different subcomponents because of their scale differences, they share the same hierarchical structure and some units are found in both levels (if they occur over a broad range of sizes). For brevity, we have combined the definitions of these units into one listing and have indicated the subcomponent(s) in which they reside.

Geoform types are varieties of geoforms that provide further information on morphology and physical processes underway at any individual geoform. Users are encouraged to apply the Type designations where applicable—but they are not required to use it if their data do not support this level of detail. Users are also encouraged to provide the full nesting (recording of upper-level attributes) for any geoforms they identify, although there will be many instances where this is not practical.

### **Geoform Origin: Geologic**

Geologic geoforms are formed by the abiotic processes of uplift, erosion, volcanism, deposition, fluid seepage, and material movement. Uplift may be a result of local and regional seismic and tectonic processes. Waves, currents, wind, chemical dissolution, seismic motion, and chemical precipitation all contribute to these geoforms and give them their distinctive qualities.

#### **Geoform: Apron (Level 1)**

An extensive, subaqueous, blanket-like deposit of alluvial, unconsolidated material that is derived from an identifiable source and deposited at the base of a mountain or seamount.

**Geoform: Bank (Level 1)**

An elevated area above the surrounding seafloor that rises near the surface. Banks generally are low-relief features, of modest-to-substantial extent, that normally remain submerged. They may have a variety of shapes and may show signs of erosion resulting from exposure during periods of lower sea level. Banks tend to occur on the continental shelf. Banks differ from shoals in having greater size and temporal persistence. The Geoform Bank differs from the Coral Reef Zone modifier Bank based on its geologic origin.

**Geoform: Bar (Levels 1 & 2)**

A relatively shallow place (in a stream, lake, sea, or other body of water) that is typically a submerged ridge, or bank consisting of (or covered) by sand or other unconsolidated material—but may also be composed of rock or other material (modified from Jackson 1997).

**Geoform Type: Bay Mouth Bar (Level 1 only)**

A bar of sand or gravel extending partially or entirely across the mouth of a bay. It usually connects two headlands, thus straightening the coast.

**Geoform Type: Longshore Bar (Level 1 only)**

A low sand ridge, built chiefly by wave action, occurring at some distance from and generally parallel with the shoreline, being submerged at least by high tides, and typically separated from the beach by an intervening trough.

**Geoform Type: Point Bar (Level 2 only)**

Low, arcuate, subaerial ridges of sand developed adjacent to an inlet and formed by the lateral accretion or movement of the channel.

**Geoform Type: Relict Longshore Bar (Level 2 only)**

A narrow, elongate, coarse-textured ridge that once rose near to, or barely above, a pluvial or glacial lake or other body of water and extended generally parallel to the shore but was separated from it by an intervening trough or lagoon; both the bar and lagoon are now relict features (Jackson 1997).

**Geoform: Basin (Level 1)**

General term for an area of the seafloor or land surface that lies below the surrounding bottom or terrain elevation. They are normally areas of low relief.

**Geoform: Beach (Levels 1 & 2)**

A gently sloping zone formed by unconsolidated material at the shoreline, typically with a concave profile. This zone extends landward from the low-water line to either (a) the place where there is a definite change in material or physiographic form (such as a cliff) or (b) the line of permanent vegetation. Only those portions of the beach within the splash zone would be within the CMECS system; areas of the beach further inland are

terrestrial systems.

**Geoform Type: Barrier Beach (Levels 1 & 2)**

A narrow, elongate, coarse-textured, intertidal, sloping landform that is generally parallel with the beach ridge component of the barrier island (or a spit), and which is adjacent to the ocean (Jackson 1997; Peterson 1981).

**Geoform Type: Mainland Beach (Levels 1 & 2)**

Any beach that is connected to the mainland, whether fronting bluffs, dunes, or extensive marshes.

**Geoform Type: Pocket Beach (Level 2 only)**

A small beach between two headlands. Because of this isolation, there is very little— or no—exchange of sediment between the pocket beach and the adjacent shorelines.

**Geoform Type: Tide-Modified Beach (Levels 1 & 2)**

Beaches that occur in areas of high tide range (3–15 times the wave height) and usually lower waves (less than 0.3 meter). Tide-modified beaches include reflective beaches with a low-tide terrace, reflective beaches with bars and rips, and ultra-dissipative beaches.

**Geoform Type: Tide-Dominated Beach (Levels 1 & 2)**

Beaches that occur in areas of high tide range (10–15 times the wave height) and usually lower waves; wave height is very low. Tide-dominated beaches include reflective beaches with sand ridges, reflective beaches with sand flats, reflective beaches with tidal sand flats, reflective beaches with tidal mud flats, and reflective beaches with rock flats.

**Geoform Type: Wave-Dominated Beach (Levels 1 & 2)**

Beaches that are exposed to persistent ocean swell, waves, and low tides (range of less than 2 meters). Wave-dominated beaches include reflective beaches, intermediate beaches, and dissipative beaches (Short 2006).

**Geoform: Beach Berm (Levels 1 & 2)**

The natural bench or platform lying below the main beach slope and above the foreshore.

**Geoform: Boulder Field (Level 1)**

An area dominated by large, boulder-sized (256 millimeters – 4,096 millimeters) stones or pieces of rock. These can occur below cliffs or at the foot of steep slopes or canyons, where they are the result of depositional processes. These fields can also occur as the result of currents that have removed the finer sediments.

**Geoform: Cave (Level 2)**

A natural passage extending beneath the Earth's surface.

**Geoform: Channel (Levels 1 & 2)**

A general term for a linear or sinuous depression on an otherwise more flat area (for

example, a valley-or groove-like feature through which water flows). This is a very broad term that is often used in connection with other terms to provide more meaning.

**Geoform Type: Pass/Lagoon Channel (Level 2 only)**

A generally narrow passage way, open on both ends, through a shoal. In coral reef settings this feature connects the lagoon with the open ocean or bay.

**Geoform Type: Sand Channel (Level 2 only)**

These are narrow passages between, and in association with, pavement formations commonly oriented perpendicular to the shore. The bottoms of these channels normally consist of sand or other unconsolidated mineral substrates. They occur in areas of moderate wave surge and have low vertical relief as compared to spur-and-groove formations.

**Geoform Type: Slough (Level 1)**

(a) A sluggish body of water in a tidal flat, bottomland, or coastal marshland; may also be called bayous or oxbows. (b) A sluggish channel of water (such as a side channel of a river) in which water flows slowly through either low, swampy ground (such as along the Columbia River) or a section of an abandoned river channel (which may contain stagnant water) that occurs in a flood plain or delta.

**Geoform Type: Tidal Channel/Creek (Levels 1 & 2)**

Linear or sinuous body of water through which ebb-and-flood tidal movement takes place. Smaller tidal creeks often branch off of these features. Portions of tidal channels may be intertidal or completely subtidal.

**Geoform: Cone (Levels 1 & 2)**

(a) A type of submarine, fan-shaped deposit— especially a deep-sea fan associated with a major active delta (such as deltas of the Mississippi, Nile, and Ganges Rivers). (b) A formation resulting from the extrusion of material onto the surrounding seabed (e.g., a volcanic cone).

**Geoform: Cove (Levels 1 & 2)**

A small, narrow, sheltered bay or recess in an estuary; often found inside a larger embayment (modified from Jackson 1997).

**Geoform Type: Barrier Cove (Levels 1 & 2)**

A subaqueous area adjacent to a barrier island (or submerged barrier beach) that forms a minor embayment or cove within the larger basin.

**Geoform Type: Mainland Cove (Levels 1 & 2)**

Small embayment or narrow indentation in a mainland coast. These coves usually have narrow entrances and are circular or oval in shape.

**Geoform: Delta (Levels 1 & 2)**

The low, nearly flat, alluvial tract of land at (or near) the mouth of a river. Deltas commonly form a triangular or fan-shaped plain of considerable area, which is crossed by many distributaries of the main river; deltas may extend beyond the general trend of the coast, and occur as a result of the accumulation of river sediment supplied in such

quantities that it is not removed by tides, waves, and currents.

**Geoform Type: Glacial (Kame) Delta (Level 1 only)**

A landform made by a stream flowing through glacial ice and then depositing material as it enters a lake or pond at the end (or terminus) of the glacier. This delta is distinctive because it has been sorted by the action of the stream. This landform may often be observed after the glacier has melted. As the glacier melts, the edges of the delta may subside (as ice under it melts); additionally, glacial till may be deposited in the lateral or side area of the delta from the melting glacier.

**Geoform Type: Ebb Tidal Delta (Level 2 only)**

A largely subaqueous (although sometimes intertidal), crudely fan-shaped delta with sand-sized sediment, which has been formed on the seaward side of a tidal inlet (modified from Boothroyd et al. 1985; Davis 1994; Ritter, Kochel, and Miller 1995).

**Geoform Type: Flood Tidal Delta (Level 2)**

Equivalent to an Ebb Tidal Delta, except that this delta occurs on the landward side of a tidal inlet (modified from Boothroyd et al. 1985; Davis 1994; Ritter et al. 1995). Flood tides transport sediment through the tidal inlet, over a flood ramp where currents slow and dissipate before entering the lagoon (Davis 1994). Generally, flood tidal deltas along microtidal coasts are multi-lobate and unaffected by ebbing currents (modified from Davis 1994).

**Geoform Type: Flood Tidal Delta Slope (Level 2 only)**

The sloping surfaces found at the edge of the tidal delta.

**Geoform Type: Levee Delta (Levels 1 & 2)**

A delta having the form of a long, narrow ridge that resembles a natural levee.

**Geoform: Delta Plain (Level 1 only)**

The level (or nearly level) surface that makes up the landward part of a large delta; strictly, a flood plain characterized by repeated channel bifurcation and divergence, multiple distributary channels, and interdistributary flood basins.

**Geoform: Depression (Level 2)**

General term for any relatively sunken part of the Earth's surface—especially a low-lying area surrounded by higher ground. Depressions often have no natural outlet for surface drainage (such as an interior basin or a karstic sinkhole) (Jackson 1997).

**Geoform Type: Scour Depression (Level 2 only)**

Depression formed by the abrasive action of sand or sediment driven by the movement of water or ice.

**Geoform: Diapir (Levels 1 & 2)**

A dome or anticlinal fold in which the overlying rocks or sediments have been ruptured when the plastic core material was squeezed out. Diapirs in sedimentary strata usually contain cores of salt or shale; igneous intrusions may also show diapiric structure.

**Geoform Type: Salt Dome (Levels 1 and 2)**

A diapir formed by the intrusion of salt into surrounding rocks.

**Geoform: Dike (Level 2)**

A tabular, igneous intrusion that cuts across the bedding or foliation of the country rock. Dikes are often more resistant to erosion than the surrounding country rock, and dikes can form long ridges.

**Geoform: Drumlin Field (Level 1)**

Groups or clusters of closely spaced drumlins or drumlinoid ridges, distributed more or less en echelon, and commonly separated by small, marshy tracts or depressions (interdrumlins).

**Geoform: Drumlin (Level 2)**

Drumlins are products of the streamline (laminar) flow of glaciers, which molded the subglacial floor through a combination of erosion and deposition. A drumlin is a low, smooth, elongated-oval hill, mound, or ridge of compact till, which has a core of bedrock or drift. A drumlin usually has a blunt nose facing the direction from which the ice approached, and a gentler slope tapering in the other direction. The longest axis is parallel to the general direction of glacier flow.

**Geoform: Dune Field (Level 1)**

An assemblage of moving and/or stabilized dunes; sand plains; interdune areas; and the ponds, lakes, or swamps produced by the blocking of waterways by migrating dunes (U.S. Department of Agriculture 2008).

**Geoform: Dune (Level 2)**

An active accumulation of sand (formed by wind action) with some elevation; dunes occur on a beach or further inland.

**Geoform: Fan (Levels 1 & 2)**

A low, outspread gently to steeply sloping mass of loose material, which is shaped like an open fan or a segment of a cone. Fans are made of material deposited by a flow of water at the place where it issues from a narrower or steeper gradient area into a broader area, valley, flat, or other feature.

**Geoform Type: Alluvial Fan (Level 1 only)**

A low, outspread, relatively flat (or gently sloping) mass of loose rock material, shaped like an open fan or a segment of a cone. The rock material was deposited by flowing water where it issues from a narrow valley or where the gradient abruptly changes. Alluvial fans are usually steeper than the surrounding surface.

**Geoform Type: Basin Floor Fan (Level 1 only)**

Deposition of submarine fans on the lower slope or basin floor; fan formation is associated with the erosion of canyons into the slope and the incision of fluvial valleys into the shelf. Siliciclastic sediment bypasses the shelf and slope through the valleys and canyons to feed the basin floor fan; sediment may be deposited at the mouth of a canyon or in an area widely separated from the canyon



mouth—or a canyon may not be evident.

**Geoform Type: Shoreline Fan (Level 1 only)**

A prograding shoreline formed where an alluvial fan is built out into a lake or sea.

**Geoform Type: Washover Fan (Levels 1 & 2)**

A fan-like landform of sand that washed over a barrier island or spit during a storm, and then deposited sand on the landward side. Washover fans can be small and completely subaerial—or they can be quite large and include subaqueous margins that extend into adjacent lagoons or estuaries. Large fans can be composed of ephemeral washover channels (micro feature) cut through dunes or beach ridges, back barrier flats, (subaqueous) washover fan flats, and (subaqueous) washover fan slopes. Subaerial or intertidal portions can range from barren to completely vegetated (U.S. Department of Agriculture 2008).

**Geoform: Flat (Levels 1 & 2)**

A general term for a level (or nearly level) surface or area of land marked by little or no relief; flats are often composed of unconsolidated sediments (such as mud or sand). These forms are more commonly encountered in the intertidal or in the shallow subtidal zones (see Figure 6.2).

**Geoform Type: Back Barrier Flat (Level 1 only)**

A subaerial, gently sloping landform on the lagoon side of the barrier beach ridge. These flats are composed predominantly of sand washed over (or through) the beach ridge during tidal surges (modified from Jackson 1997).

**Geoform Type: Barrier Flat (Level 1 only)**

A relatively flat, low-lying area that is separating the exposed (or seaward) edge of a barrier beach or barrier island from the lagoon behind it. Barrier flats commonly include pools of water, and may be barren or vegetated. These flats are an assemblage of both deflation flats left behind migrating dunes and/or storm washover sediments.

**Geoform Type: Ebb Tidal Delta Flat (Level 2 only)**

The relatively flat, dominant component of the ebb tidal delta. At extreme low tide, this landform may be exposed for a relatively short period (U.S. Department of Agriculture 2008).

**Geoform Type: Flood Tidal Delta Flat (Level 2 only)**

The relatively flat, dominant component of the flood tidal delta. At extreme low tide, this landform may be exposed for a relatively short period

**Geoform Type: Tidal Flat (Levels 1 & 2)**

An extensive, nearly horizontal, barren (or sparsely vegetated) tract of land that is alternately covered and uncovered by the tide. Tidal flats consist of unconsolidated sediment (mostly clays, silts and/or sand, and organic materials).

**Geoform Type: Washover Fan Flat (Level 1 only)**

A gently sloping, fan-like, subaqueous landform created by overwash from storm surges that transports sediment from the seaward side to the landward side of a barrier island (Jackson 1997). Sediment is carried through temporary overwash channels that cut through the dune complex on the barrier spit (Fisher and Simpson 1979; Boothroyd et al. 1985; Davis 1994) and spill out onto the lagoon-side platform, where they coalesce to form a broad belt. Also called Storm-Surge Platform Flat (Boothroyd et al. 1985) and Washover Fan Apron (Jackson 1997).

**Geoform Type: Wind Tidal Flat (Level 1 only)**

A broad, low-lying, nearly level sand flat that is alternately flooded by ponded rainwater or inundated by wind-driven marine and estuarine waters. Salinity fluctuations and prolonged periods of exposure preclude establishment of most types of vegetation (except for mats of filamentous blue-green algae).

**Geoform: Fluvio-Marine Deposit (Levels 1 & 2)**

Stratified materials (clay, silt, sand, or gravel) formed by both marine and fluvial processes, resulting from non-tidal sea-level fluctuations, subsidence, and/or stream migration (e.g., materials originally deposited in a nearshore environment and subsequently reworked by fluvial processes as the sea level fell).

**Geoform: Fracture (Levels 1 & 2)**

A crack or split formed in a rock or bedrock as a result of local erosion or rock stress; they are not due to tectonic actions (which form larger faults and fracture zones).

**Geoform: Hole/Pit (Level 2)**

A generally more steep-sided indentation or depression that is lower than the surrounding surface formed through a variety of processes.

**Geoform Type: Scour Hole (Level 2 only)**

A hole formed by the powerful and concentrated clearing and digging action of flowing air, water, or ice—especially the downward erosion by stream water (in sweeping away mud and silt on the outside curve of a bend) or during the time of a flood.

**Geoform Type: Solution Hole/Pit (Level 2 only)**

An indentation formed on a rock surface by a solution.

**Geoform: Hydrothermal Vent Field (Levels 1 & 2)**

An area where several hydrothermal vents, either active or inactive, are present.

**Geoform: Hydrothermal Vent (Level 2)**

Structures on the seafloor through which materials related to volcanic activity are extruded. These often form tall, chimney-like structures and can support diverse chemosynthetic biota and associated communities.

**Geoform: Inlet (Levels 1 & 2)**

Inlets are narrow constrictions through which water flows. The term is commonly used to describe gaps between barrier islands that allow tidal exchange with the adjacent—more enclosed—bays, lagoons, or marshes.

**Geoform Type: Tidal Inlet (Level 1 only)**

Any inlet through which water alternately floods landward, with the rising tide, and ebbs seaward, with the falling tide (Jackson 1997).

**Geoform Type: Relict Tidal Inlet (Level 1 only)**

A channel remnant that is left from a former tidal inlet. The channel was cut off or abandoned by infilling from migrating shore sediments.

**Geoform: Island (Levels 1 & 2)**

An area of land completely surrounded by water—or an elevated area of land surrounded by swamp or marsh, which is isolated at high water or during floods.

**Geoform Type: Barrier Island (Levels 1 & 2)**

A long, narrow, sandy island that is above high tide and parallel to the shore. Barrier islands commonly have dunes, vegetated zones, and swampy or marshy terrains extending lagoon-ward from the beach.

**Geoform: Karren (Level 2)**

Repeating, surficial solution channels, grooves, or other forms that are etched onto massive, bare limestone surfaces; types range in depth from a few millimeters up to one meter, and they are separated by ridges. May also refer to the total complex (all varieties) of surficial solution forms found on compact, pure limestone (U.S. Department of Agriculture 2008).

**Geoform: Knob (Level 2)**

A rounded protuberance, usually prominent or isolated with steep sides; also including peaks or other projections from seamounts, or a group of boulders, or other protruding areas of resistant rocks

**Geoform: Lagoon (Levels 1 & 2)**

Lagoons tend to be shallow, highly enclosed, with reduced exchange with the ocean, often experiencing high evaporation, and quiescent in terms of wind, current, and wave energy. They tend to have a very high surface to volume ratio, low to moderate watershed to water area ratio and can have a high wetland to water ratio. The flushing times tend to be long relative to riverine estuaries and even embayments, as the restricted exchange with the marine end member and reduced river input lengthen residence times.

**Geoform: Lava Field/Plain (Level 1)**

A relatively well-defined area that is covered by lava flows. These can be found either along the coast or in deeper water. Terrain in lava fields can be rough and broken or it can be relatively smooth; the terrain can also include vent structures (e.g., small cinder cones or spatter cones), surface flow structures (e.g., pressure ridges or tumuli), and small, intermittent areas covered with pyroclastics.

**Geoform: Ledge (Levels 1 & 2)**

Bedding planes that are exposed (either on the surface or at depth) often form ledges that have a high habitat value and support colonizing plants and animals. Ledges often

provide a more level surface than the bounding slopes. Ledges in the intertidal zone can form shelves or projections of rock (that are much longer than they are wide) on a rock wall or cliff face. They are formed along a coast by differential wave action on softer rocks and may be eroded by biological and chemical weathering.

**Geoform: Marine Lake (Level 1)**

An inland body of permanently standing brackish or saline water whose water level is commonly influenced by ocean tides through subterranean cavities connecting to nearby lagoons. The lake is generally of appreciable size (larger than a pond) and too deep to permit emergent vegetation to take root completely across the expanse of water. Such water bodies can have unique biota (e.g., the stingless jellyfish of Palau).

**Geoform: Marsh Platform (Levels 1 & 2)**

The flat, often thick, accumulation of peat that supports emergent marsh vegetation. It is commonly dissected by tidal creeks, and it is occasionally buried and re-exposed through the action of beach erosion and new inlet development.

**Geoform: Megaripples (Level 1)**

Large, sand waves or ripple-like features having wavelengths greater than 1 meter or a ripple height greater than 10 centimeters; Megaripples are formed in a subaqueous environment, and they are also known as subaqueous dunes. They may be superimposed with smaller bedforms (Bates and Jackson 1984).

**Geoform: Moraine (Level 1)**

A mound, ridge, or other distinct accumulation of unsorted, unstratified, glacial drift (predominantly till) that is deposited chiefly by direct action of glacier ice.

**Geoform Type: Disintegration Moraine (Level 1)**

A drift topography characterized by chaotic mounds and pits (generally randomly oriented) developed in supraglacial drift by collapse and flow as the underlying stagnant ice melted. Slopes may be steep and unstable, and there will be used and unused stream courses and lake depressions interspersed with the morainic ridges. Characteristically, there are numerous abrupt changes (lateral and vertical) between unconsolidated materials of differing lithology.

**Geoform Type: End Moraine (Level 1)**

A ridge-like accumulation that is being (or was) produced at the outer margin of an actively flowing glacier at any given time; a moraine that has been deposited at the outer or lower end of a valley glacier.

**Geoform Type: Ground Moraine (Level 1)**

An extensive, low-relief area of till, that has an uneven or undulating surface and is commonly bounded on the distal end by a recessional or end moraine. Ground moraines usually consist of poorly sorted rock and mineral debris (till), which has been dragged along, in, on, or beneath a glacier, and then deposited by basal lodgment and release from downwasting stagnant ice by ablation.

**Geoform Type: Kame Moraine (Level 1)**

An end moraine that contains numerous kames, commonly comprising the slumped or erosional remnants of a formerly continuous outwash plain that built up over the foot of rapidly wasting or stagnant ice.

**Geoform Type: Lateral Moraine (Level 1)**

A ridge-like moraine carried on (and deposited at) the side margin of a valley glacier. It is composed chiefly of rock fragments derived from valley walls by either glacial abrasion and plucking or colluvial accumulation from adjacent slopes.

**Geoform Type: Recessional Moraine (Level 1)**

An end or lateral moraine, built during a temporary—but significant—halt in the final retreat of a glacier. May also refer to a moraine built during a minor re-advance of the ice front during a period of general recession.

**Geoform Type: Terminal Moraine (Level 1)**

An end moraine that marks the farthest advance of a glacier; usually has the form of a massive arcuate or concentric ridge (or complex of ridges) underlain by till and other drift types.

**Geoform: Mound/Hummock (Levels 1 & 2)**

A low, rounded, natural hill of unspecified origin, which is generally less than 3 meters high and composed of Earthy material.

**Geoform Type: Tar Mound (Level 2 only)**

A mound of extruded tar (or other viscous hydrocarbons) on the seafloor that has some relief above the surrounding bottom. Tar mounds in southern California are typically 10 -100 meters in diameter and can coalesce to form tar reefs. Over time, tar mounds can come to support a diversity of colonizing organisms (Lorenson et al. 2009).

**Geoform: Mud Volcano (Level 2)**

An accumulation (usually conical in shape) of mud and rock formed by volcanic gases; may also refer to a similar accumulation formed by escaping petroliferous gases (Bates and Jackson 1984) (see Figure 6.3).

**Geoform: Natural Levee (Level 1)**

An embankment of sediment, bordering one or both sides of a submarine canyon, fan valley, deep-sea channel, river, or other feature. A natural levee has a long, broad, low shape and is composed of sand and coarse silt, which was built by a stream on its flood plain and along both sides of its channel—especially in time of flood when water overflowing the normal banks is forced to deposit the coarsest part of its load. It has a gentle slope away from the river and toward the surrounding floodplain, and its highest elevation is closest to the river bank.

**Geoform Type: Lava Levee (Level 1)**

The scoriaceous sheets of lava that overflowed their natural channels and solidified to form a levee, similar to levees formed by an overflowing stream of

water.

**Geoform: Overhang (Cliff) (Levels 1 & 2)**

A rock mass jutting out from a slope, especially the upper part or edge of an eroded cliff projecting out over the lower, undercut part (as above a wave-cut notch). Generally, these are characterized as having a slope greater than 90 degrees.

**Geoform: Panne (Level 2)**

Shallow depressions or flats, often occurring in and adjacent to marshes in the high intertidal that zone that receive saltwater inflow on an infrequent basis. They often are unvegetated and can have encrustations of salt left by evaporation.

**Geoform: Pavement Area (Levels 1 & 2)**

Flat (or gently sloping), low-relief, solid, carbonate rock with little or no fine-scale rugosity. These areas can be covered with algae, hard coral, gorgonians, zooanthids, or other sessile vertebrates; the coverage may be dense enough to partially obscure the underlying surface. On less colonized pavement features, rock may be covered by a thin sand veneer (Kendall et al. 2001).

**Geoform: Platform (Levels 1 & 2)**

Any level or nearly level surface, ranging in size from a terrace or bench to a plateau defined by slopes around its edges.

**Geoform Type: Wave-Cut Platform (Level 1 only)**

A gently sloping surface produced by wave erosion, which extends into the sea or lake from the base of the wave-cut cliff. When subaqueous, they are relict, erosional landforms that originally formed as a wave-cut bench and abrasion platform (from coastal wave erosion), which were later submerged by rising sea level or subsiding land surface (modified from Jackson 1997).

**Geoform: Pockmark Field (Level 1)**

An area of the seafloor dominated by many pockmarks.

**Geoform: Pockmark (Level 2)**

Small craters in the seabed caused by fluids (gas and liquids) erupting and streaming through the sediments. Some pockmarks discovered off Nova Scotia have been up to 150 meters in diameter and 10 meters deep.

**Geoform: Ridge (Levels 1 & 2)**

A long, narrow elevation, usually sharp crested with steep sides. Larger ridges can form an extended upland between valleys.

**Geoform Type: Beach Ridge (Levels 1 & 2)**

A low, essentially continuous mound of beach (or beach-and-dune material) heaped up by the action of waves and currents on the backshore of a beach, beyond the present limit of storm waves or the reach of ordinary tides. The ridge can occur singly or as one of a series of approximately parallel deposits. The ridges are roughly parallel to the shoreline and represent successive positions of an advancing shoreline.

**Geoform Type: Esker (Levels 1 & 2)**

A long, narrow, sinuous, steep-sided ridge composed of irregularly stratified sand and gravel that was deposited as the bed of a stream flowing in a subglacial ice tunnel (within or below the ice) or between ice walls on top of the ice of a wasting glacier. Eskers remain behind as high ground when the glacier melts. Eskers range in length from less than a kilometer to more than 160 kilometers, and the height range is 3 -30 meters.

**Geoform: Ripples (Level 2)**

Small, linear structures that form as a result of water movement over unconsolidated sediments. The shape and pattern of the ripples provide indications of the general water movement regime in the area. Ripples can be straight, sinuous, catenary, or linguoid.

**Geoform: Rock Outcrop (Levels 1 & 2)**

An area where bedrock is exposed at the Earth's surface.

**Geoform Type: Authigenic Carbonate Outcrop (Level 2 only)**

These outcrops result from the slow seepage of fluid containing dissolved carbon. They form pavements, chimneys, and rings, donuts, or slabs (Stakes et al. 1999).

**Geoform: Rubble Field (Level 1)**

A loose mass of angular rock fragments. These can occur both on land and underwater.

**Geoform: Runnel/Rill (Level 2)**

A small, transient channel carrying the water of a wave after it breaks on a beach. They can also be formed by tidal ebb or runoff (following moderate rains or ice/snow melts). Larger runnels can have steep sides.

**Geoform: Sediment Wave Field (Levels 1 & 2)**

An area of wave-like bedforms in sand or other unconsolidated material which are formed by the action of tides, currents, or waves. These bedforms range from centimeters to meters in size and may be superimposed on larger features. Sand waves lack the deep scour associated with dunes or megaripples (Bates and Jackson 1984).

**Geoform: Scarp/Wall (Levels 1 & 2)**

A relatively straight, cliff-like face or slope of considerable linear extent, which breaks up the general continuity of the land by separating surfaces lying at different levels (as along the margin of a plateau or mesa). The term wall can be applied to steep or vertical areas on the seaward or exposed side of a reef. Although hard corals may be present, walls in this setting are formed by geologic processes and are not the result of reef-building activities by corals. A wall may be vertical or terraced, and is often referred to as the "dropoff."

**Geoform Type: Fault Scarp (Levels 1 & 2)**

A feature caused by the rapid erosion of soft rock on the side of a fault (as compared to that of more resistant rock on the other side), for example, the east face of the Sierra Nevada in California.



**Geoform Type: Erosion Scarp (Levels 1 & 2)**

A long, steep slope or line of cliffs at the edge of a plateau or ridge formed by erosion.

**Geoform Type: Beach Scarp (Levels 1 & 2)**

An almost vertical slope (caused by wave erosion) that fronts a berm on a beach. Scarps may range in height from several centimeters to a few meters, depending on the character of the wave action and the nature and composition of the beach.

**Geoform: Scar (Levels 1 & 2)**

A scar can be either a gouge or deformation of the bottom, or an area where the surface of the substrate, vegetation, or other colonizing organisms have been removed by abrasion or impact. These may be temporary or permanent features.

**Geoform Type: Iceberg Scour Scar/Furrow (Levels 1 & 2)**

A scar formed by an iceberg dragging across the substrate. These can occur in shallow water and extend for long distances.

**Geoform Type: Slump Scar (Levels 1 & 2)**

A scar formed by the removal of surface sediment as a result of mass wasting. These scars have the appearance of fresh, unweathered, or colonized sediment.

**Geoform: Seamount (Level 1)**

An elevation of the seafloor, which is 1,000 meters or higher. Seamounts may be discrete, arranged in a linear or random grouping, or connected at their bases and aligned along a ridge or rise.

**Geoform Type: Guyot (Level 1)**

A type of seamount that has a flat top.

**Geoform Type: Knoll Seamount (Level 1)**

A submerged elevation of rounded shape that rises from the ocean floor, but is less prominent than a seamount.

**Geoform Type: Pinnacle Seamount (Level 1)**

A steep-sided, often isolated peak that can occur at depth or reach close to the surface. They are often important aggregation points for fish and other marine life.

**Geoform: Sediment Sheet (Level 2)**

A thin, widespread, sedimentary deposit, formed by a transgressive sea advancing for a considerable distance over a stable shelf area; may also be called a blanket deposit (Bates and Jackson 1984).

**Geoform: Shelf Valley (Level 1)**

A valley crossing the continental shelf, often forming an extension of an existing terrestrial river and terminating in a canyon as the valley reaches the shelf break. Shelf valleys were formed during periods of lower sea level, and continental, glacial melt water contributed to their genesis.



**Geoform: Shoal (Levels 1 & 2)**

A relatively shallow area in a body of water that rises very close to, or reaches, the surface. Shoals have a variety of shapes that are influenced by tidal and river currents. They tend to consist of (or be covered by) sand or other unconsolidated sediments, but may also be composed of rock or other materials. Unlike banks, shoals can be exposed during low tide or periods of low water flow in rivers or streams (modified from Jackson 1997).

**Geoform Type: Moraine Shoal (Levels 1 & 2)**

The submerged portion of a glacial moraine that reaches close to the surface. These often occur where sea-level rise has drowned former terrestrial glacial features.

**Geoform: Shore Complex (Level 1)**

Generally, a narrow, elongate area that parallels a coastline—commonly cutting across diverse inland landforms. Shore complexes are dominated by landforms derived from active coastal processes that give rise to beach ridges, washover fans, beaches, dunes, wave-cut platforms, barrier islands, cliffs, etc. (Schoeneberger and Wysocki 2005).

**Geoform: Shore (Levels 1 & 2)**

The intersection of a specified plane of water with the beach that migrates with changes of the tide or of the water level.

**Geoform Type: Foreshore (Levels 1 & 2)**

The zone of the shore or beach that is regularly covered and uncovered by the rise and fall of the tide.

**Geoform Type: Backshore (Levels 1 & 2)**

The upper or inner zone of the shore or beach that is above the high-water line of mean spring tides and below the upper limit of shore-zone processes. The backshore is usually dry or moistened by spray, and is acted upon by waves (or covered by water) only during exceptionally severe storms or unusually high tides. It is essentially horizontal or slopes gently landward, and it is divided from the foreshore by the crest of the most seaward berm.

**Geoform: Slope (Levels 1 & 2)**

An inclined area of ground or substrate with a change in depth or elevation between its upper and lower limits. Slopes occur at all scales and can refer to broad areas of inclined topography to the flanks of small mounds or depressions in the Earth's surface.

**Geoform Type: Washover Fan Slope (Level 1 only)**

A subaqueous extension of a washover fan flat, which slopes toward deeper water of a lagoon or estuary and away from the washover fan flat.

**Geoform: Spit (Level 1)**

(a) A small point, low tongue, or narrow embankment of land, which commonly consists of sand or gravel deposited by longshore transport. One end of the spit is attached to the mainland, and the other terminates in open water (usually the sea); a spit is a finger-

like extension of the beach. (b) A relatively long, narrow shoal or reef extending from the shore into a body of water (Jackson 1997).

**Geoform: Stack (Level 2)**

A rocky subaerial landform consisting of a steep (and often vertical) column or columns of rock in the sea near a coast which have been isolated from the mainland by wave erosion.

**Geoform: Submarine Slide Deposit (Level 1)**

This form includes a wide variety of mass-movement landforms and processes involving the down slope transport (under gravitational influence) of soil and rock material *en masse*. Geoforms that could occur within (or as a result of) landslides are Rubble Field.

**Geoform: Swale/Slack (Level 2)**

A long, narrow, generally shallow trough-like depression between two beach ridges and aligned roughly parallel to the coastline. These typically will be found in the intertidal or supratidal zones.

**Geoform: Terrace (Level 1)**

Any long, narrow, relatively level or gently inclined surface, generally less broad than a plain, but broader than a ledge and bounded along one edge by a steeper descending slope and along the other by a steeper ascending slope. Terraces may border a valley floor or shoreline, and they can represent the former position of a flood plain, lake, or sea shore. Terraces may be created by erosion, wave action, uplift, currents, or any other process.

**Geoform Type: Fluvio-marine Terrace (Level 1)**

A constructional, coastal strip, which slopes gently seaward and/or down valley and is veneered by (or completely composed of) unconsolidated fluvio-marine deposits—typically silt, sand, and fine gravel (Schoeneberger and Wysocki 2005).

**Geoform Type: Wave-Built Terrace (Level 1)**

A subaqueous, relict, depositional landform originally constructed by river or longshore, sediment deposits along the outer edge of a wave-cut platform, and then later submerged by rising sea level or subsiding land surface (modified from Jackson 1997).

**Geoform Type: Marine Terrace (Level 1)**

(a) A narrow, coastal strip, formed of deposited material, that slopes gently seaward. (b) An elevated marine-cut bench or a wave-cut platform that has been exposed by uplift along a seacoast (or by lowering of sea level). Marine Terrace may also refer to a wave-cut platform that merges into a wave-built terrace (Bates and Jackson 1984).

**Geoform: Tidepool (Level 2)**

A pool of salt water left by an ebbing tide that generally persists until the next flood tide. These normally occur in rock substrates and support diverse animal and plant communities (see Figure 6.4).

**Geoform: Till Surface (Levels 1 & 2)**

An area of substrate (predominantly unsorted and unstratified drift) that is generally unconsolidated, because it was deposited directly by a glacier without subsequent reworking by melt water. The surface consists of a heterogeneous mixture of clay, silt, sand, gravel, stones, and boulders; rock fragments of various lithologies are imbedded within a finer matrix that can range from clay to sandy loam.

**Geoform: Tombolo (Level 1)**

A sand or gravel bar or barrier that connects an island with the mainland (or with another island).

**Geoform Origin: Biogenic**

Biogenic geoforms are physical features and landforms that were created by the action of living organisms (bioherms). These primarily consist of the different types of reefs. Examples of these generally hard, fixed structures include the incorporation of dissolved calcium carbonate into reef structure by corals, aggregations of mollusk shells into a fixed cohesive substrate, or the cementation of existing sediments into an aggregation of worm tubes. As with all geoforms the characteristic of concern in this component is the physical shape of these reef features, not the living biology that may have participated in their genesis. Any of the reef geoforms may or may not have living coral or other life present.

**Geoform: Atoll (Level 1)**

A ring-like coral reef that nearly (or entirely) encloses a reef lagoon. The volcanic island normally associated with an atoll may or may not be present. Atolls appear in plain view as a roughly circular reef that is surmounted by a chain of closely spaced, low, coral islets that encircle (or nearly encircle) a shallow lagoon in which there is no land or islands of non-coral origin; the reef is surrounded by open sea.

**Geoform Type: Submerged Atoll/Atoll Reef (Level 1)**

Atoll structure in which new coral growth has not kept up with rising sea levels (or is overcome by the effects of subsidence such that it now lies below the surface). It may still support living coral communities.

**Geoform: Burrows/Bioturbation (Level 2)**

Tubes, holes, furrows, and small mounds formed by the digging, feeding, and movement of benthic fauna. These can bring nutrients and other compounds to the surface—as well as destabilize the substrate.

**Geoform Type: Tilefish Burrow (Level 2)**

Burrows formed by the Tilefish (sp.). These can be up to 3 meters wide and 1 -2 meters deep. In some areas, the density of these burrows can be over 1,000 per square kilometer, thus significantly altering the benthos.

**Geoform: Coral Reef Island (Levels 1 & 2)**

A tropical island built of organic material derived from the skeletons of corals and other reef associates. Coral islands are usually low and may be several kilometers in size. Typically, their structure is integrally part of a living or relatively recent coral reef.

**Geoform: Mollusk Reef (Levels 1 & 2)**

An area of many shell reefs surrounded and intermixed with channels and unvegetated flats.

**Geoform Type: Fringing Mollusk Reef (Level 2 only)**

Narrow, linear reefs, which are usually lying below the marsh platform. These reefs form along the shore of tidal creeks, and they are typically intertidal (see Figure 6.5).

**Geoform Type: Linear Mollusk Reef (Level 2 only)**

Narrow straight or sinuous, ridge-like reefs formed primarily by oysters but also by other mollusks. These are also usually intertidal. Examples of this type of reef can be found in areas with small tidal ranges such as Apalachicola Bay and Nueces Bay, Texas (see Figure 6.6).

**Geoform Type: Patch Mollusk Reef (Level 2 only)**

Mounded, generally round or lobate reefs that have some vertical relief above the surrounding substrate. These are usually intertidal, but they can occur in subtidal settings (see Figure 6.7).

**Geoform Type: Washed Shell Mound (Level 2 only)**

Generally linear accumulations of dead shell that form high in the intertidal zone along tidal creeks and on the landward side of barrier islands. The shells are loose, and they are usually bleached by the sun—giving them a bright appearance (see Figure 6.8).

**Geoform: Deep/Cold-Water Coral Reef (Levels 1 & 2)**

Reefs formed by deepwater azooxanthellate (i.e., lacking symbiotic algae), stony corals (Order Scleractinia). Aggregations of these colonial corals can form structures that range from small patch reefs that are several meters across, to large reefs and giant carbonate mounds up to 300 meters high and several kilometers in diameter; these reefs form over many thousands to millions of years (Roberts, Wheeler, and Freiwald 2006).

**Geoform Type: Biogenic Deep Coral Reef (Levels 1 & 2)**

Persistent structures, formed by deepwater corals, whose growth exceeds (bio) erosion. These reefs result in local topographic highs that alter hydrodynamic and sedimentary regimes. The actual reef structure remains, often with the growing reefs on their crest or side. The coral thickets and skeletal remains trap sediments, contributing to the accretion of the reef (Roberts et al. 2009).

**Geoform Type: Deep Coral Carbonate Mound (Levels 1 & 2)**

Topographic seafloor structures that are the result of previous periods of coral growth, often with successive periods of reef development, sedimentation, and erosion. These are elevated structures, composed of coral fossils and accumulated interstitial sediments. This type includes structures variously referred to as carbonate knolls, coral banks, bio-buildups, and lithoherms. Coral carbonate mounds can take on various shapes and sizes, reaching tens of meters in height and tens of kilometers in size. They may or may not currently include

biogenic reefs (Roberts et al. 2009).

**Geoform Type: Shallow/Mesophotic Coral Reef (Levels 1 & 2)**

Light-dependent coral reefs that occur within the photic zone (the mesophotic reefs occur in the lower part of this zone at depths of 30 -150 meters).

(<http://www.mesophotic.org>).

**Geoform Type: Aggregate Coral Reef (Levels 1 & 2)**

Continuous, high-relief coral formation that occurs in various shapes and lacks sand channels. This type includes linear coral formations that are oriented parallel to the shelf edge (Zitello et al. 2009).

**Geoform Type: Shallow/Mesophotic Coral Carbonate Mound (Levels 1 & 2)**

Topographic seafloor structures that are the result of previous periods of coral growth, often with successive periods of reef development, sedimentation, and erosion. These are elevated structures, composed of coral fossils and accumulated interstitial sediments. This type includes structures variously referred to as carbonate knolls, coral banks, bio-buildups, and lithoherms. Coral carbonate mounds can take on various shapes and sizes, reaching tens of meters in height and tens of kilometers in size. They may or may not currently include biogenic reefs (Roberts et al. 2009).

**Geoform Type: Coral Head/Bomme (Level 2 only)**

Individual, massive coral colonies—usually with a boulder or mound-like shape.

**Geoform Type: Coral Pinnacle (Level 2 only)**

A hard, columnar structure formed primarily by the growth of hard corals and other encrusting organisms. These can occur as isolated vertical structures or in association with other pinnacles.

**Geoform Type: Fragile Mesophotic Coral Reef (Levels 1 & 2)**

Coral reef characterized by delicate branching corals and other reef organisms.

**Geoform Type: Fringing Coral Reef (Levels 1 & 2)**

Fringing coral reefs are generally linear and generally aligned with the nearby coast. They have the same general morphology as the larger barrier reefs but occur at smaller scales.

**Geoform Type: Halo (Levels 1 & 2)**

The zone of low-relief, generally bare, sand surrounding Patch Coral Reefs. Halos are often formed by the action of grazing herbivores in the adjacent patch reef itself.

**Geoform Type: Linear Coral Reef (Levels 1 & 2)**

These are linear coral formations that are oriented parallel to shore or the shelf edge. They follow the contours of the shore/shelf edge. This category is used for such commonly used terms as forereef, fringing reef, and shelf edge reef.

**Geoform Type: Patch Coral Reef (Levels 1 & 2)**

Individual patch coral reefs are coral formations with circular or oblong shapes and vertical reliefs of one meter or more in relation to the surrounding seafloor. These reefs are isolated from other coral reef formations by bare sand, seagrass, rhodoliths, or other habitats—and have no organized structural axis relative to the contours of the insular shelf edge (Zitello et al. 2009).

**Geoform Type: Pinnacle Coral Reef (Levels 1 & 2)**

A reef structure formed by the aggregation of many individual pinnacles

**Geoform Type: Spur and Groove Coral Reef (Levels 1 & 2)**

Habitat having alternating sand and coral formations that are oriented perpendicular to the shore or bank/shelf escarpment. The coral formations (spurs) of this feature typically have a high vertical relief (compared to pavement with sand channels), and they are separated from each other by 1 -5 meters of sand or bare hardbottom (grooves)—although the height and width of these elements may vary considerably. This geoform type typically occurs in the forereef or bank/shelf escarpment zone.

**Geoform: Tree Fall (Level 2)**

Tree falls are trees or woody parts that have sunk to the deep ocean floor (generally 2,000 meters or deeper) and may remain there for decades. They are colonized by a specialized group of wood-boring organisms such as xylophaga (a bivalve) and several crustaceans. Tree falls also support a suite of predators and scavengers.

**Geoform: Whale Fall (Level 2)**

Whale carcasses that have fallen to the deep ocean floor (generally 2,000 meters or deeper), and which support a wide variety of arthropods and worms—and a limited number of fish. Whale falls can persist for decades (see Figure 6.9).

**Geoform: Worm Reef (Level 2)**

Reefs that consist of the consolidated tubes of many individual tube worms, often of the sabellaria and serpulid genera. They may be calcareous or siliceous, and the outer surface of these reefs may support living worm communities.

**Geoform Type: Patch Worm Reef (Level 2)**

These reefs are often massive, boulder-like structures separated from each other by unconsolidated sediments.

**Geoform Type: Linear Worm Reef (Level 2)**

Linear or bench-like reefs formed by worms in the intertidal zone.

**Geoform Origin: Anthropogenic**

In many coastal and deep oceans, artificial structures (such as piers, breakwaters, bulkheads, berms, drilling rigs, and artificial reefs) are a significant part of the environment. The continually (or intermittently) submerged portions of features attract vagile fauna and provide attachment surfaces for plants and sessile animals. These features can also provide shelter from predators and prevailing current, and they can support niche communities that increase overall biodiversity. However, these structures can also have negative effects (such as altering natural

hydrodynamic patterns, interfering with animal movement, and increasing contaminant loading into nearshore areas), and thus are often of interest to resource managers.

The same relationship between Level 1 and Level 2 geoforms prevails in this origin type as in the geologic and biogenic categories; however, due to the complexity of some of the anthropogenic structures, many more Level 2 units may be present in a single Level 1 geoform. Besides physical structures, features that are the result of human activity (such as scars and trawl marks) are included among the anthropogenic geoforms.

**Geoform: Aquaculture Structure (Levels 1 & 2)**

These structures can take many forms: lines suspended over the sediment, floating wooden frameworks sub-tidal structures attached to the benthos such as wooden piers and platforms, and pens and enclosures (both at the surface and submerged). These structures are associated with the cultivation of fish, crustaceans, and shellfish for human use or consumption. They may be integrated into shallow water bays and ponds, or they may be deployed in deeper water. Due to their structural aspects, they can be attractive to fish and other animals. They are often sources of nutrients and, thus, have impacts on the surrounding ecology.

**Geoform: Artificial Bar (Level 1)**

Shoal or bar constructed by human activity to influence the movement of water and tides—or reduce surface wave activity within an area.

**Geoform Type: Harbor Bar (Level 1)**

A bar built across the exit to a harbor, in some cases to reduce wave energy within the harbor itself.

**Geoform: Artificial Dike (Level 1)**

A raised, linear barrier intended to contain or hold back water in order to prevent flooding of adjacent land. These may be concrete or fill structures.

**Geoform Type: Artificial Levee (Level 1)**

(a) A dike along the side of a river channel erected to prevent overflow during floods, usually running along the channel direction and near the natural levee crests of streams. (b) An artificial embankment constructed along the bank of a watercourse or an arm of the sea to protect land from inundation (or to confine stream flow to its channel).

**Geoform: Artificial Reef (Level 2)**

An artificial structure placed on the ocean floor to provide a hard substrate for sea life to colonize. Artificial reefs are constructed by sinking dense materials (such as old ships and barges, concrete-ballasted tire units, concrete and steel demolition debris, and dredge rock) on the seafloor within designated reef sites.

**Geoform: Artificial Scar (Level 2)**

A gouge or deformation of the bottom, or an area where the surface of the substrate, vegetation, or other colonizing organisms have been removed by abrasion or impact. These may be temporary or permanent features.



**Geoform Type: Prop Scar (Level 2)**

A scar that is the result of boat or ship propellers making contact with the bottom. Usually these are linear features occurring in shallow areas or shoals.

**Geoform Type: Trawling Scar (Level 2)**

A groove or cleared area of the substrate that is the result of dragging nets or weights across the seafloor. These scars can extend for a long distance and may overlap older scars. They are generally associated with damage to epibenthic organic communities.

**Geoform: Buoy (Level 2)**

Anchored objects that float in a relatively fixed position at the water surface. Most buoys are used as navigational aids and markers for channels, but many buoys also contain scientific or other observational instruments.

**Geoform: Breakwater/Jetty (Level 2)**

Structures extending more or less perpendicularly from the shore into a body of water, which are designed to direct and confine the current or tide, to protect a harbor, or to prevent shoaling of a navigable inlet by littoral materials.

**Geoform Type: Groin (Level 2)**

A small jetty extending perpendicular from the shore designed to reduce beach erosion. Groins provide hard substrate in what is often an area dominated by unconsolidated sediments.

**Geoform: Breachway (Level 2)**

The shoreline that is created along the channel formed by jetties.

**Geoform: Bulkhead (Level 2)**

An artificially reinforced section of the shoreline (or the structure itself). These can be composed of piles of natural material (such as rip-rap), or they may resemble walls of timbers or other substance. They may have many purposes but generally are not intended to prevent flooding of lower areas.

**Geoform: Cable Area (Level 1)**

An area through which one or more cables have been placed in (or on) the substrate. These areas can be navigation hazards, so they are commonly noted on nautical charts. Scarring, debris, and other features associated with cable installation or maintenance may be present.

**Geoform: Cable (Level 2)**

Structures that serve as linear conduits for electricity or as supporting lines for other in-water or above-water infrastructure.

**Geoform: Canal (Levels 1 & 2)**

(a) Man-made channels produced to facilitate navigation between water bodies. (b) Generally linear, dredged, closed-ended ditches that have been dug between housing units along the coast.

**Geoform: Dam (Levels 1 & 2)**



An obstruction across a flow that produces a lake, pond, or other widening.

**Geoform: Dock/Pier (Level 2)**

A landing place for vessels normally oriented perpendicular to the shore with a flat surface for off-loading materials. Docks may be fixed in position through anchors or piles, or be supported by pilings or other structures.

**Geoform: Dredged/Excavated Channel (Levels 1 & 2)**

A roughly linear, deep area within an existing water body formed by a dredging operation for navigation purposes (after Wells et al. 1994).

**Geoform: Dredge Deposit (Levels 1 & 2)**

An accumulation on the seafloor (or land surface) where spoil materials from a dredging operation are placed. They often exhibit some topographical expression and can support biological communities that are different than the surrounding area. These deposits are often unconsolidated in character, but they can also be relatively stable.

**Geoform Type: Dredge Deposit Shoal (Levels 1 & 2)**

A subaqueous area that is substantially shallower than the surrounding area, which resulted from the deposition of materials from dredging and dumping.

**Geoform Type: Dredge Deposit Bank (Levels 1 & 2)**

A subaerial mound or ridge (which permanently stands above the water) composed of randomly mixed sediments deposited during dredging and dumping.

**Geoform: Dredge Disturbance (Level 2)**

An area of the seafloor impacted by dredging activities. In this instance, the term is meant to apply to secondary scarring, smothering, or destruction of epibenthic and near-surface infaunal communities by dredging activity (rather than the direct removal of material by dredging which would be characterized under the Dredged Channel or other geoforms).

**Geoform: Drilling (Oil and Gas) Rig (Level 2)**

Large structures built to house workers and machinery needed to drill wells in the ocean bed in order to extract oil or other natural resources. They may be attached to the ocean floor, consist of an artificial island, or be floating; rigs often provide important structure and attachment points for marine animals.

**Geoform: Fill Area (Level 2)**

A topographically low area into which unconsolidated material has been placed in order to raise the ground level as part of development or expansion of coastal infrastructure.

**Geoform Type: Landfill (Level 2)**

A fill area where some form of solid waste is being used as the fill material.

**Geoform: Fish Pond (Level 2)**

These are mostly enclosed basins, usually along the shore used to trap fish. During high tide they are open to the sea but as the tide recedes they become cut off to allow

capture of the trapped fish. These features may be very old and have strong cultural and archaeological significance.

**Geoform: Harbor (Level 1)**

A small bay or a sheltered part of a sea, lake, or other large body of water. A harbor is usually well protected (either naturally or artificially) against high waves and strong currents and serves as a safe anchorage for ships and where port facilities are present. Many smaller anthropogenic geoforms may be encountered within a harbor.

**Geoform: Lock (Level 2)**

A chamber designed to lift vessels—from one water body to another—by adjusting the level of water in the chamber.

**Geoform: Lost/Discarded Fishing Gear (Level 2)**

This consists of nets, floats, weights and cabling associated with fishing activities, usually at a commercial level. This type of debris forms a serious hazard for marine life and can persist in the environment for long periods.

**Geoform: Marina/Boat Ramp (Level 2)**

A series of docks, walkways, slips, and support infrastructure (such as cables and small pipelines) for in-water storage of yachts and boats. Marinas commonly include one or more boat ramps, which consist of a sloping driveway for launching small, trailered vessels.

**Geoform: Mooring Field (Level 1)**

These are anchorages with many small, fixed buoys in place for securing yachts and other vessels.

**Geoform: Mosquito Ditch (Level 2)**

Straight, narrow channels that were dug to drain the upper reaches of salt marshes in order to control the populations of mosquitoes that breed there. However, draining the standing water also impacts populations of mosquito-eating fish that live in those waters (<http://www.edc.uri.edu/restoration/html/intro/salt.htm>).

**Geoform: Outfall/Intake (Level 2)**

Outfalls are pipelines or tunnels that discharge municipal or industrial wastewater, storm water, combined sewer overflows, cooling water, or brine effluents to a receiving water body. Intakes are pipes designed (and placed) to draw lake or seawater into a man-made pond or other facility.

**Geoform: Pilings (Level 2)**

A structure formed by piles that are long, slender columns—usually made of timber, steel, or reinforced concrete (see Figure 6.10).

**Geoform: Pipeline Area (Level 1)**

A corridor through which one or more pipelines have been placed.

**Geoform: Rip Rap Deposit (Level 2)**

An accumulation of rock or boulders placed along a waterway or shoreline to reduce

erosion.

**Geoform: Salt Pond Complex (Level 1)**

A series of shallow ponds separated by berms or levels, designed to produce salt from marine water or other brines through the process of evapotranspiration. The ponds are periodically drained to harvest salts. These can support various microalgal communities while water is present.

**Geoform: Salt Pond (Level 2)**

Usually enclosed areas just landward of the shoreline with a permanent-to-intermittent flooding regime of saline-to-hypersaline waters.

**Geoform: Seawall (Level 1)**

A man-made wall or embankment of stone, reinforced concrete, or other material along a shore that was built to prevent wave erosion. These are similar to jetties, but seawalls are more commonly oriented along the water's edge (instead of perpendicular to the shore).

**Geoform: Tidal/Wave Energy Structure (Level 2)**

Structures that consist of long booms deployed at the surface or turbines placed on the seafloor or other structures. Some portions of these structures may form attachment surfaces for sessile fauna.

**Geoform: Trash Aggregation (Levels 1 and 2)**

Aggregations of submerged, floating or suspended trash. These may be loose and mobile as when floating at the water's surface or consolidated by sediment on the bottom or along shore. Trash aggregations may be the result of local storm or seismic events such as floods or tsunamis. Trash aggregations can also form over long periods due to the action of large gyres and currents as in the mid-Pacific Ocean.

**Geoform: Wharf (Level 2)**

A structure on the shore of a harbor where ships may dock to load and unload cargo or passengers. A wharf is usually a fixed platform, often on pilings. Smaller and more modern wharves are sometimes built on flotation devices (pontoons) to keep them at the same level as the ship—even during changing tides. Wharves form attachment surfaces for shellfish and sessile epifauna, and they are common aggregation points for fish. Also, wharves are often locations where contaminants are introduced into the environment (through spills or waste disposal).

**Geoform: Wind Energy Structure (Level 2)**

Structures deployed in the marine environment in order to produce energy from the wind. These structures often consist of piling, cabling supports, and associated anchoring devices.

**Geoform: Wreck (Level 2)**

Any of a variety of man-made structures (such as sunken ships or collapsed drilling rigs) that have fallen to the seafloor. They may be either completely or partially submerged. Wrecks often provide valuable habitat for attaching organisms or fish, but they may also

leach contaminants into the environment.

## Biotic Component

The Biotic Component (BC) of CMECS is a classification of the living organisms of the seabed and water column together with their physical associations at a variety of spatial scales. The BC is organized into a branched hierarchy of five nested levels: biotic setting, biotic class, biotic subclass, biotic group, and biotic community (Table 8.1). The biotic setting indicates whether the biota are attached or closely associated with the benthos or are suspended or floating in the water column. Biotic classes and biotic subclasses describe major biological characteristics at a fairly coarse level. Biotic groups are descriptive terms based on finer distinctions of taxonomy, structure, position, environment, and salinity levels. Biotic communities are descriptions of repeatable, characteristic assemblages of organisms. In the absence of complete species association data, biotic communities can be approximated using dominant or diagnostic species and then refined once more information is available. When identified in the context of repeating environmental circumstances, biotic communities can be used as the basis for defining and fully describing biotopes. A biotope assigns a more complete description of the feature; involving all other applicable components of CMECS, listing the defining species and explaining the ecological and societal values of the biotope (see Section 9).

Unless otherwise noted, biotic classification units in the BC are defined by the dominance of life forms, taxa, or other classifiers in an observation. For collected observations (such as grab samples or cores), dominance is measured in terms of biomass or numbers of individuals, as specified by the user. In the case of images and visual estimates, dominance is assigned to the taxa with the greatest percent cover in the observational footprint. For example, an observation with 60% seagrass, 20% soft corals, and 20% sponges is classified as an Aquatic Vegetation Bed—whereas an observation with 60% soft corals, 20% seagrass, and 20% sponges is classified as a Faunal Bed. It may be important for some users to note the presence of the non-dominant biota, which can be achieved by using a Co-occurring Element in an observation. See Section 10 for information about how to note Co-occurring Elements and Associated Taxa.

### Biotic Setting: Planktonic Biota

Planktonic Biota includes biota that drift, float, or remain suspended in the water column in aggregations that are big enough to be (a) detected by the human eye (or with mild magnification) or (b) sampled with a fine-plankton net. Planktonic biota are not regularly associated with the seafloor. Water parcels may be examined for plankton using a dipnet, a water sampler, a towed plankton net, imagery (including "Plankton Cameras" that are moved through the water), or other means. In all cases, plankton are assigned classifications based on perceived dominance by the observer (either based on mass or numbers, as specified by the user/observer). Because most plankton communities are mixes of many types of zooplankton and phytoplankton, practitioners should consider the widespread use of the Co-occurring Elements modifier (when non-dominant taxa are covered in other parts of the CMECS classification) or the Associated Taxa modifier (when non-dominant taxa do not constitute a CMECS classification unit).

### **Biotic Class: Zooplankton**

Water parcels or layers in which zooplankton are perceived to be the dominant feature. Zooplankton are heterotrophic biota of the water column; zooplankton drift with the currents, but may (or may not) be able to move through the water under their own power. Zooplankton may feed on phytoplankton, other zooplankton, or on detritus. CMECS classifies zooplankton that may range in size from gigantic salp chains (strings of gelatinous filter feeding tunicates that attain a length of 30 meters or more), to radiolarians (minute, shelled amoebas). CMECS was not designed to be used for the smallest planktonic forms (nanoplankton or picoplankton). CMECS Class Zooplankton includes both Holoplankton (that live out their entire life histories in the plankton) and Meroplankton (that are transient in the plankton). Meroplankton are typically larval stages that develop into nekton or benthos as they mature. Meroplankton in general are difficult to identify; specialized taxonomic knowledge and sets of regional keys are generally required. Both Holoplankton and Meroplankton are quite diverse and include members of most marine phyla.

Aggregations of specific types of zooplankton (or of mixed zooplankton/phytoplankton communities) may occur in many forms. In general, an “Aggregation” is a relatively dense and homogeneous group of plankton that may be produced by rapid reproduction in-place under favorable conditions (by phytoplankton and holoplankton), by hydrodynamic forcing, by a common mass origin, by plankton motility (e.g., diurnal vertical migrations), by barriers to movement (e.g., pycnoclines), or by other phenomena. A Spawning Aggregation forms after a mass spawning event when synchronous spawning by many individuals produces large pulses of gametes and larvae. Classification of a Spawning Aggregation requires some evidence of recent mass spawning. Aggregations of all types may occur as amorphously shaped packets of water, may occur in layers at various depths, and may occur as diurnal migrations, among other forms.

#### **Biotic Subclass: Crustacean Holoplankton**

Water parcels in which crustacean holoplankton are the perceived dominant feature. Crustaceans constitute the vast bulk of zooplankton in many areas of the ocean.

##### **Biotic Group: Amphipod Aggregation**

Water parcels in which amphipods (laterally compressed or stick-like, elongated, generally small crustaceans) aggregate and are the dominant form of zooplankton.

Biotic Community: *Hyperia* Aggregation

Biotic Community: Caprellid Aggregation

##### **Biotic Group: Copepod Aggregation**

Water parcels in which copepods aggregate and are the dominant form of zooplankton. Planktonic copepods are thought to be among the most abundant multi-cellular animals on Earth. Most planktonic copepods use their large antennae to move in a series of jerky motions.

Biotic Community: *Acartia* Aggregation

Biotic Community: *Calanus* Aggregation

**Biotic Group: Krill Aggregation**

Water parcels in which shrimp-like krill constitute the dominant form of zooplankton. Most krill species are filter feeders, with a preference for diatoms. Biomass per square meter can be very high in krill aggregations, and they are a critical food source for many large consumers.

Biotic Community: *Euphausia* Aggregation

Biotic Community: Aggregation

**Biotic Subclass: Crustacean Meroplankton**

Water parcels in which crustacean meroplankton are the perceived dominant feature. These zooplankters typically go through several very different larval stages, and can be difficult to identify.

**Biotic Group: Decapod Larval Aggregation**

Water parcels in which crab, shrimp, and lobster larvae aggregate and are the dominant form of zooplankton.

Biotic Community: Brachyuran Crab Larval Aggregation

Biotic Community: Anomuran Crab Larval Aggregation

Biotic Community: *Pandalus* Larval Aggregation

**Biotic Group: Mixed Crustacean Larvae**

Water parcels in which several forms of crustacean larvae are mixed, and together they constitute the dominant form of zooplankton. This biotic group is meant to be used for mixes where it is very difficult to identify a dominant Crustacean genus or species.

**Biotic Subclass: Coral Meroplankton**

Water parcels in which coral larval life-history stages are the perceived dominant feature. This generally occurs during and after synchronous spawning events in reef areas with high coral biomass.

**Biotic Group: Coral Spawning and Larval Aggregation**

Water parcels in which coral gametes and larvae are aggregated during and after simultaneous spawning (often in astronomical numbers). In events that involve synchronous spawning of multiple species of corals, the concept of species-specific or group-specific biotic communities (below) may not apply, and the feature is identified at the biotic group level.

Biotic Community: Acroporid Spawning Aggregation

Biotic Community: *Montastraea* Spawning Aggregation

**Biotic Group: Coral Larval Aggregation**

Water parcels in which coral larvae aggregate post-spawning, with no evidence of a recent spawning event, and they are the dominant form of zooplankton.

Biotic Community: Acroporid Larval Aggregation

Biotic Community: *Montastraea* Larval Aggregation

**Biotic Subclass: Echinoderm Meroplankton**

Water parcels in which echinoderm larvae are the perceived dominant feature. Echinoderms go through distinctive larval stages, most of which are characterized by different series of ciliated bands that are arranged with bilateral symmetry. Each echinoderm group features different larval forms (e.g., pluteus larvae or bipinnaria larvae).

**Biotic Group: Mixed Echinoderm Larval Aggregation**

Water parcels in which these larval forms aggregate and are the dominant form of zooplankton.

Biotic Community: Ophiuroid Larval Aggregation

Biotic Community: Asteroidean Larval Aggregation

Biotic Community: Holothurian Larval Aggregation

**Biotic Subclass: Fish Meroplankton**

Water parcels in which fish meroplankton are the perceived dominant feature. Fish go through several larval stages as they progress from embryo to juvenile. Unlike many phyla, most of these stages do bear some resemblance to the adult (they are fish-like); nonetheless, the taxonomy of fish larvae is a specialized skill.

**Biotic Group: Fish Spawning and Larval Aggregation**

Water parcels in which fish gametes and larvae are aggregated (often in large numbers) after simultaneous spawning, and are the dominant form of zooplankton.

Biotic Community: Damselfish Spawning and Larval Aggregation

Biotic Community: Grouper Spawning and Larval Aggregation

Biotic Community: Surgeonfish Spawning and Larval Aggregation

**Biotic Group: Fish Larval Aggregation**

Water parcels in which fish larvae aggregate and are the dominant form of zooplankton.

Biotic Community: Clupeid Larval Aggregation

Biotic Community: Engraulid Larval Aggregation

Biotic Community: Sciaenid Larval Aggregation

**Biotic Subclass: Gelatinous Zooplankton**

Water parcels in which gelatinous zooplankton (generally transparent, often quite large organisms, in which water constitutes a very high percentage of the body mass) are the perceived dominant feature. Most gelatinous zooplankton are predators on other zooplankton.

**Biotic Group: Ctenophore Aggregation**



Water parcels in which ctenophores aggregate so as to constitute the dominant form of zooplankton. Ctenophores are small, gelatinous, ciliated animals with a generally rounded or lobed form. Two retractable feeding tentacles may also be present.

Biotic Community: *Beroe* Aggregation

Biotic Community: *Mnemiopsis* Aggregation

Biotic Community: *Pleurobrachia* Aggregation

**Biotic Group: Jellyfish Aggregation**

Water parcels in which jellyfish (free-swimming Medusozoan life-history stages) aggregate and are the dominant form of zooplankton. Most jellyfish are predators, and many have venomous nematocysts (stinging capsules in specialized cells).

Biotic Community: *Aurelia* Aggregation

Biotic Community: *Chrysaora* Aggregation

**Biotic Group: Salp Aggregation**

Water parcels in which salps (bag-like gelatinous filter-feeding tunicates) aggregate and are the dominant form of zooplankton. Many salps grow in a chain formation that can consist of 100 individuals or more, sometimes reaching 30 meters or greater in length, although much shorter chains are more common.

Biotic Community: *Thalia* Aggregation

Biotic Community: *Pegia* Aggregation

**Biotic Group: Siphonophore Aggregation**

Water parcels in which these jellyfish-like animals aggregate and are the dominant form of zooplankton. Siphonophores are colonies of many individual animals (polyps) that are each specialized for various roles (stinging tentacles, locomotion, and digestion) but appear and function as a single animal. Siphonophores are important predators on other zooplankton and small fishes. Most siphonophores are actively mobile, but the best-known siphonophore (the Portuguese man-of-war, *Physalia*) drifts with the wind using a gas-filled sac.

Biotic Community: *Bargmannia* Aggregation

Biotic Community: *Nanomia* Aggregation

Biotic Community: *Physalia* Aggregation

**Biotic Subclass: Mixed Zooplankton**

Water parcels in which complex mixes of zooplankton are the perceived dominant feature.

**Biotic Group: Mixed Zooplankton Aggregation**

Water parcels in which several phyla exist, with no clear dominant taxon. Biotic Communities are described by listing abundant or potentially dominant taxa.



Biotic Community: Chaetognath, Salp, and Fish Larval Aggregation

Biotic Community: Ctenophore, Worm and Copepod Aggregation

**Biotic Subclass: Molluscan Holoplankton**

Water parcels in which mollusk holoplankton are the perceived dominant feature.

Certain molluscan taxa with reduced shells exist entirely in the plankton.

**Biotic Group: Pteropod Aggregation**

Water parcels in which pteropod mollusks (characterized by a reduced shell and an expansive, wing-like foot) are the dominant form of zooplankton. They are sufficiently abundant in some areas of the ocean that their dead shells form ooze after sinking to the seafloor.

Biotic Community: *Carolla* Aggregation

Biotic Community: *Clione* Aggregation

**Biotic Subclass: Molluscan Meroplankton**

Water parcels in which molluscan larvae are the perceived dominant feature.

**Biotic Group: Veliger Aggregation**

Water parcels in which veligers or pedi-veligers (the distinctive larvae of many mollusks) are the dominant form of zooplankton. Veligers are characterized by ciliated lobes attached to a formative shell and body.

Biotic Community: Bivalve Veliger Aggregation

Biotic Community: Gastropod Veliger Aggregation

**Biotic Subclass: Protozoan Holoplankton**

Water parcels in which single-celled protozoans are the perceived dominant feature.

CMECS considers only the larger, visible protozoans that form tests or shells.

**Biotic Group: Foraminiferan Aggregation**

Water parcels in which these numerous protists aggregate and are the dominant form of zooplankton. Most planktonic foraminifera are amoeboids that live in a 1 millimeter to 2 millimeters calcium carbonate test that is composed of several growth chambers. Amoeboid pseudopods extend through holes in the test.

Biotic Community: *Globigerina* Aggregation Layer

**Biotic Group: Radiolarian Aggregation**

Water parcels in which radiolarians (amoeboid protists living in an intricate silica test) aggregate and are the dominant form of zooplankton. Radiolarians are particularly abundant in equatorial regions of the oceans.

Biotic Community: *Acantharea* Aggregation

Biotic Community: *Polycistina* Aggregation

**Biotic Subclass: Worm Holoplankton**

Water parcels in which various holoplanktonic worm phyla are the perceived dominant

feature.

**Biotic Group: Chaetognath Aggregation**

Water parcels in which chaetognaths aggregate and are the dominant form of zooplankton. Chaetognaths are small, fish-shaped worms with large "teeth," and they are ferocious predators. They are commonly known as Arrow Worms.

Biotic Community: *Flaccisagitta* Aggregation

Biotic Community: *Sagitta* Aggregation

**Biotic Group: Polychaete Aggregation**

Water parcels in which holoplanktonic polychaetes (distinctively segmented worms, generally with parapodia and setae modified into swimming appendages) are the dominant form of zooplankton.

Biotic Community: Syllid Aggregation

Biotic Community: *Tomopteris* Aggregation

**Biotic Subclass: Worm Meroplankton**

Water parcels in which various meroplanktonic worm phyla are the perceived dominant feature. Many worm taxa spawn planktonic larvae, and identification can be difficult.

**Biotic Group: Larval Worm Spawning Aggregation**

Water parcels in which gametes and larvae from various worm taxa are aggregated (often in very high abundance) after simultaneous spawning, and they are the dominant form of zooplankton. Epitokes may also be present. Epitokes are the detachable swimming gonad sections that form the posterior end of many species of polychaetes in their pre-breeding stage; these epitokes are released during spawning events, and appear as free-swimming worms.

Biotic Community: *Neanthes* Spawning Aggregation

Biotic Community: Nereid Spawning Aggregation

Biotic Community: Palolo (*Eunice*) Spawning Aggregation

**Biotic Group: Larval Worm Aggregation**

Water parcels in which larvae of various worm taxa aggregate and are the dominant form of zooplankton. Many worm larvae are difficult to identify. The initial larval stage of annelids (the rounded, ciliated trochophore stage) is very similar to the trochophore stage of larval mollusks. Annelid larvae will continue growth by adding segments, however, and become more worm-like.

Biotic Community: Nereid Larval Aggregation

Biotic Community: Nemeretean Larval Aggregation

Biotic Community: Polychaete Larval Aggregation

**Biotic Class: Floating/Suspended Plants and Macroalgae**

This class includes areas dominated by vascular plants, detached plant parts, or macroalgae

that are floating on the surface or are suspended in the water column- that is, plants and macroalgae that are not rooted or attached to the bottom.

**Biotic Subclass: Floating/Suspended Macroalgae**

Areas dominated by macroalgae species that are floating on the surface or suspended freely in the water column.

**Biotic Group: Algal Rafts**

Water parcels in which these jellyfish-like animals aggregate and are the dominant form of zooplankton. Siphonophores are colonies of many individual animals (polyps) that are each specialized for various roles (stinging tentacles, locomotion, and digestion) but appear and function as a single animal. Siphonophores are important predators on other zooplankton and small fishes. Most siphonophores are actively mobile, but the best-known siphonophore (the Portuguese man-of-war, *Physalia*) drifts with the wind using a gas-filled sac.

Biotic Community: *Gracilaria* Rafts

Biotic Community: Kelp Rafts

Biotic Community: Rockweed Rafts

Biotic Community: *Sargassum* Rafts

Biotic Community: *Ulva* Rafts

**Biotic Group: Algal Particles**

Areas dominated by live drifting or floating macroalgae, or macroalgal pieces. They do not form rafts, but their distribution in the water column is at a density that can be clearly observed with the human eye.

Biotic Community: *Gracilaria* Particles

Biotic Community: Kelp Particles

Biotic Community: Rockweed Particles

Biotic Community: *Sargassum* Particles

Biotic Community: *Ulva* Particles

**Biotic Subclass: Floating/Suspended Vascular Vegetation**

Areas dominated by vascular vegetation that is floating on the surface or suspended freely in the water column. This subclass is limited to freshwater and brackish species. (There are no known marine, floating or suspended vascular, plant species.) Vascular vegetation that is floating on the surface, but rooted in the substrate is included in the Aquatic Vegetation Bed Class.

**Biotic Group: Floating/Suspended Freshwater and Brackish Vegetation**

Areas dominated by freshwater and brackish vascular vegetation that is floating on the surface or suspended in the water column.

Biotic Community: *Eichornia* Mats

Biotic Community: *Pistia* Mats

**Biotic Class: Phytoplankton**

This class includes areas of floating or suspended microscopic algae that are capable of photosynthesis. Although some species are motile, they are generally passively transported by water movements. Under certain conditions, they can form aggregations, large blooms or colonies.

The spatial and temporal expressions of phytoplankton are described as three types in CMECS. (1) Aggregations are detectable concentrations of one or more species within a defined volume or area. Aggregations form when conditions are sufficient for growth of phytoplankton and are typically represented as mixed aggregations, but often with a single species or group predominating. (2) Blooms are defined as rapid growth and multiplication of single species to high density in an area of surface waters within a short period of time (days), often to the exclusion of other species. Blooms are often considered to be harmful to the ecology of the system and may represent an imbalance of conditions. (3) Phytoplankton maxima layers are expressed as defined layers of one or more species, often with one group predominating, that form at depth within the water column, whose thickness is small relative to its areal extent. Maxima layers generally occur in response to presence of optimal conditions, such as salinity and temperature or the supply of a limiting resource, such as nutrients, for growth along an interface."

**Biotic Subclass: Chlorophyte Phytoplankton**

Areas dominated by Chlorophytes (green algae that are unicellular, flagellated, and sometimes colonial phytoplankton), occurring more predominantly in the tropics.

**Biotic Group: Chlorophyte Aggregation**

Waters dominated by Chlorophytes. This group is known to aggregate at frontal zones and under ice pack.

Biotic Community: *Chlorella* Aggregation

**Biotic Group: Chlorophyte Bloom**

Surface waters where rapid growth and very high densities of chlorophytes occur, particularly under quiescent conditions when nutrients are in excess.

Biotic Community: *Pyramimonas* Bloom

**Biotic Group: Chlorophyte Maximum Layer**

Relatively thin layer dominated by chlorophytes at depth in the water column where nutrients are optimal. Chlorophytes are adapted to low light levels.

Biotic Community: *Ostreococcus* Maximum Layer

**Biotic Subclass: Chrysophyte Phytoplankton**

Waters dominated by Chrysophyte Phytoplankton, single-celled algae found mostly in freshwater (although several orders occur in brackish and salt water). The pigment fucoxanthin gives them a yellow or brown color, and there are a variety of forms of the so-called "golden algae," including plasmoid, amoeba-like, flagellated, naked, and

silicious.

**Biotic Group: Chrysophyte Aggregation**

Waters dominated by chrysophytes; these cells can aggregate via mucus excretions that bind single cells into colonies, often combined with mineral particles and bacterial communities. Chrysophytes occur in coastal waters where nutrients and light are sufficient.

Biotic Community: *Apindella* Aggregation

**Biotic Group: Chrysophyte Bloom**

Surface waters where rapid growth and very high densities of chrysophytes occur. These organisms form brown tide blooms that are common in coastal waters and estuaries and often damage seagrass beds (by shading). They also may exhibit toxicity to grazers and filter feeders.

Biotic Community: *Aureococcus* Bloom

**Biotic Group: Chrysophyte Maximum Layer**

Relatively thin layer dominated by chrysophytes at depth in the water column; some chrysophytes are flagellated and can adjust their position in the water column. These and other plankton form maxima at depths where nutrients are in optimal concentrations.

Biotic Community: *Dinobryon* Maximum Layer

**Biotic Subclass: Coccolithophore Phytoplankton**

This class includes areas of floating or suspended microscopic algae that are capable of photosynthesis. Although some species are motile, they are generally passively transported by water movements. Under certain conditions, they can form aggregations, large blooms or colonies.

The spatial and temporal expressions of phytoplankton are described as three types in CMECS. (1) Aggregations are detectable concentrations of one or more species within a defined volume or area. Aggregations form when conditions are sufficient for growth of phytoplankton and are typically represented as mixed aggregations, but often with a single species or group predominating. (2) Blooms are defined as rapid growth and multiplication of single species to high density in an area of surface waters within a short period of time (days), often to the exclusion of other species. Blooms are often considered to be harmful to the ecology of the system and may represent an imbalance of conditions. (3) Phytoplankton maxima layers are expressed as defined layers of one or more species, often with one group predominating, that form at depth within the water column, whose thickness is small relative to its areal extent. Maxima layers generally occur in response to presence of optimal conditions, such as salinity and temperature or the supply of a limiting resource, such as nutrients, for growth along an interface.

**Biotic Group: Coccolithophore Aggregation**

Waters dominated by coccolithophores. This group is distributed throughout the

oceans and tends to have high light requirements, often aggregating in the upper water column and surface layer.

Biotic Community: *Coccolithus pelagicus* Aggregation

**Biotic Group: Coccolithophore Bloom**

Surface waters where rapid growth and very high densities of coccolithophores occur. These organisms form enormous blooms in the coastal and offshore oceans. Blooms may be linked to upwelling events.

Biotic Community: *Emiliania huxleyi* Bloom

**Biotic Group: Coccolithophore Maximum Layer**

Relatively thin layer dominated by coccolithophores at depth in the water column where nutrients are optimal. Coccolithophores are not generally found at depth; however, when surface nutrients are depleted and the water column is clear, some instances of a deeper maximum in the epipelagic layer have been noted.

Biotic Community: *Crenolithus* Maximum Layer

**Biotic Subclass: Cryptophyte Phytoplankton**

Water parcels or layers in which zooplankton are perceived to be the dominant feature. Zooplankton are heterotrophic biota of the water column; zooplankton drift with the currents, but may (or may not) be able to move through the water under their own power. Zooplankton may feed on phytoplankton, other zooplankton, or on detritus. CMECS classifies zooplankton that may range in size from gigantic salp chains (strings of gelatinous filter feeding tunicates that attain a length of 30 meters or more), to radiolarians (minute, shelled amoebas). CMECS was not designed to be used for the smallest planktonic forms (nanoplankton or picoplankton). CMECS Class Zooplankton includes both Holoplankton (that live out their entire life histories in the plankton) and Meroplankton (that are transient in the plankton). Meroplankton are typically larval stages that develop into nekton or benthos as they mature. Meroplankton in general are difficult to identify; specialized taxonomic knowledge and sets of regional keys are generally required. Both Holoplankton and Meroplankton are quite diverse and include members of most marine phyla.

Aggregations of specific types of zooplankton (or of mixed zooplankton/phytoplankton communities) may occur in many forms. In general, an "Aggregation" is a relatively dense and homogeneous group of plankton that may be produced by rapid reproduction in-place under favorable conditions (by phytoplankton and holoplankton), by hydrodynamic forcing, by a common mass origin, by plankton motility (e.g., diurnal vertical migrations), by barriers to movement (e.g., pycnoclines), or by other phenomena. A Spawning Aggregation forms after a mass spawning event when synchronous spawning by many individuals produces large pulses of gametes and larvae. Classification of a Spawning Aggregation requires some evidence of recent mass spawning. Aggregations of all types may occur as amorphously shaped packets of water, may occur in layers at various depths, and may occur as diurnal migrations, among other

forms.

**Biotic Group: Cryptophyte Aggregation**

Waters dominated by aggregations of cryptophytes. Cryptophytes aggregate in waters where nutrient concentrations are seasonally in low supply and nutritional needs can be met by consuming bacteria.

Biotic Community: *Chrysophaeum* Aggregation

**Biotic Group: Cryptophyte Bloom**

Surface waters where rapid growth and very high densities of cryptophytes occur. Blooms are generally not toxic and can form in coastal and estuarine waters.

Biotic Community: *Myrionecta* Bloom

**Biotic Group: Cryptophyte Maximum Layer**

Relatively thin layer dominated by cryptophytes at depth in the water column. Motility allows the group to avoid predation and to optimize their heterotrophic grazing.

Biotic Community: *Teleaulax* Maximum Layer

**Biotic Subclass: Cyanophyte Phytoplankton**

Areas dominated by cyanophytes, blue-green algae that are photosynthetic bacteria. Some of these are nitrogen fixing, some form resting cysts, and they can exist singly or in colonies.

**Biotic Group: Cyanophyte Aggregation**

Waters dominated by cyanophytes, which can aggregate under appropriate conditions in both coastal and open ocean environments. Those with nitrogen-fixing capability have a competitive advantage in nitrogen-poor environments, and coccoid cyanophytes are often dominant in oligotrophic tropical oceans.

Biotic Community: *Nodularia* Aggregation

**Biotic Group: Cyanophyte Bloom**

Surface waters where rapid growth and very high densities of cyanophytes occur. Cyanophyte Blooms are increasingly common in coastal waters, and can be toxic.

Biotic Community: *Synechococcus* Bloom

**Biotic Group: Cyanophyte Maximum Layer**

Relatively thin layer dominated by cyanophytes at depth in the water column. Cyanophytes can be found in a maximum layer where nutrients are sufficient (often at the base of the nutricline). They are often associated with an oxygen maximum layer due to their high rates of photosynthetic production.

Biotic Community: *Trichodesmium* Maximum layer

**Biotic Subclass: Diatom Phytoplankton**



Waters dominated by Diatom Phytoplankton, single-cell algae that circulate passively or sink in the water column. This non-flagellated group possesses silica-based frustules that can form large and elaborate static appendages. They are considered desirable, high-quality food for grazers, supporting healthy food webs.

**Biotic Group: Diatom Aggregation**

Waters dominated by diatoms that aggregate passively during blooms or via exudation of sticky polymers that act as glue to bind cells together. (Bacteria may play an important role in the binding process.) Diatom aggregations play an important role in the marine carbon budget, and since aggregations sink more rapidly than single cells, they transport carbon to lower waters and the benthos.

Biotic Community: *Thalassiosira* Aggregation

**Biotic Group: Diatom Bloom**

Surface waters where rapid growth and very high densities of diatoms occur. Diatoms are large cells and tend to have high nutrient requirements. Spring diatom blooms occur in many estuarine and coastal waters, as diatoms have low light requirements and are well adapted to the hydrologic period when turbid riverine inputs are highest. They have higher nutrient requirements than other groups and require silica, needed to produce frustules. Land runoff contains silica making the spring period ideal for formation of coastal diatom blooms. The rise of the bloom is important in initiating food webs of zooplankton and other grazers and the decay of the bloom is important in nutrient cycling, and potentially contributes to the later formation of hypoxic bottom water as organic material accumulates in the lower water column.

Biotic Community: *Skeletonema* Bloom

**Biotic Group: Diatom Maximum Layer**

Relatively thin layer dominated by diatoms at depth in the water column. Layers of high diatom density generally form in the surface mixed layer and have also been found at deep subsurface maxima. These are associated with nutrient or temperature maxima.

Biotic Community: *Asterionellopsis* Maximum Layer

**Biotic Subclass: Dinoflagellate Phytoplankton**

Areas dominated by flagellated phytoplankton that have some motility and can control their position in the water column to a degree, diurnally migrating from surface to bottom to maximize conditions for growth. This group has both photosynthetic and heterotrophic species, which play a large role in coastal and estuarine trophic dynamics. These phytoplankton also can form noxious and harmful blooms, including red tides that may be toxic to higher consumers and to humans. Their complex life cycle goes through many stages, which can include resting cysts that spend prolonged periods in the benthic sediments.

**Biotic Group: Dinoflagellate Aggregation**



Waters dominated by dinoflagellates that aggregate in coastal and marine waters throughout the world. Some evidence suggests that both heterotrophic and mixotrophic feeding adaptations supplement autotrophy, giving dinoflagellates a competitive advantage over other groups- especially during periods of low nutrient availability. Aggregations are responsible for bioluminescence, which may reduce predation by disrupting grazers and by triggering secondary predators that consume dinoflagellate predators (Latz et al. 2004)

Biotic Community: *Noctiluca* Aggregation

**Biotic Group: Dinoflagellate Bloom**

Surface waters where rapid growth and very high densities of dinoflagellates occur. These blooms have caused a number of problems in coastal waters because many species are toxic to consumers. Shellfish and fish can accumulate toxins and pass them on to higher trophic levels, including humans.

Biotic Community: *Karenia* Bloom

**Biotic Group: Dinoflagellate Maximum Layer**

Relatively thin layer dominated by dinoflagellates at depth in the water column. Dinoflagellates migrate vertically through the water column to layers where nutrients and light are optimal for growth. Often the maxima can occur at the surface when nutrients are saturating throughout the water column. There is also evidence that migration is an adaptive strategy to avoid predation (Baek et al. 2011).

Biotic Community: *Gymnodinium* Maximum Layer

**Biotic Class: Floating/Suspended Microbes**

Aggregations of microbes that are floating or suspended in the water column and not attached to the bottom or to any benthic substrate.

**Biotic Subclass: Films and Strands**

Aggregations of microbes in a very thin layer (millimeters or less) on the water's surface or at a discontinuity layer within the water column. The air-water interface is a site of intense biological activity due to the abundance of light, oxygen and energy. The density gradients and discontinuity at the surface of the water column or at fronts and discontinuities within the water column are ideal for the aggregation of microbes in films covering large areas and strands that follow the movements of water currents (Cunliffe and Murrell 2009). The concentration of microbes creates numerous niches for feeding by higher trophic levels and for the processing of biogenic and inorganic compounds that are important to marine chemistry, including controlling carbon, nitrogen and sulfur redox processes (Hansel and Francis 2006). The film created by microbial concentration also creates a biological barrier that can either facilitate or impede transgression of materials across the air-water interface or other layer.

**Biotic Subclass: Microbial Foam**

Aggregations of microbes within the foam matrix that forms on the water's surface. Sea foam is the foam that lies on the sea surface, in the surf zone and at times on intertidal areas, created from dissolved organic compounds when air is forcefully injected into the water column (Harden and Williams 1989). Foam formation is aided by properties of lignans, proteins and carbohydrates that act as surfactants or foaming agents. The large area presented by the micro-bubbles composing seafoam is an ideal surface for concentration and adherence of microbial communities including bacteria, viruses and microscopic plankton. The characteristics of the air-water interface, and particularly of sea foam are unique compared to the bulk water column (Lion and Leckie 1981) and possess unique physical and chemical properties. The foams are well-oxygenated, sites of photolytic processes and tend to support high levels of aerobic metabolism with high organic processing rates. Surface foam is the site of intense trophic activity at the microbial level because of the concentration of microbial biomass, sugars, lipids and other growth compounds and thus represents an important part of the marine microbial food web. Concentration and transformation of trace metals, nutrient compounds, contaminants and pollutants also occurs in sea foam and can enter the food web via microbial pathways. The properties of the foam have also been identified as delivering growth-promoting nutrients and organic material to seagrass and kelp communities.

**Biotic Subclass: Microbial Aggregation**

Aggregations of microbes within the water column that have detectable, visible color. Microbial communities suspended in the water column can reach high concentrations and even be the dominant biota in an area, both numerically and in terms of biomass. Suspended free-floating microbes, as well as those adsorbed to suspended particulates are important in the marine food web. The concentration of bacterial communities has been linked to discoloration of the water column (Hansel and Francis 2006) via oxidation of molecular compounds in the water, such as manganese and iron.

**Biotic Setting: Benthic/Attached Biota**

This biotic setting describes areas where biota lives on, in, or in close association with the seafloor or other substrates (e.g., pilings, buoys), extending down into the sediment to include the sub-surface layers of substrate that contain multi-cellular life. As a rule, Benthic/Attached Biota units are characterized by the various life histories and taxonomic characteristics of the dominant life forms.

**Biotic Class: Reef Biota**

Areas dominated by reef-building fauna, including living corals, mollusks, polychaetes or glass sponges.

In order to be classified as Reef Biota, colonizing organisms must be judged to be sufficiently abundant to construct identifiable biogenic substrates. When not present in densities sufficient to construct reef substrate, the biota is classified in the Aquatic Vegetation Bed or Faunal Bed classes.

The Reef Biota Class refers to only the living component of reef structures. If referring to

the reef structure, users should use the reef units in the Geoform Component. If referring to the composition of the reef substrate independent of the living cover, users should employ the Coral Substrate, Shell Substrate, or Worm Substrate Classes in the Substrate Component (SC).

**Biotic Subclass: Deep-Water/Cold-Water Coral Reef Biota**

Areas dominated by biota closely associated with the structures and settings created by azooxanthellate (lacking symbiotic algae), deep-water, stony corals (Order Scleractinia) or stylasterid corals (Order Anthoathecatae; Family Stylasteridae). Biotic groups and communities for the Deep-Water/Cold-Water Coral Reef subclass recognize coral reef areas as structural settings that were constructed by the framework-forming corals. The living coral reef is characterized by the presence of live reef-forming corals, but may or may not be dominated by living corals; other fauna may in fact exceed the corals in percent cover.

The Deep-Water/Cold-Water Coral Reefs are separated into two Biotic Groups based on whether they are formed by stony corals or stylasterid corals. The growth forms of those corals and the reefs they create are structurally different. Biotic communities are characterized by the dominant species of framework-forming, deep-sea coral. For example, a Deep-Water/Cold-Water *Lophelia* Reef would be dominated by *Lophelia pertusa* coral, but may include other stony corals such as *Madrepora oculata*, *Enallopsammia rostrata*, or *Solenosmilia variabilis*.

**Biotic Group: Deep-Water/Cold-Water Stony Coral Reef**

Areas dominated by deep-water stony corals. There are 17 known species of deep-water, azooxanthellate, stony corals (Class: Anthozoa; Order: Scleractinia) that form larger, branching colonies and contribute to reef frameworks. Six of these are particularly widespread or important, and these are major contributors to the framework of their respective habitats. These species form branching colonies (generally less than 1 - 2 meters in size), and aggregations of these living colonies- and their immediately adjacent dead framework and rubble- are important habitats for numerous other sedentary and mobile species.

Biotic Community: *Enallopsammia* Reef

Biotic Community: *Goniocorella* Reef

Biotic Community: *Lophelia* Reef

Biotic Community: *Madrepora* Reef

Biotic Community: *Oculina* Reef

Biotic Community: *Solenosmilia* Reef

**Biotic Group: Deep-Water/Cold-Water Stylasterid Coral Reef**

Areas dominated by stylasterid corals. A number of stylasterid coral species (Class: Hydrozoa; Order: Anthoathecatae; Family: Stylasteridae) form smaller branching colonies that can dominate certain habitats, primarily in deeper,

colder waters. Stylasterid coral reefs often predominate on oceanic islands, seamounts, and archipelagos (Cairns 1992).

Biotic Community: Mixed Stylasterid Reef

Biotic Community: *Stylaster* Reef

**Biotic Group: Colonized Deep-Water/Cold-Water Reef**

Areas dominated by deep-water reefs where live reef building hard corals are present, but not clearly dominant. Cover is dominated by non-reef-forming biota, including black corals, gold corals, gorgonians, sponges, and other sedentary or attached macro-invertebrates. If no living reef-forming corals are present, then the biotic class is Faunal Bed.

Biotic Community: Black Coral Colonized Deep-Water/Cold-Water Reef

Biotic Community: Gold Coral Colonized Deep-Water/Cold-Water Reef

Biotic Community: Gorgonian Colonized Deep-Water/Cold-Water Reef

Biotic Community: Mix Colonized Deep-Water/Cold-Water Reef

Biotic Community: Sponge Colonized Deep-Water/Cold-Water Reef

**Biotic Subclass: Shallow/Mesophotic Coral Reef Biota**

Areas with ample light that are dominated by hermatypic (reef-building) hard corals or non-hermatypic reef colonizers.

The Shallow and Mesophotic Coral Reef Biota are largely based on the growth form of the dominant corals that (a) reflect differences in environmental conditions and (b) provide varied habitat circumstances (such as increased cover) for associated fish and invertebrate species. The same coral species can present different growth forms under different environmental circumstances. For example, *Acropora* sp. can have both branching and table growth forms, depending on the environment. To reflect the differences in the physical and biological environments, the same species may be used to define communities in more than one coral group.

**Biotic Group: Branching Coral Reef**

Reefs in shallow or mesophotic situations dominated by branching corals (includes arborescent, arboreal, digitate, corymbose, ramose, and elkhorn corals) that grow in a tree-like shape and have numerous branches, some with secondary branches. This group includes both fragile, branching corals and more robust, branching corals that have exceptionally thick and sturdy antler-like branches (such as elkhorn corals). See Figure 8.2 for an example of the branching coral growth form.

Biotic Community: Branching *Acropora* Reef

Biotic Community: Branching *Madracis* Reef

Biotic Community: Branching *Pocillopora* Reef

Biotic Community: Branching Coral Reef    Branching *Porites* Reef

**Biotic Group: Columnar Coral Reef**

Areas dominated by columnar corals that emerge from a massive base in a pillar form and do not branch. They are commonly found in mild water flow at mid-depth water levels.

Biotic Community: Columnar *Dendrogyra* Reef

Biotic Community: Columnar *Psammocora* Reef

**Biotic Group: Encrusting Coral Reef**

Reefs or reef-like, rocky structures dominated by encrusting corals (also called crustose corals) that (a) cover the substrate in a sheet and (b) expand in diameter rather than height. Encrusting corals are highly tolerant of strong water currents, and they are frequently found on rocky shorelines lacking a beach. See Figure 8.3 for an example of the encrusting coral growth form.

Biotic Community: Encrusting *Millepora* Reef

Biotic Community: Encrusting *Porites* Reef

**Biotic Group: Foliose Coral Reef**

Areas dominated by foliose corals that have a vase-like structure and whorl-like growth pattern similar to the open petals of a flower. The structure of these corals provides shelter for fish and invertebrate species. See Figure 8.4 for an example of the foliose coral growth form.

Biotic Community: Foliose *Agaricia* Reef

Biotic Community: Foliose *Milipora* Reef

**Biotic Group: Massive Coral Reef**

Reefs dominated by massive corals (also known as boulder or mound corals) that are characteristically ball- or boulder-shaped and relatively slow growing. This group includes reefs dominated by submassive corals, which are similar to massive corals, but have a lumpier structure. Brain corals are an example of massive coral.

Massive and submassive corals are resistant to strong water currents, and are therefore commonly found in shallow and mid-depth waters. These forms are common on back-reef slopes. See Figure 8.5 for an example of the massive coral growth form.

Biotic Community: Massive *Diploria* Reef

Biotic Community: Massive *Montastraea* Reef

Biotic Community: Massive *Porites* Reef

**Biotic Group: Plate Coral Reef**

Reefs dominated by plate corals that grow in a flattened plate, saucer-like, or thin sheet fashion- often in a terraced pattern. Plate corals (also known as laminar, leaf, or sheet corals) usually have thin, disc-shaped colonies with

corallites growing only on one side. See Figure 8.6 for an example of a plate coral growth form.

Biotic Community: Plate *Agaricia* Reef

Biotic Community: Plate *Leptoseris* Reef

Biotic Community: Plate *Montastraea* Reef

**Biotic Group: Table Coral Reef**

Reefs dominated by table corals that form platforms that are made up of small, tightly packed branches. Table corals are usually found in shallow waters. See Figure 8.7 for an example of the table coral growth form.

Biotic Community: Table *Acropora* Reef

**Biotic Group: Turbinate Coral Reef**

Areas dominated by turbinate corals that are cone shaped. Turbinate corals are often found in calmer water at mid-depth levels, often on back reef-slopes.

Biotic Community: Turbinate *Madracis* Reef

**Biotic Group: Mixed Shallow/Mesophotic Coral Reef**

Areas where multiple coral growth forms are present and none are clearly dominant.

**Biotic Group: Colonized Shallow/Mesophotic Reef**

Tropical coral reef substrate where live reef building corals are present, but not clearly dominant. Cover is dominated by non-reef-forming corals (such as soft corals, gorgonians [e.g., sea fans and sea whips], and sea pansies), sponges, other sedentary or attached macro-invertebrates, occasional seagrasses, macroalgae, echinoderms, and other reef associates. Reef-building, hard corals are present, but not clearly dominant. If no living coral is present, then the biotic class is Faunal Bed.

Biotic Community: Black Coral Colonized Shallow/Mesophotic Reef

Biotic Community: Gold Coral Shallow/Mesophotic Reef

Biotic Community: Calcareous Algae Colonized Shallow/Mesophotic Reef

Biotic Community: Coral Garden Reef

Biotic Community: Coralline/Crustose Algae Colonized Shallow/Mesophotic Reef

Biotic Community: Gorgonian Colonized Shallow/Mesophotic Reef

Biotic Community: Soft Coral Colonized Shallow/Mesophotic Reef

Biotic Community: Sponge Colonized Shallow/Mesophotic Reef

**Biotic Subclass: Glass Sponge Reef Biota**

Areas dominated by live, deep-water, glass sponges (Order: Hexactinosida) present in densities that are judged sufficient to form substrate. These sponges construct a

complex siliceous skeleton that provides structure and relief on the seafloor, creating habitat for many other organisms.

**Biotic Group: Glass Sponge Reef**

Areas dominated by one or more of the three species of glass sponges that appear to be the primary contributors to the framework of extant glass sponge reefs: *Heterochone calyx*, *Aphrocallistes vastus*, and *Farrea occa*. See Figure 8.8 for an example of a Glass Sponge Reef.

Biotic Community: Hexactinosida Reef

**Biotic Subclass: Mollusk Reef Biota**

Areas dominated by consolidated aggregations of living and dead mollusks, usually bivalves (e.g., oysters or mussels or giant clams) or gastropods (e.g., vermetids) attached to their conspecifics and sufficiently abundant to create substrate.

**Biotic Group: Gastropod Reef**

Areas dominated by consolidated aggregations of living and dead gastropod mollusks, typically those of the Family Vermetidae or the Genus *Crepidula*. Shells in a "reef" must have consolidated or conglomerated into a reef structure with some relief and permanence; a reef is more than an accumulation of loose shells. Vermetids construct tubes that are cemented to hard substrates and to conspecifics, generally in intertidal habitats, e.g., *Serpulorbis*. *Crepidula* forms reefs through preferential settling of larvae on conspecifics (Zhao and Qian 2002) combined with very limited mobility, and sediment infilling. *Crepidula* reefs are generally flat features with little vertical relief.

Biotic Community: *Crepidula* Reef

Biotic Community: Vermetid Reef

Biotic Community: *Serpulorbis* Reef

**Biotic Group: Mussel Reef**

Areas dominated by the ridge- or mound-like structures formed by the colonization and growth of mussels that are attached to a substrate of live and dead conspecifics. Mussels use byssal threads and a powerful glue to tether their shells to a substrate, and their reefs also provide valuable habitat and filtration.

Biotic Community: *Modiolus* Reef

Biotic Community: *Mytilus* Reef

**Biotic Group: Oyster Reef**

Areas dominated by the ridge- or mound-like structures formed by the colonization and growth of oysters that are attached (cemented) to a substrate of live and dead conspecifics. Oyster reefs provide excellent structural habitat as well as effective water filtration.

Biotic Community: *Crassostrea* Reef

Biotic Community: *Ostrea* Reef

**Biotic Subclass: Worm Reef Biota**

Areas dominated by relatively stable, ridge- or mound-like aggregations of living and non-living material formed by the colonization and growth of worm species (e.g., sabellariids).

**Biotic Group: Sabellariid Reef**

Areas dominated by ridge- or mound-like features formed by the colonization and growth of living sabellariid worm species that have cemented sediment grains into complex structures. Certain types of sabellariid reefs most often occur parallel to an ocean shoreline in shallow water, but many are also found in deeper waters where current energy is high.

Biotic Community: *Phragmatopoma* Reef

Biotic Community: *Sabellaria* Reef

**Biotic Group: Serpulid Reef**

Areas dominated by mound-like, bush-like, or patchy growths of living Serpulid worms that have secreted tubes of calcium carbonate to form complex aggregated structures. Serpulid worms can be distinguished from Sabellariid worms (see above) by the presence of a hard operculum that seals the hard, shell-like Serpulid tube. Living Serpulid reefs are extremely rare in U.S. coastal waters, but recently extinct Serpulid reef structures do occur, e.g., in certain Gulf of Mexico embayments. If no living Serpulid worms are present and the reef is extinct, it is classified in CMECS as Substrate (see Section 7.4.2). Living Serpulid reefs are, however, found in other parts of the world, and are considered valuable structure-forming habitat.

Biotic Community: *Serpula vermicularis* Reef

**Biotic Class: Faunal Bed**

Seabeds dominated or characterized by a cover of animals that are closely associated with the bottom, including attached, clinging, sessile, infaunal, burrowing, laying, interstitial, and slow-moving animals, but not animals that have created substrate (Reef Biota). Unlike Reef Biota, Faunal Bed biota cannot (or are not sufficiently abundant to) construct identifiable substrate. "Slow-moving" animals included in the Faunal Bed class are defined as being incapable of moving outside the boundaries of the classification unit within one day. Faunal Bed organisms are aquatic, but they may be able to withstand periods of exposure to air.

Faunal Bed food webs may receive basic trophic inputs from benthic photosynthesis or chemosynthesis, plankton, allochthonous detritus and debris, or other sources. In nature, Faunal Bed habitats are often composed of complex mixes and associations of animals of different phyla, sizes, feeding strategies, and habits, and these areas can be difficult to classify. Faunal Bed classifications are determined in CMECS by greatest percent cover of fauna or faunal structures, or (particularly for infauna) by estimates of greatest biomass. The inherent complexity of these areas is addressed through Co-occurring Elements and Associated Taxa



Modifiers (Sections 10.6.2 and 10.3.1).

In the photic zone, primary producers often constitute the greatest biotic percent cover of substrate, and so define the biotic group of an area (e.g., Filamentous Algal Bed, Microphytobenthos). Faunal Bed organisms, when present in these areas, are classified in CMECS as Co-occurring Elements, for example: "Biotic Group: Coralline/Crustose Algal Bed with Co-occurring Element: *Strongylocentrotus purpurata*".

In waters deeper than the photic zone, however, most Faunal Bed biotic groups and communities are defined by immobile or slow-moving suspension-feeders and detritivores that dominate percent cover or biomass, and create a distinct living environment for other fauna. Other Faunal Bed biotic groups and communities are defined by slow-moving grazers or predators (e.g., urchins, starfish), when these are the clearly dominant fauna. However, practitioners should attempt to identify a biotic group that is providing "forage" for these predatory or herbivorous species. If a "forage" biotope is present, it will often dominate percent cover, and practitioners should characterize the area accordingly as (for example): "Biotic Community: Nassariid Bed with Co-occurring Element: *Pisaster*". The Co-occurring Elements modifier (see Section 10.6.2) is used to describe areas where any two (or more) biotic groups, biotic communities, or other biotic classification units described in CMECS occur simultaneously. In these cases, the classification units exist together, as a mix, in a single location, and the non-dominant units are termed Co-occurring Elements. Further local research may indicate that the mix of biotic groups and co-occurring elements is, in fact, a repeatable unit that should be designated as a single defined biotic group or biotope.

Other common animals in seafloor environments include opportunistic predators or herbivores that are capable of moving outside the bounds of the classification unit within one day, such as portunid crabs, cancrid crabs, horseshoe crabs, cephalopods, other mobile benthic crustaceans, fishes, and other nekton. These animals actively move over the seafloor searching for prey, and are defined in CMECS as Associated Taxa (see Section 10.3.1).

As in other BC classes, practitioners may apply Genus and/or species names to define local biotic communities that are not listed in the current version of CMECS. In these cases, observations in the field must verify that these new biotic communities are predictable and repeating aggregations or assemblages of dominant or characteristic species. These names should be submitted as part of the CMECS Dynamic Content Standard (see Section 13)."

#### **Biotic Subclass: Attached Fauna**

Areas characterized by rock substrates, gravel substrates, other hard substrates, or mixed substrates that are dominated by fauna which maintain contact with the substrate surface, including firmly attached, crawling, resting, interstitial, or clinging fauna. Fauna may be found on, between, or under rocks or other hard substrates or substrate mixes. These fauna use pedal discs, cement, byssal threads, feet, claws, appendages, spines, suction, negative density, or other means to stay in contact with the (generally) hard substrate, and may or may not be capable of slow movement over the substrate. However, these fauna are not able to achieve speeds sufficient to move beyond the unit boundary within one day. Many attached fauna are suspension feeders

and feed from the water column. Other attached fauna are benthic feeders, including herbivores, predators, detritivores, and omnivores. Within Attached Fauna, the Biotic Group is identified as the biota making up the greatest percent cover on the hard attachment surface within the classified area. Biota present at lesser percent cover values within the classified area may be identified as Co-occurring Elements (See Section 10.6.2) or (if not a CMECS Biotic Group) Associated Taxa (See Section 10.3.1).

**Biotic Group: Mineral Boring Fauna**

Areas where specialized fauna have bored into hard mineral substrate (rock, shell, carbonate reef, peat, compacted stiff clay) and constitute the dominant biological feature by percent cover or biomass. Several taxa (including sponges, sipunculids, clams, mussels, gastropods, annelids and others) have developed mechanisms for boring into rock, shell and other mineral substrates.

Biotic Community: *Cliona celata*

Biotic Community: Boring *Penitella*

Biotic Community: Boring *Lithophaga*

**Biotic Group: Wood Boring Fauna**

Anthropogenic or natural wood substrate areas characterized or dominated by specialized fauna that have bored into the wood. Several taxa, including teredos or shipworms (bivalves), gribbles (crustaceans), and others have developed the ability to bore into wood so as to obtain food, protection, or both. Once wood-boring fauna have begun to break the wood apart, other fauna will move in to occupy spaces within the wood, feeding on detritus, wood-borers, plankton, and other fauna.

Biotic Community: Boring *Bankia*

Biotic Community: Boring *Limnoria*

Biotic Community: Boring *Teredo*

**Biotic Group: Diverse Colonizers**

Areas dominated by highly varied and diverse communities of mixed fauna that have attached to a biotic or abiotic hard substrate (which may be rock, cobble, oyster reef, non-living coral reefs, or other substrates). Common colonizing taxa include anemones, tunicates, barnacles, mollusks, hydroids, bryozoans, gorgonians, soft or leather corals, sponges, and/or other taxa. Diverse Colonizers on living coral reefs are included in the Colonized Shallow and Mesophotic Reef Biotic Group. Diverse Colonizers can be further described using the Invertebrate Community Organism Size Modifiers: Meiofauna (dominants *0.5 millimeter*), *Small Macrofauna* (dominants *0.5 millimeter to 2 millimeters*), *Large Macrofauna* (dominants *> 2 millimeters to 1 centimeter*), *Megaafauna* (dominants *> 1 centimeter to 3 centimeters*), *Large Megaafauna* (dominants *> 3 centimeters*), with all measurements in the smallest dimension (e.g., width or height) and not including the length of slender lateral projections (e.g., arms or tentacles). As

with all biotic groups, this unit may be used when communities cannot be identified, as in "Diverse Colonizers (Megafauna)", which provides important information despite limitations of data, e.g., video information.

Biotic Community: Anemone/Mussel/Bryozoan Colonizers (Large Macrofauna)

Biotic Community: Mollusk/Sponge/Tunicate Colonizers (Large Megafauna)

Biotic Community: Sponge/Gorgonian Colonizers

**Biotic Group: Attached Tube-Building Fauna**

Hard substrate areas with a percent cover dominated by tube builders, including annelids, phoronids, sipunculids, crustaceans, gastropods, pogonophorans, echiurans, priapulids, and other phyla. These animals construct chitinous, leathery, calcareous, sandy, mucus, or other types of tubes that are cemented or otherwise attached to hard substrate, and can occur in very high densities. If the tubes are built from a more permanent material (e.g., calcium carbonate) and occur in densities sufficient to construct substrate, these areas may be classified as Reef Biota.

Biotic Community: Attached Phoronids

Biotic Community: Attached Pogonophorans

Biotic Community: Attached *Sabellaria*

Biotic Community: Attached *Serpula*

Biotic Community: Attached *Serpulorbis*

**Biotic Group: Vent/Seep Communities**

Areas near deep-sea vents and seeps, often dominated by very large fauna (e.g., bivalves, pogonophorans) which derive nutrition from chemoautotrophic bacteria that can utilize the chemicals present in the vent or seep as an energy source. Many Vent/Seep Communities are spectacular ecosystems with very high biomass and a diversity of unusual fauna. These areas are often characterized by hard substrates due to the active geologic processes that create vents and seeps.

Biotic Community: *Calyptogena* Communities

Biotic Community: *Riftia* Communities

**Biotic Group: Attached Anemones**

Hard substrate areas dominated by attached anemones (coelenterates which secure themselves to a hard substrate with a pedal disc). These assemblages are common in certain rocky, coastal areas.

Biotic Community: Attached *Aiptasia*

Biotic Community: Attached *Metridium*

**Biotic Group: Barnacles**

Areas dominated by barnacles (small filter-feeding crustaceans in a protective shell that is attached to hard substrate) and associated fauna (e.g., the snail, *Littorina*; see Figure 8.9).

Biotic Community: *Balanus* Communities

Biotic Community: *Chthamalus* Communities

**Biotic Group: Attached Basket Stars**

Hard or mixed substrate areas characterized by brushy, many-armed echinoderms known as basket stars. Basket stars and brittle stars (see below) are both members of the class Ophiuroidea, but the arms of basket stars bifurcate many times to form a large complex that is reminiscent of a basket. Basket stars are usually larger than brittle stars, and maintain an upright form, generally clinging to hard substrate or solid objects using their bifurcated arms, which also function in suspension feeding.

Biotic Community: Attached *Astrophyton*

Biotic Community: Attached *Gorgonocephalus*

**Biotic Group: Attached Brachiopods**

Areas dominated by brachiopods, a phylum of animals with two shells, a stalk-like peduncle, and a tentacular, ciliated feeding organ. Brachiopods resemble clams, but are not mollusks. In some species, the peduncle is used to attach the animal to hard substrate, or one of the valves is cemented to the substrate. In other species, the peduncle and the valves are adapted to burrowing in soft sediment (see Burrowing Brachiopods, below). Brachiopods may occur in very high densities in some areas and are common on the U.S. west coast. Certain species can be identified by the wide gape between their shells when they are feeding, but not all species exhibit this wide gape. Most Brachiopods feed on plankton or on detritus.

Biotic Community: Attached *Crania*

Biotic Community: Attached *Laqueous*

Biotic Community: Attached *Terebratalia*

**Biotic Group: Brittle Stars on Hard or Mixed Substrates**

Assemblages dominated by crawling, epifaunal, crevice-dwelling brittle stars, often living on, between, or under rocks. Brittle stars (together with basket stars) are Ophiuroids, a relatively mobile class of echinoderms. Some brittle star species are specialized for life on or among rocks and other hard substrates, others are specialized for infaunal burrowing, and some species may be generalists, found in a variety of substrates, and utilizing a variety of feeding methods.

Biotic Community: *Amphipholis* Communities

Biotic Community: *Ophioderma* Communities

Biotic Community: *Ophiothrix* Communities

**Biotic Group: Attached Bryozoans**

Areas dominated by abundant or structurally complex, attached bryozoan communities that are may be habitat-forming. These colonial filter-feeding animals have a protective chinitous or calcareous covering that adds structural support. They may occur on hard substrates as flat encrusting growths, as feathery branched structures, as complex calcareous shapes, as fouling communities, and in other forms. Certain species of bryozoans may create extensive habitats.

Biotic Community: Attached *Bugula*

Biotic Community: Attached *Celleporaria*

Biotic Community: Attached *Tubulipora*

**Biotic Group: Chitons**

Areas dominated by attached chitons, gastropod-like mollusks with eight calcareous dorsal plates (valves), a broad foot for attachment to hard substrates, and a scraping radula for feeding. Several species can reach high abundances on intertidal or subtidal rocks. Some chitons will create a depression in rock substrate for improved protection; however, they are classified here as Chitons, rather than above as Mineral Boring Fauna.

Biotic Community: Attached *Acanthopleura*

Biotic Community: Attached *Katharina*

Biotic Community: Attached *Nutallina*

**Biotic Group: Attached Corals**

Subtidal (and deeper) substrates that are dominated by non-reef-forming corals. These include hexacorals such as black corals (Order Antipatharia) and gold corals (Order Zoanthidea, family Gerardiidae). All octocorals are non-reef forming, including soft corals and gorgonian sea fans and sea whips (Order Alcyonacea). Also in this group, bamboo corals are generally larger, erect, tree-shaped branching octocoral forms (with an articulated, bamboo-like skeleton) that are common in the deep sea. None of the octocorals produce the calcium carbonate structures associated with coral reefs, but octocorals can form important habitat areas, particularly in the deep sea, where large communities may cover significant area. Most species require a hard substrate for attachment, which may range from bedrock to a single pebble. Octocorals in the order Pennatulacea (sea pens, sea pansies, and sea feathers) are in general specialized for life on soft substrates, and are addressed in the Soft Sediment Fauna subclass.

Biotic Community: Attached Black Corals

Biotic Community: Eugorgia Communities

Biotic Community: Attached Gold Corals

Biotic Community: Attached Gorgonians

Biotic Community: Isididae Communities

Biotic Community: Paragorgia Communities

Biotic Community: Attached Soft Corals

**Biotic Group: Attached Crinoids**

Assemblages on hard or mixed substrates that are dominated by either attached, stalked crinoids (or "sea lilies") or motile (but often stationary, see Barnes 1980), comatulid (or "feather stars"). These animals are common in the deep sea and in other areas. Crinoids are a Class of echinoderm characterized (in general) by a stalk that supports the body, mouth, and arms of the animal. The branching arms are equipped with ciliated grooves that carry food items to the central, upward-facing mouth.

Biotic Community: Attached *Comanthus*

Biotic Community: Attached *Diplocrinus*

**Biotic Group: Mobile Crustaceans on Hard or Mixed Substrates**

Areas where the epifaunal community is dominated by slow-moving crustaceans on hard or mixed substrates, often living on, between, or under rocks. Many of these animals feed on organic detritus, debris, or small fauna. This group is limited to the epifaunal crustacean taxa that are relatively non-motile (e.g., hermit crabs, xanthid crabs, grapsid crabs, mysids, palaemonids and other small shrimps, amphipods, isopods) and cannot move outside the boundaries of the classification unit within one day. This group does not include the larger, more mobile, usually predatory crustacean forms (e.g., swimming crabs, Cancer crabs, large spider crabs, penaeid shrimps), which should be recorded as Associated Taxa with another Biotic Group (see Section 10.3.1).

Biotic Community: Caprellid Communities

Biotic Community: *Crangon* Communities

Biotic Community: *Pagurus* Communities

**Biotic Group: Sessile Gastropods**

Hard substrate areas dominated by sessile (or mostly sessile) gastropods, often suspension feeders. Fauna in this biotic group may construct thick calcareous growths, but do not occur in abundance that is judged sufficient to construct a substrate; where these species are sufficiently abundant that they do construct substrate, they are classified in the Reef Class as Mollusk Reef (see above).

Biotic Community: Attached *Acmaea*

Biotic Community: Attached *Crepidula*

Biotic Community: Attached *Haliotis*

Biotic Community: Attached *Vermetids*

**Biotic Group: Attached Holothurians**

Areas where the epifaunal community is dominated by sessile or slow-moving holothurians (sea cucumbers) on hard or mixed substrates. Holothurians living on hard substrate may attach firmly, or may be capable of movement over the substrate. Many forms are adapted to feeding by moving their sticky tentacles over the substrate; other forms are suspension-feeders.

Biotic Community: Attached *Parastichopus*

Biotic Community: Attached *Psolus*

**Biotic Group: Attached Hydroids**

Areas dominated by mounds or mats of hydroids that are attached to a hard substrate. Hydroids are colonies of individual cylindrical polyps arranged in a branching structure, as a furry or brushy covering, or in other forms. Polyps are specialized for support, reproduction, and defense, and are armed with nematocysts (stinging capsules in specialized cells). Hydroids are the benthic life stage of planktonic jellyfish medusae, and most are predators on small life forms. Hydroid mounds or mats may form very dense assemblages.

Biotic Community: Attached *Sertularia*

Biotic Community: Attached *Tubularia*

**Biotic Group: Mobile Mollusks on Hard or Mixed Substrates**

Areas dominated by slow-moving mollusks, most commonly gastropods. In general, the forms that reach densities sufficient to be defined as a Biotic Group are detritivores or suspension feeders. Slow-moving predatory mollusks (e.g., whelks, drills, octopods) tend to be less abundant, and would more typically be classified in CMECS as Co-occurring Elements, together with another Biotic Group.

Biotic Community: *Bittium* Communities

Biotic Community: *Littorina* Communities

Biotic Community: *Urosalpinx* Communities

**Biotic Group: Attached Mussels**

Areas dominated by dense accumulations of mussels attached to a substrate other than conspecifics. This group includes associated faunal communities and predators on mussels (e.g., starfish), which may be highly conspicuous. Areas where mussels have constructed substrate are classified as Mussel Reef. Areas where mussels are not attached to a hard substrate are classified as Soft Sediment Fauna, Mussel Bed.

Biotic Community: Attached *Modiolus*

Biotic Community: Attached *Mytilus*

**Biotic Group: Attached Oysters**

Areas dominated by fauna that consists of accumulations of oysters attached to a substrate other than conspecifics. Areas where oysters have constructed substrate are classified as Oyster Reef (see above). Areas where oysters are not attached to the substrate are classified as Soft Sediment Oyster Bed.

Biotic Community: Attached *Crassostrea*

Biotic Community: Attached *Ostrea*

**Biotic Group: Attached Sponges**

Hard or mixed substrate areas that are dominated by sponges and their associated communities, e.g., where non-reef building sponge species grow attached to hard substrate or are nestled among hard substrate, or where reef-building sponges grow on hard substrates in densities that are not judged sufficient to constitute a reef. Most sponge species do not have fused silica spicules, and so do not create lasting skeletons that build reefs. Nonetheless, these more fibrous and ephemeral sponges provide seafloor relief and excellent habitat for other fauna, including many commensal species that live within the tissues of the sponge.

Biotic Community: Attached *Cliona*

Biotic Community: Attached *Halichondria*

Biotic Community: Attached *Hyalonema*

Biotic Community: Attached *Microciona*

Biotic Community: Attached *Scypha*

**Biotic Group: Attached Starfish**

Hard or mixed substrate areas in which starfish (sea stars) occur in large aggregations and clearly dominate the biota. Practitioners should note that, in most cases, starfish are predators on another Biotic Group (e.g., Attached Mussels) which (as the forage base) would normally constitute the dominant percent cover. In those cases, Starfish would be described as a Co-occurring Element, e.g., "Biotic Group: Attached *Mytilus edulis* with Co-occurring Element: Attached *Asterias rubens*". The Attached Starfish biotic group is intended to describe areas where starfish constitute the dominant life form in percent cover, not areas with occasional or scattered starfish.

Biotic Community: Attached *Asterias*

Biotic Community: Attached *Pisaster*

**Biotic Group: Attached Tunicates**

Areas dominated by attached members of the subphylum Tunicata, known as tunicates, ascidians, or sea squirts. Tunicates are bag-like filter feeders with an incurrent and an excurrent siphon. In some areas they reach high abundances. One species (*Didemnum*, see Figure 8.10) is a rapid invasive that blankets large



areas, excludes other fauna, and has invaded many countries around the world, including the United States, on both the East and West coasts.

Biotic Community: Attached *Didemnum*

Biotic Community: Attached *Molgula*

**Biotic Group: Attached Sea Urchins**

Hard or mixed substrate areas dominated by mobile sea urchins. Many sea urchins are omnivorous, consuming algae, debris, sessile invertebrates, and other foods. In some situations, sea urchins will occur in great numbers, clearly constituting the dominant Biotic Group. These fauna may be associated with another Biotic Group (upon which they are feeding) and may be considered as Co-occurring Elements if the "forage" group occurs in greater percent cover, or dominates biomass.

Biotic Community: Attached *Strongylocentrotus droebachiensis*

Biotic Community: Attached *Strongylocentrotus purpurata*

**Biotic Subclass: Soft Sediment Fauna**

Areas that are characterized by fine unconsolidated substrates (sand, mud) and that are dominated in percent cover or in estimated biomass by infauna, sessile epifauna, mobile epifauna, mobile fauna that create semi-permanent burrows as homes, or by structures or evidence associated with these fauna (e.g., tilefish burrows, lobster burrows). These animals may tunnel freely within the sediment or embed themselves wholly or partially in the sediment. In many cases, they will regularly leave their burrows, and may move rapidly or swim actively after doing so, but any animal that creates a semi-permanent home in the sediment can be classified as Soft Sediment Fauna. These animals may also move slowly over the sediment surface, but are not capable of moving outside of the boundaries of the classification unit within one day. Most of these fauna possess specialized organs for burrowing, digging, embedding, tube-building, anchoring, or locomotory activities in soft substrates. Biotic communities in the Soft Sediment Fauna subclass are identified with the term "Bed", to distinguish them from Attached Fauna biotic communities (which do not include the term "Bed").

Within Soft Sediment Fauna, the Biotic Group is identified as the biota making up the greatest percent cover or the greatest estimated biomass within the classified area. Biota present at lesser percent cover or estimated biomass values within the classified area may be identified as Co-occurring Elements (See Section 10.6.2) or (if not a CMECS Biotic Group) as Associated Taxa (See Section 10.3.1). Associated Taxa include rapid epifaunal predators such as crustaceans, fishes, and other nekton that are capable of leaving the boundaries of the classification unit within one day. Associated Taxa may be capable of digging into the sediment surface to feed or hide (e.g., portunid crabs) but do not construct a semi-permanent burrow as would define Soft Sediment Fauna. For practitioners who wish to better characterize Soft Sediment Fauna, the Community Successional Stage Modifier (Section 10.3.2, including Figure 10.1 and Table 10.3) is a helpful addition to classifying soft sediment fauna, and can be applied to almost every

soft-sediment area. This modifier provides ecological and functional information, and adds an element of assessment.

**Biotic Group: Larger Deep-Burrowing Fauna**

Assemblages dominated by the presence—or evidence—of larger, deep-burrowing, soft-bodied, generally worm-like infauna. Characteristic taxa include larger (body width > 2 millimeters) annelids (segmented worms), enteropneusts (acorn worms), sipunculids (peanut worms), priapulids (phallus worms), nemerteans (ribbon worms), echiuroids (spoon worms), and/or other worm-like fauna, typically living > 5 centimeters below the sediment-water interface. Diverse mixes of fauna are common, and biotic communities may or may not be identifiable with an abundant or distinctive dominant taxon. Large fecal casts, mounds, burrows, feeding voids, etc., may be taken as evidence of deep-burrowing fauna. However, areas characterized by larger, tube-building worms (that construct a significant tube structure rising above the sediment-water interface, but may live with a body position below the sediment surface) are classified as Larger Tube-Building Fauna. Burrowing fauna with shells (e.g., clams and crustaceans) are covered below in other biotic groups.

Biotic Community: *Balanoglossus* Bed

Biotic Community: *Boniella* Bed

Biotic Community: *Glycera* Bed

Biotic Community: *Nephtys* Bed

Biotic Community: *Sipunculid* Bed

**Biotic Group: Small Surface-Burrowing Fauna**

Areas dominated by small, burrowing, often worm-like fauna with a body width usually < 2 millimeters; animals are typically found within 5 centimeters of the sediment-water interface. Common fauna include oligochetes, polychaetes, sipunculids, flatworms, nematodes, priapulids, small enteropneusts (acorn worms), and other phyla. Burrowing fauna other than worms may also be characteristic (e.g., small, surface-burrowing amphipods, mysids, copepods, or isopods). In many areas, surface fauna will be abundant, but individual animals generally associated with this group will be found living deeper than 5 centimeters; these areas are still classified as Small Surface-Burrowing Fauna.

Biotic Community: Capitellid Bed

Biotic Community: Harpacticoid Bed

Biotic Community: *Leptocheirus* Bed

Biotic Community: Lumbrinerid Bed

Biotic Community: Nematode Bed

Biotic Community: Oligochaete Bed

Biotic Community: Turbellarian Bed

**Biotic Group: Diverse Soft Sediment Epifauna**

Highly varied and diverse communities of mixed fauna that are present on the surface of soft unconsolidated substrates. Common taxa include annelids, holothurians, ophiuroids, anemones, tunicates, mollusks, sea pansies, hydroids, bryozoans, sea urchins, sponges, echiuroids, priapulids, and many others. Diverse Fine Sediment Epifauna can be further described using the Invertebrate Community Organism Size Modifiers: Meiofauna (dominants < 0.5 millimeter), Small Macrofauna (dominants > 0.5 millimeter to 2 millimeters), Large Macrofauna (dominants > 2 millimeters to 1 centimeter), Megafauna (dominants > 1 centimeter to 3 centimeters), Large Megafauna (dominants > 3 centimeters), with all measurements in the smallest dimension (e.g., width or height) and not including the length of slender lateral projections (e.g., arms or tentacles). As with all Biotic Groups, this unit may be used when Communities cannot be identified, as in "Diverse Soft Sediment Epifauna (Large Macrofauna), which provides important information despite limitations of data, e.g., video information.

Biotic Community: *Aphrodite* Bed

Biotic Community: Bryozoan/Anemone Bed (Megafauna)

Biotic Community: Holothurian/Ophiuroid Bed

Biotic Community: Sand Dollar/Sea Pansy/Mobile Mollusk Bed (Large Megafauna)

**Biotic Group: Larger Tube-Building Fauna**

Soft sediment areas dominated by larger tube builders (tube width > 2 millimeters, or tube length > 30 millimeters), most commonly polychaetes, but including many other worm-like phyla (*phoronids*, *sipunculids*), crustaceans, and others. The tubes may be constructed in a variety of ways to produce calcareous, leathery, sandy, mucus-bound, chitinous, fibrous, papery, and other types of tubes. The animal itself may reside above or below the sediment surface, within the constructed tube. Some tube-building species (e.g., *Asabellides oculata*) may form extremely dense mounds of tubes that rise many centimeters above the seafloor. If colonization and growth of these fauna and their tubes results in the construction of substrate that is relatively stable, these faunal structures may be classified as Reef Biota.

Biotic Community: Robust *Ampelisca* Bed

Biotic Community: *Asabellides* Bed

Biotic Community: *Asychis* Bed

Biotic Community: *Chaetopterus* Bed

Biotic Community: *Diopatra* Bed

Biotic Community: *Lagis* Bed

Biotic Community: *Loimia* Bed

Biotic Community: Phoronid Bed

Biotic Community: *Phoronopsis* Bed

**Biotic Group: Small Tube-Building Fauna**

Soft sediment areas dominated by tube-building annelids (e.g., spionids, sabellids), amphipods, small phoronids, or other small, surface-dwelling, tube-building fauna. These animals have a small tube width (< 2 millimeters), and the tubes often occur in dense mats. The animal itself may reside above or below the sediment surface within the constructed tube, which may be composed of a variety of materials (e.g., glued sediments, calcium carbonate, mucus, chitin, proteins).

Biotic Community: Thin *Ampelisca* Bed

Biotic Community: *Chone* Bed

Biotic Community: *Paraprionospio* Bed

Biotic Community: *Polydora* Bed

Biotic Community: *Streblospio* Bed

**Biotic Group: Tunneling Megafauna**

Intertidal or Subtidal areas dominated by burrowing or construction activities of larger (megafaunal) organisms that create a water-filled tunnel with a diameter of > 1 centimeter. Tunneling activities are often attributable to crustaceans (generally decapods), but fishes (e.g., tilefish) and other taxa may also create large tunnel features. An associated mound of sediment may also be constructed. This biotic group is usually identified by the presence of tunnels or structures; the actual animal may be difficult to locate.

Biotic Community: *Callichirus* Bed

Biotic Community: *Lepidophthalmus* Bed

Biotic Community: *Lopholatilus* Bed

Biotic Community: *Neotrypaea* Bed

Biotic Community: *Nephrops* Bed

Biotic Community: *Squilla* Bed

Biotic Community: *Upogebia* Bed

**Biotic Group: Oligozoic Biota**

Zones that are devoid of macrofauna, larger fauna, and microbial mats, i.e., where no evidence of larger multicellular life can be detected when a sufficient area of the substrate is sampled to deliver sub-millimeter resolution, and where microbial communities are not visible to the naked eye. Interstitial meiofauna,

however, may be present or inferred. It is inappropriate to identify this biotic group with sampling methods that are not capable of sub-millimeter resolution and cannot detect infauna that may reside below the surface in soft sediments. Sampling methods which can resolve this biotic group include retrieval of substrate followed by sieving with < 0.5 millimeter mesh size and stereoscopic examination, and sediment profile imaging with cameras that provide sub-millimeter resolution at the faceplate. This biotic group is found in areas of extremely high stress (e.g., anoxic zones, highly toxic areas, and high-energy pebble or cobble beaches) where conditions cannot support larger multicellular life. Oxic areas of subtidal mineral sands are generally sparsely colonized by multicellular organisms (e.g., haustoriid amphipods, syllids and other small polychaetes) and are not considered Oligozoic Biota.

Biotic Community: Anoxic Oligozoic Bed

Biotic Community: Bacterial Bed

Biotic Community: Meiofaunal Bed

**Biotic Group: Burrowing Anemones**

Areas dominated by anemones (solitary coelenterates) that use their pedal disc to burrow in soft substrates. Many species are characterized by a whorl of tentacles at the sediment surface; when disturbed, the animal may very rapidly retract its tentacles into a burrow. These anemones occur at a range of densities, which requires sampling gear with an appropriate resolution and observational footprint (e.g., video transects or plan-view still photographs).

Biotic Community: *Cerianthus* Bed

Biotic Community: *Edwardsia* Bed

**Biotic Group: Soft Sediment Basket Stars**

Sandy or muddy areas characterized by brushy, many-armed echinoderms known as basket stars. Basket stars and the more common brittle stars are members of the class Ophiuroidea, but the arms of basket stars bifurcate many times to form a large complex that is reminiscent of a basket. Basket stars are usually larger than brittle stars, and maintain an upright form, generally clinging to solid objects, conspecifics, or other fauna using their bifurcated arms. In some soft sediment locations, basket stars form large entangled aggregations consisting of many individuals and covering large areas. Most basket stars are suspension feeders, but some species are more omnivorous or predaceous.

Biotic Community: *Asteronyx* Bed

Biotic Community: *Gorgonocephalus arcticus* Bed

**Biotic Group: Brachiopod Bed**

Soft-sediment areas dominated by burrowing, clam-like brachiopods, a phylum of animals with two shells, a stalk-like peduncle, and a tentacular, ciliated

feeding organ. In soft sediment dwelling species, the peduncle and the valves are adapted to burrowing. In other brachiopod species, the animal is adapted to attach to hard substrate (see Attached Brachiopods, above). Most brachiopods feed on plankton or on detritus. Brachiopods may occur in very high densities in some soft sediment areas, including intertidal areas (particularly on the west coast of the United States).

Biotic Community: *Glottidia* Bed

Biotic Community: *Lingula* Bed

**Biotic Group: Soft Sediment Brittle Stars**

Fine substrate assemblages dominated by crawling, burrowing or infaunal brittle stars, which are a relatively mobile class of echinoderms. Brittle stars may be either epifaunal or infaunal depending on the species and/or environmental conditions. In some situations, the central disc and several arms will be buried, but the remaining arm or arms will protrude typically ~ 1 centimeter to ~ 3 centimeters into the water column, where they may be mistaken for worms.

Biotic Community: *Amphiura* Bed

Biotic Community: *Ophiothrix* Bed

Biotic Community: *Ophiura* Bed

**Biotic Group: Soft Sediment Bryozoans**

Areas dominated by bryozoans (small colonial filter-feeding animals with a calcareous skeleton) that may grow in complex branched structures, bushy shapes, or other forms). Bryozoans may be either embedded in fine substrates or resting, unattached, on the sediment surface.

Biotic Community: *Bugula* Bed

Biotic Community: *Celleporaria* Bed

Biotic Community: *Schizoporella* Bed

**Biotic Group: Cephalochordates**

Soft-sediment areas (typically sandy) that are dominated by the rapidly burrowing, fish-like *Amphioxus*, or by other similar Genera of the subphylum Cephalochordata, a group of animals with characteristics of both vertebrates and invertebrates. These small (typically 2 - 15 centimeters in length) slender animals live buried just under the surface of sandy sediments. They feed on plankton or detritus that is strained from the water with a specialized feeding apparatus. *Amphioxus* and the related Genera have a worldwide distribution, and may occur in very high densities in some areas.

Biotic Community: *Amphioxus* Bed

Biotic Community: *Branchiostoma* Bed

**Biotic Group: Clam Bed**

Areas where either: (a) living clams, siphons, or siphon holes are the dominant surface feature, or; (b) clams dominate the faunal biomass. Siphons or shells may (or may not) be visible from above the sediment surface. The Clam Bed biotic group includes clams of all sizes; clam size can be specified using the Invertebrate Community Organism Size Modifiers: Meiofauna (dominants < 0.5 millimeter), Small Macrofauna (dominants > 0.5 millimeter to 2 millimeters), Large Macrofauna (dominants > 2 millimeters to 1 centimeter), Megafauna (dominants > 1 centimeter to 3 centimeters), Large Megafauna (dominants > 3 centimeters), with all measurements in the smallest dimension (e.g., the smallest shell width for most clams).

Biotic Community: *Arctica* Bed

Biotic Community: *Donax* Bed

Biotic Community: *Macoma* Bed

Biotic Community: *Mercenaria* Bed

Biotic Community: *Mulinia* Bed

Biotic Community: *Mya* Bed

Biotic Community: *Nucula* Bed

Biotic Community: *Rangia* Bed

Biotic Community: *Spisula* Bed

Biotic Community: *Venus* Bed

Biotic Community: *Yoldia* Bed

**Biotic Group: Soft Sediment Crinoids**

Areas dominated by crinoid species that are not attached to a hard substrate. Stalked crinoids or "sea lilies" may fix themselves to the soft seafloor or may move along the bottom. These animals and the motile (but often stationary, see Barnes 1980) comatulid "feather stars" are common in the deep sea and in other areas. They may be resting on the sediment surface, or they may be partially embedded in the sediment. Both groups of crinoids (sea lilies and feather stars) are suspension-feeding echinoderms with many branched arms.

Biotic Community: *Comanthus* Bed

Biotic Community: *Diplocrinus* Bed

Biotic Community: *Rhizocrinus* Bed

**Biotic Group: Mobile Crustaceans on Soft Sediments**

Areas where the epifaunal or surface community is dominated by slow-moving crustaceans. This group is limited to the relatively non-motile, epifaunal, crustacean taxa (e.g., hermit crabs, mole crabs, amphipods, mysids, isopods) and does not include the more mobile arthropod forms (e.g., swimming crabs,

horseshoe crabs, penaeid shrimps) which can leave the classified area in less than one day and are defined as Associated Taxa. Larger mobile crustacean forms that construct a semi-permanent home (lobsters, burrowing shrimps, etc.) are classified as Tunneling Megafauna. Small burrowing crustaceans with a body measuring < 2 mm in the smallest dimension are classified as Small Surface-Burrowing Fauna.

Biotic Community: Caprellid Bed

Biotic Community: *Emerita* Bed

Biotic Community: Haustoriid Bed

Biotic Community: Mysid Bed

Biotic Community: *Pagurus* Bed

**Biotic Group: Echiurid Bed**

Soft-sediment areas dominated by unsegmented echiurids or "spoon worms" which are abundant on the U.S. west coast in both intertidal and subtidal habitats. This group also includes communities where U-shaped echiurid burrows constitute the dominant or characteristic faunal feature, even if all animals have retracted into their burrows and cannot be seen.

Biotic Community: *Echiurus* Bed

Biotic Community: *Listriolobus* Bed

Biotic Community: *Urechis* Bed

**Biotic Group: Holothurian Bed**

Soft sediment assemblages dominated by holothurians or "sea cucumbers", which are common in both shallow and deep areas of the ocean. Holothurians common on sand or mud bottoms generally have features adapting them to life in soft sediment, and many species feed by ingesting sediment and associated organic matter as they burrow through the substrate. Tracks, trails, or feces left by these echinoderms may also be characteristic (see Fecal Mounds, also Tracks and Trails in the Inferred Fauna section below). The Holothurian Bed group is used only when the holothurians are present; use the Tracks and Trails or Fecal Mounds Biotic Groups when there is evidence of their presence, but living individuals are not seen.

Biotic Community: *Caudina* Bed

Biotic Community: *Kolga* Bed

Biotic Community: *Leptosynapta* Bed

Biotic Community: *Stichopus* Bed

**Biotic Group: Hydroid Bed**

Areas dominated by hydroid species that are not attached to a hard substrate. These animals may be resting on the sediment surface or may be partially



embedded in the sediment. Hydroids are the benthic life stage of planktonic jellyfish medusae, and most are predators on small life forms. Hydroids are colonies of individual polyps usually arranged in a branching or bushy pattern. The polyps are specialized for various roles, and defensive/prey capture polyps are armed with nematocysts (stinging capsules in specialized cells). Hydroids may form large mounds or mats in some soft sediment areas.

Biotic Community: *Sertularia* Bed

Biotic Community: *Tubularia* Bed

**Biotic Group: Mobile Mollusks on Soft Sediments**

Areas dominated by epifaunal, slow-moving, generally detritivorous, herbivorous, or omnivorous gastropods, scaphopods, or other mollusks foraging at the surface of unconsolidated sediments. These animals may be partly buried in the substrate. Predatory mobile mollusks such as moon snails, octopods, or whelks are generally preying on another Biotic Group (e.g., Clam Bed) which (as the forage base) would normally constitute the dominant percent cover. In those cases, Mobile Mollusks would be described as a Co-occurring Element, e.g., "Biotic Group: *Spisula* Bed with Co-occurring Element: Polinices Bed".

Biotic Community: Nassariid Bed

Biotic Community: *Olivella* Bed

Biotic Community: *Polinices* Bed

Biotic Community: Scaphopod Bed

Biotic Community: Turritellid Bed

**Biotic Group: Mussel Bed**

Soft-sediment areas dominated by mussel species that are not attached to a hard substrate. These animals may be resting on the sediment surface, partially embedded in the sediment, or attached to conspecifics (by using their byssal threads), or to a piece of gravel in Slightly Gravelly Fine Sediments. Individuals in the Mussel Bed Group are not present in densities sufficient to construct substrate; in that case, they would be classified as Mussel Reef.

Biotic Community: *Modiolus* Bed

Biotic Community: *Mytilus* Bed

**Biotic Group: Oyster Bed**

Soft-sediment areas dominated by oyster species that are not attached to a hard substrate and are not present in densities sufficient to construct substrate. These animals may be resting on the sediment surface, partially embedded in the sediment, or attached to conspecifics.

Biotic Community: *Crassostrea* Bed

Biotic Community: *Ostrea* Bed

**Biotic Group: Pennatulid Bed**

Subtidal soft-bottom habitats that are dominated by sea pens or sea pansies (Phylum Cnidaria, Order Pennatulacea). These are colonial octocorals with a central stem-like support attached to a root-like peduncle, adapted for life in soft sediments. An arrangement of suspension-feeding polyps in a single plane on two sides of the central stem (which is a specialized polyp) gives some sea pens the overall appearance of a feather or quill pen. The root-like peduncle is embedded in soft sediments, but the sea pen can move to a new area if conditions are unfavorable. Sea pansies are more compact and fleshier than sea pens. Pennatulids are often common in deeper waters.

Biotic Community: *Halipteris* Bed

Biotic Community: *Pennatula* Bed

Biotic Community: *Renilla* Bed

Biotic Community: *Stylatula* Bed

**Biotic Group: Sand Dollar Bed**

Assemblages dominated by surface-dwelling, "irregular" echinoids of the Phylum Echinodermata and Order Clypeasteroidea (e.g., sand dollars, sea biscuits). Sand dollars typically move on top of the sediment surface or burrow in the top few centimeters of sediment. Sand dollars are characterized by a flat body and short spines, to visually distinguish them from Burrowing Urchins and Soft Sediment Sea Urchins (see biotic groups below). Most sand dollars are deposit feeders; some are suspension feeders.

Biotic Community: *Clypeaster* Bed

Biotic Community: *Dendaster elongatus* Bed

Biotic Community: *Mellita* Bed

**Biotic Group: Scallop Bed**

Areas dominated by accumulations of scallops. Scallops have a series of small eyes and are mobile, clapping their shells together and pulsing through the water to escape predators such as starfish. Scallops may occur in high densities, but populations can be significantly affected by a number of factors, including larval recruitment, predation, and fishing pressure.

Biotic Community: *Argopecten* Bed

Biotic Community: *Placopecten* Bed

**Biotic Group: Sponge Bed**

Sandy or muddy areas of the seafloor that are dominated by sponges and their associated communities, but do not create substrate such that they would be considered Reef Biota. Hexactinellid "glass sponges" that are capable of forming reefs may be classified as a Sponge Bed when occurring on sand or mud in densities not deemed adequate to compose a reef. Many sponge species have

developed holdfast organs that adapt them to life in soft sediments, and can provide excellent structural habitat for other creatures, including the many commensal organisms that typically inhabit the tissues of living sponges.

Biotic Community: *Monoraphis* Bed

Biotic Community: *Tetilla mutabilis* Bed

**Biotic Group: Starfish Bed**

Soft sediment areas in which starfish occur in large aggregations and clearly dominate the biota. Practitioners should note that, in most cases, starfish are predators on another Biotic Group (e.g., Clam Bed) which (as the forage base) would normally constitute the dominant percent cover or biomass. In those cases, Starfish would be described as a Co-occurring Element, e.g., "Biotic Group: Clam Bed with Co-occurring Element: *Astropecten*".

Biotic Community: *Asterias* Bed

Biotic Community: *Astropecten* Bed

**Biotic Group: Tunicate Bed**

Sandy or muddy areas dominated by members of the subphylum Urochordata, including ascidians, sea squirts, and other tunicates. Tunicates are bag-like organisms that use incurrent and excurrent siphons for filter feeding and respiration. These animals may be resting on the sediment surface, partially embedded in the sediment, or attached to conspecifics. On both East and West coasts of the U.S., and in many other areas worldwide, colonies of the invasive sea squirt *Didemnum* are rapidly invading and smothering local biotopes.

Biotic Community: *Ciona* Bed

Biotic Community: *Didemnum* Bed

**Biotic Group: Burrowing Urchins**

Assemblages dominated by burrowing, "irregular" echinoids (e.g., burrowing urchins, heart urchins). These flattened urchins typically live underneath the sediment surface and feed on mud or on particles of detritus.

Biotic Community: *Echinocardium* Bed

Biotic Community: *Lovenia cordiformis* Bed

**Biotic Group: Sea Urchin Bed**

Sandy or muddy areas dominated by "regular" echinoids (e.g., sea urchins). These rounded urchins typically live on top of the sediment surface, and several species are well adapted to life on soft sediments, occurring in great numbers in certain locations.

Biotic Community: *Lytechinus anamesus* Bed

Biotic Community: *Lytechinus pictus* Bed

**Biotic Subclass: Inferred Fauna**

Areas dominated by evidence (real or inferred) of faunal activity, but where the fauna themselves are not currently present or evident, given the sampling methodology.

**Biotic Group: Egg Masses**

Areas distinguished by egg masses, egg cases, or other lasting evidence of gametes or reproduction. Many burrowing or tube-dwelling polychaetes will produce egg masses that look like bags of mucus attached to the soft sediment seafloor. Gastropods also often produce distinctive egg cases.

Biotic Community: *Busycon* Egg Cases

Biotic Community: Polychaete Mucus Cases

Biotic Community: *Polynices* Egg Collars

Biotic Community: Squid Egg Masses

**Biotic Group: Fecal Mounds**

Areas distinguished by large fecal mounds or castings. These features are characteristic of larger deposit-feeding polychaetes and other mud-ingesting fauna. Mounds or castings are not always present even when these fauna are abundant, particularly when water movements (currents, waves) are sufficient to remove the deposits.

Biotic Community: *Arenicola* Castings

Biotic Community: Balanoglossid Castings

Biotic Community: Holothurian Castings

**Biotic Group: Pelletized, Fluid Surface Layer**

Areas distinguished by a fluid, fecal-rich, pelletized surface layer, which is typically 5 - 15 millimeters thick (Rhoads and Young 1970). This layer is characteristic of deposit-feeding polychaetes, deposit-feeding clams, and/or other fauna. This layer is indicative of deposit feeders, but is not always present in deposit feeding communities, particularly when currents are sufficient to remove the layer.

Biotic Community: Fluidized Capitellid Layer

Biotic Community: Fluidized Deposit Feeder Layer

Biotic Community: Fluidized Maldanid Layer

Biotic Community: Fluidized *Yoldia* Layer

**Biotic Group: Tracks and Trails**

Areas where sediment surface patterns are dominated by tracks and trails left by locomotion of mobile epifauna (e.g., snails, holothurians, crustaceans), and other fauna that are no longer present. These are common in deeper waters, and in other areas where sediments are less disturbed by physical energy. The appropriate invertebrate size modifier (e.g., Megafaunal, Macrofaunal) may be used to describe the sizes of the organisms suspected of leaving the marks being

evaluated.

Biotic Community: Decapod Tracks

Biotic Community: Gastropod Trails

Biotic Community: Holothurian Trails

### **Biotic Class: Microbial Communities**

Areas dominated by colonies of microscopic or single-celled organisms that form a hard structure, visible film, layer, or mat on or near the surface of the substrate. Colonies may be composed of benthic microalgae (e.g., diatoms), photosynthetic bacteria (e.g., cyanobacteria), archaea, saprotrophic bacteria (e.g., decomposers or decay organisms), chemoautotrophic bacteria, or other microbial groups. These features may exist on or near the surface of the sediment either subtidally or subaerially (Figure 8.12), or they may exist as extensive areas of decay associated with dead organisms that have fallen to the seafloor (Figure 8.13).

Note: There may be high levels of biotic diversity within microbial mats. Microbial mats are often encountered in extreme environments where grazing pressure from multi-cellular organisms is reduced; for example, they can be observed in the high intertidal zone, in areas of low dissolved oxygen, and in deep-sea areas around thermal vents."

#### **Biotic Subclass: Structure Forming Microbes**

Areas dominated by microbes that form a hard structure, generally through secretions and entrapment of minerals and sediments.

##### **Biotic Group: Xenophyophores**

Areas (typically found in hadal zones and on the abyssal plains) dominated by tests of large, living, benthic foraminifera ("forams"), most of which are epifaunal, moving very slowly over the seabed. The tests of these single-celled organisms may be surprisingly large, several or many centimeters in size. The multi-nucleated single cell lives in the interlaced fine tubules that constitute the structure of the test. The tests are made of secretions, scavenged minerals, and small particles around the tubules, and may take many shapes- rounded, globular, densely branching, or stick-like (protruding vertically from the sediment, with a portion that is buried). Evidence suggests that Xenophyophores exist in high densities over large areas of the abyssal and hadal seafloor.

Biotic Community: *Occultammia* Communities

Biotic Community: *Syringammia* Communities

##### **Biotic Group: Stromatolites**

Areas dominated by large, mound-like formations built up in shallow marine areas by secretions of cyanobacteria, which further entrap minerals and sediment. They form Earth's oldest fossils and originated over 3 billion years ago.

Biotic Community: Stromatolite Mound Communities

#### **Biotic Subclass: Mat/Film Forming Microbes**

Areas dominated by microbes that form soft structures, generally through

accumulations of conspecifics and other microbes into a matrix that appears as strands, a thin film, or a thicker mat.

**Biotic Group: Microphytobenthos**

Areas dominated by a visible accumulation of benthic diatoms, cyanobacteria, unicellular algae, and other single-celled organisms. These may appear at the surface of the substrate in the form of either (a) a thin film or stain or (b) a thicker crust or "felt." These forms may occur on rock or unconsolidated substrates in subtidal, intertidal, or supratidal areas.

Biotic Community: Diatom Felt

Biotic Community: Microbial Stain

**Biotic Group: Bacterial Mat/Film**

Areas dominated by colonies of bacterial decomposers and other decay organisms. These colonies can range in appearance from delicate and filamentous to a dense mass that may blanket the sediment surface. See Figure 8.12 for an example of a bacterial mat.

Biotic Community: *Beggiatoa* Communities

**Biotic Group: Bacterial Decay**

Areas dominated by colonies of bacterial decomposers and other decay organisms that are observed covering and rotting larger organic matter (such as macroalgal debris, fish kills, or similar large organic inputs). See Figure 8.13 for an example of bacterial decay.

Biotic Community: *Beggiatoa* Communities on Decaying Materials

**Biotic Group: Vent Microbes**

Areas dominated by chemoautotrophic bacteria living on or near hydrothermal vents. These bacteria can use the chemicals present around the vent as an energy source. The bacteria are present in the water column and on substrate near vents as bacterial mats, films, and strands. They form the primary food source (as symbionts or as free-living bacterial clusters) for the gigantic and diverse fauna that inhabit Vent Communities. Vent Microbes colonize new vents, making the area hospitable to other fauna.

Biotic Community: *Thiobacillus* Communities

Biotic Community: Thermoacidophiles Communities

**Biotic Class: Moss and Lichen Communities**

Tidal areas dominated by submerged or emergent mosses or lichens. Communities dominated by mosses are limited to freshwater situations. Although some mosses have been reported in tidal salt marshes, they have not been reported as dominant (Garbary et al. 2008). Lichens, on the other hand, occur in both freshwater and marine environments in relatively recognizable zones based on, among other factors, the extent to which they are submerged or flooded (Hawksworth 2000; Fletcher 1973; Gilbert and Giavarini 1997). Lichens are generally recognized

as a symbiotic association with a fungus and an alga (or cyanobacterium) living together and forming patches or a visible pattern on the surface of the substrate.

**Biotic Subclass: Freshwater Tidal Lichens**

Freshwater tidal areas dominated by salt-intolerant lichen species that form patches or visible patterns on the surface of the substrate. Freshwater lichen Biotic Groups are based on a modification of Gilbert and Giavarini (1997).

**Biotic Group: Freshwater Submerged and Regularly Flooded Tidal Lichen Zone**

Submerged or regularly flooded freshwater tidal areas dominated by lichens that can tolerate regular inundation. This zone includes the Submerged Zone described by Gilbert and Giavarini.

**Biotic Group: Freshwater Irregularly Flooded Tidal Lichen Zone**

Tidal areas that are irregularly flooded (less often than daily) by tidal or non-tidal floods. Areas are generally characterized by lichen species that require moist or damp substrates. This zone corresponds to the Fluvial Mesic and Fluvial Xeric Zones described by Gilbert and Giavarini, but the CMECS group only includes the parts related to the Tidal Lichen Zones.

**Biotic Subclass: Marine Lichens**

Marine tidal areas dominated by lichen species that form patches or visible patterns on the surface of the substrate. Marine Lichen Biotic Groups are based on a modification of Fletcher (1973).

**Biotic Group: Marine Intertidal Lichen Zone**

Zones dominated by patches of lichens that are regularly submerged by marine tides. This zone corresponds to the Littoral Zone described by Fletcher.

Biotic Community: *Cocotrema* Communities

Biotic Community: *Lecanora* Communities

Biotic Community: Intertidal *Verrucaria* Communities

**Biotic Group: Marine Supratidal Lichen Zone**

Zones dominated by patches of lichens in association with the supratidal zone (splash zone). These areas are rarely submerged, but are regularly wetted by splash and sea spray. These lichen zones are most often associated with rocky shores with abundant sea spray. This zone corresponds to the Supralittoral Zone described by Fletcher.

Biotic Community: *Anaptychia* Communities

Biotic Community: *Caloplaca* Communities

Biotic Community: *Ramalina* Communities

Biotic Community: *Xanthoria* Communities

Biotic Community: Supratidal *Verrucaria* Communities

**Biotic Subclass: Freshwater Tidal Moss**

Freshwater tidal areas dominated by moss species.

**Biotic Group: Submerged Freshwater Tidal Moss**

Freshwater tidal areas dominated by submerged or regularly flooded moss species.

Biotic Community: *Fontinalis antipyretica* Nonvascular Vegetation

**Biotic Group: Emergent Freshwater Tidal Moss**

Emergent freshwater tidal marshes dominated by mosses.

**Biotic Class: Aquatic Vegetation Bed**

This class includes subtidal or intertidal bottoms and any other areas characterized by a dominant cover of rooted vascular plants, attached macroalgae, or mosses, which are usually submersed in the water column or floating on the surface. They may be exposed during low tides. Non-rooted floating vegetation and free floating macroalgae are included with the Planktonic Biota Biotic Setting under the Floating/Suspended Plants and Macroalgae Subclass.

**Biotic Subclass: Benthic Macroalgae**

Aquatic beds dominated by macroalgae attached to the substrate, such as kelp (Figure 8.14), intertidal fucoids, and calcareous algae. Macroalgal communities can exist at all depths within the photic zone, on diverse substrates, and across a range of energy and water chemistry regimes. In the CMECS framework, macroalgae that dominate the benthic environment and form a vegetated cover fall within this subclass. Macroalgal communities (typically coralline/crustose algae) that build substrate in a reef setting are categorized in the BC Reef Biota Class instead.

Many macroalgal types and communities have low temporal persistence and can bloom and die-back within short periods. This aspect of macroalgae is reflected with the temporal persistence modifier, which allows further description of the units in this subclass.

While many researchers organize macroalgae based on their pigmentation, CMECS takes a growth morphology approach to defining benthic algal biotic groups. This decision was driven by the fact that macroalgal assemblages often include a variety of co-existing algal species, making delineations of individual species difficult. This approach also captures the influence that the algal growth structure has in shaping the local environment- by providing shelter, shade, and detrital material to an area, which is important to associated fauna.

The Biotic Group level of classification here is a modification of the “Littler functional-form model” for marine macroalgae, as described by Littler, Littler, and Taylor (1983) and promoted by Lobban and Harrison (1997). The Littler functional form groups are the sheet group, filamentous group, coarsely branched group, thick leathery group, jointed calcareous group, and crustose group. Littler, Littler, and Taylor (1983) discuss the morphological, metabolic, and ecological significance of each group, and they point out that these groups are best considered as recognizable points along a continuum (rather



than as discrete bins). Biotic Groups and Communities defined by macroalgae generally also include a diversity of associated fauna, including many that consume macroalgae (e.g., sea urchins and mollusks); these may be characterized as Modifiers: Associated Taxa, or Co-occurring Elements.

**Biotic Group: Calcareous Algal Bed**

Areas dominated by calcareous algae that incorporate calcium carbonate into their tissues, support their own weight, and have an upright growth form. Calcareous algae can form carpets on the bottom, and- as they decay- the calcareous skeletons remain behind, occasionally forming loose accumulations on the bottom resembling chips. Calcareous algae that occur in a reef setting are included in the Colonized Shallow and Mesophotic Reef biotic group.

Biotic Community: *Corallina* Communities

Biotic Community: *Halimeda* Communities

Biotic Community: *Jania* Communities

Biotic Community: *Penicillus* Communities

**Biotic Group: Canopy-Forming Algal Bed**

Areas dominated by canopy-forming algae that have complex growth forms with holdfasts and well-defined stipes and blades. Canopy forming algae are distinguished from other types of macroalgae, in that they often reach heights of several meters or greater. Their presence alters water energy patterns and provides shelter for other marine organisms. Kelp beds are an example of canopy forming algal communities (Figure 8.14).

Biotic Community: *Alaria* communities

Biotic Community: *Laminaria saccharina* Communities

Biotic Community: *Macrocystis* Communities

Biotic Community: Mixed Kelp Communities

Biotic Community: *Nereocystis* Communities

**Biotic Group: Coralline/Crustose Algal Bed**

Areas dominated by coralline or crustose algae that incorporate calcium carbonate into their tissues and form crusts on the substrate in many marine environments. Coralline algae can be attached or unattached (as in the rhodoliths that form nodules, which can occur in loose accumulations on the substrate). In the attached algae, the thalli are fixed to the substrate. Coralline/Crustose algae that occur in a reef setting are included in the Colonized Shallow and Mesophotic Reef biotic group.

Biotic Community: *Hildenbrandia* Communities

Biotic Community: *Lithothamnion* Communities

Biotic Community: *Lithophyllum* Communities

Biotic Community: *Peyssonnelia* Communities

Biotic Community: *Porolithon* Communities

Biotic Community: *Phymatolithon* Communities

**Biotic Group: Filamentous Algal Bed**

Areas dominated by filamentous algae that have a growth form consisting of fine filaments or strands with no blades or stipes. Filaments may branch, but they lack complex structures. The strands are undifferentiated (with a growth axis in one direction). Filamentous algae can form dense mats.

Biotic Community: *Aghardiella* Communities

Biotic Community: *Chaetomorpha* Communities

Biotic Community: *Chordaria* Communities

Biotic Community: *Cladophora sericia* Communities

**Biotic Group: Leathery/Leafy Algal Bed**

Areas dominated by leathery/leafy algae have a variety of specialized tissues (including thalli) that resemble stems and leaf-like blades. They generally maintain their shape when removed from water, and they often possess air bladders (pneumatocysts) and other flotation bodies.

Biotic Community: *Ascophyllum* Communities

Biotic Community: *Caulerpa* Communities

Biotic Community: *Chondrus* Communities

Biotic Community: *Codium* Communities

Biotic Community: *Fucus distichus* Communities

Biotic Community: *Palmaria* Communities

**Biotic Group: Mesh/Bubble Algal Bed**

Areas dominated by mesh or bubble algae that form small, generally spherical masses attached to the benthos. They may develop lobes as they grow, but they do not further differentiate at the macro level. These masses may be hard or leathery, and they can sometimes be hollow. Bubble algae can be fast growing, quickly colonizing exposed reef surfaces, overtaking new coral growth, and deterring other animals from attaching there.

Biotic Community: *Dichyosphaeria* Communities

Biotic Community: *Valonia* Communities

Biotic Community: *Ventricaria* Communities

**Biotic Group: Sheet Algal Bed**

Areas dominated by sheet (thallose) algae that form thin, undifferentiated, membranous sheets with no stipe or blades. Growth in these algae occurs in two

directions. The sheets can be as thin as a single cell.

Biotic Community: *Agardhiella* Sheet Algae Communities

Biotic Community: *Grinella americana* Communities

Biotic Community: *Monostroma grevillei* Communities

Biotic Community: *Ulva lactuca* Communities

**Biotic Group: Turf Algal Bed**

Areas dominated by turf algae that represent a multi-specific assemblage of diminutive, often filamentous, algae that attain a canopy height of only 1 - 10 millimeters (see Steneck 1988 for review). These microalgal species have a high diversity (more than 100 species in the western Atlantic), although only 30 - 50 species commonly occur at one time. There is a high turnover of individual turf algal species seasonally; only a few species are able to persist or remain abundant throughout the year. But turf algae- when observed as a functional group- remain relatively stable year-round (Steneck and Dethier 1994), and they are often able to recover rapidly after being partially consumed by herbivores. Turfs are capable of trapping ambient sediment, and they kill corals by gradual encroachment.

Biotic Community: Mixed Algal Turf Communities

**Biotic Subclass: Aquatic Vascular Vegetation**

Aquatic vascular vegetation beds dominated by submerged, rooted, vascular species (such as seagrasses, Figure 8.15) or submerged or rooted floating freshwater tidal vascular vegetation (such as hornworts [*Ceratophyllum* spp.] or naiads [*Najas* spp.]).

Note: Nomenclatural standards and punctuation for vegetated biotic communities are taken directly from FGDC-STD-005-2008. Strata are separated by a "/" (i.e., tree/shrub/herbaceous). Hyphens between species names indicate that they are in the same strata. Parentheses indicate that the species is important in defining the association, but may not be in every observation of the association. The name of the FGDC-STD-005-2008 Class is always used at the end of the association name. The epithet, "[Provisional]" is used when the type has been identified, but not yet formally incorporated into FGDC-STD-005-2008.

**Biotic Group: Seagrass Bed**

Tidal aquatic vegetation beds dominated by any number of seagrass or eelgrass species, including *Cymocedea* sp., *Halodule* sp., *Thalassia* sp., *Halophilla* sp., *Vallisneria* sp., *Ruppia* sp., *Phyllospadix* sp., and *Zostera* sp. Seagrass beds (Figure 8.15) may occur in true marine salinities, and they may extend into the lower salinity zones of estuaries.

Seagrass beds are complex structural habitats that provide refuge and foraging opportunities for abundant and diverse faunal communities in shallow waters. Seagrass beds require a specific set of ecological conditions for success, and they

are generally perceived as areas of high environmental quality.

The list of biotic communities for this group is long: a few examples are provided below, and the complete list is available in Appendix F.

Biotic Community: *Ruppia maritima* Herbaceous Vegetation

Biotic Community: *Syringodium filiformis* - (*Thalassia testudinum*)  
Herbaceous Vegetation

Biotic Community: *Halodule wrightii* Herbaceous Vegetation

Biotic Community: *Halophila decipiens* Herbaceous Vegetation [Provisional]

Biotic Community: *Halophila engelmannii* Herbaceous Vegetation

Biotic Community: *Halophila hawaiiiana* Herbaceous Vegetation [Provisional]

Biotic Community: *Halophila johnsonii* Herbaceous Vegetation [Provisional]

Biotic Community: *Halophila minor* Herbaceous Vegetation [Provisional]

Biotic Community: *Halophila ovalis* Herbaceous Vegetation [Provisional]

Biotic Community: *Phyllospadix scouleri* Herbaceous Vegetation [Provisional]

Biotic Community: *Phyllospadix serrultus* Herbaceous Vegetation  
[Provisional]

Biotic Community: *Phyllospadix torreyi* Herbaceous Vegetation [Provisional]

Biotic Community: *Thalassia testudinum* - *Syringodium filiformis*  
Herbaceous Vegetation

Biotic Community: *Thalassia testudinum* Herbaceous Vegetation

Biotic Community: *Vallisneria americana* Estuarine Bayou Herbaceous  
Vegetation

Biotic Community: *Zostera marina* Herbaceous Vegetation

**Biotic Group: Freshwater and Brackish Tidal Aquatic Vegetation**

Tidal aquatic vegetation beds dominated by submerged, rooted, vascular species that have limited (or no) salt tolerance. Some species, such as *Ruppia maritima*, can have a wide range of salt tolerance, and are included in this group when occurring in low salt environments or with other salt intolerant species that indicate low salt environments.

Biotic Community: *Ceratophyllum demersum* - *Vallisneria americana* - *Najas* spp. Tidal Herbaceous Vegetation

Biotic Community: *Ruppia maritima* - *Stuckenia pectinata* Herbaceous  
Vegetation

**Biotic Subclass: Emergent Wetland**

Areas in this class are characterized by erect, rooted, herbaceous hydrophytes-excluding emergent mosses and lichens. This vegetation is present for most of the

growing season in most years. These wetlands are usually dominated by perennial plants. This CMECS class is equivalent to the Emergent Wetland Class from FGDC-STD-004 (FGDC 1996b).

**Biotic Group: Emergent Tidal Marsh**

Communities dominated by emergent, halophytic, herbaceous vegetation (with occasional woody forbs or shrubs) along low-wave-energy, intertidal areas of estuaries and rivers.

Biotic communities in this subclass are equivalent to National Vegetation Classification Associations of FGDC-STD-005-2008, and follow their naming conventions (FGDC 2008). However, FGDC-STD-005-2008 does not split marshes into "herbaceous" or "scrub-shrub" at their Group level. As a result, some of the names of FGDC-STD-005-2008 types (which correspond to the CMECS Emergent Wetland class) indicate that the biotic community is a "Dwarf-shrubland." These specific communities are dominated by woody forbs, which- while technically dwarf-shrubs- function more like herbaceous vegetation. These types were included in Emergent Tidal Marsh, because their total floristics and physiognomy indicate an herbaceous marsh setting.

Vegetation in this subclass is composed of emergent aquatic macrophytes, especially halophytic species- chiefly graminoids (such as rushes, reeds, grasses and sedges), shrubs, and other herbaceous species (such as broad-leaved emergent macrophytes, rooted floating-leaved and submergent species [aquatic vegetation], and macroscopic algae). The vegetation is usually arranged in distinct zones of parallel patterns, which occur in response to gradients of tidal flooding frequency and duration, water chemistry, or other disturbances.

Tides may expose mudflats that contain a sparse mix of pioneering forb and graminoid species. Salinity levels (which control many aspects of salt-marsh chemistry) vary depending on a complexity of factors, including frequency of inundation, rainfall, soil texture, freshwater influence, fossil salt deposits, and more. Salt marshes often grade into (or are intermixed with) scrub-shrub wetlands in higher areas. See Figure 8.16 for an example of an emergent tidal marsh.

**Biotic Group: Brackish Marsh**

Marshes dominated by species with a wide range of salinity tolerance. Depending on the salinity levels (0.5-30), more or less salt-intolerant species may be present. The list of biotic communities for this group is long: a few examples are provided below, and the complete list is available in Appendix F.

Biotic Community: *Amaranthus cannabinus* Tidal Herbaceous Vegetation

Biotic Community: *Calamagrostis nutkaensis* - *Argentina egedii* - *Juncus balticus* Herbaceous Vegetation

Biotic Community: *Carex hyalinolepis* Tidal Herbaceous Vegetation

- Biotic Community: *Paspalum vaginatum* - *Spartina patens* Oligohaline Herbaceous Vegetation
- Biotic Community: *Phragmites australis* Tidal Herbaceous Vegetation
- Biotic Community: *Sagittaria subulata* - *Limosella australis* Tidal Herbaceous Vegetation
- Biotic Community: *Schoenoplectus americanus* - (*Spartina patens*) - *Typha* spp. Herbaceous Vegetation
- Biotic Community: *Schoenoplectus pungens* Tidal Herbaceous Vegetation
- Biotic Community: *Schoenoplectus robustus* - *Spartina alterniflora* Herbaceous Vegetation
- Biotic Community: *Spartina alterniflora* - *Lilaeopsis chinensis* Herbaceous Vegetation
- Biotic Community: *Spartina alterniflora* - *Polygonum punctatum* - *Amaranthus cannabinus* Herbaceous Vegetation
- Biotic Community: *Spartina cynosuroides* Herbaceous Vegetation
- Biotic Community: *Spartina patens* - *Typha* spp. Chenier Plain Oligohaline Herbaceous Vegetation
- Biotic Community: *Spartina patens* - *Vigna luteola* Mississippi River Deltaic Plain Herbaceous Vegetation
- Biotic Community: *Typha angustifolia* - *Hibiscus moscheutos* Herbaceous Vegetation
- Biotic Community: *Typha domingensis* Tidal Herbaceous Vegetation
- Biotic Community: *Ambrosia trifida* Herbaceous Vegetation
- Biotic Community: *Bidens cernua* Herbaceous Vegetation [Provisional]
- Biotic Community: *Carex obnupta* - *Argentina egedii* ssp. *egedii* Herbaceous Vegetation
- Biotic Community: *Carex obnupta* - *Juncus patens* Herbaceous Vegetation
- Biotic Community: *Carex obnupta* Herbaceous Vegetation
- Biotic Community: *Carex stricta* - *Peltandra virginica* - *Sagittaria (lancifolia* ssp. *media, latifolia*) Tidal Herbaceous Vegetation
- Biotic Community: *Cladium mariscus* ssp. *Jamaicense* Tidal Herbaceous Vegetation
- Biotic Community: *Deschampsia caespitosa* - *Horkelia marinensis* Herbaceous Vegetation
- Biotic Community: *Eleocharis fallax* - *Eleocharis rostellata* - *Schoenoplectus americanus* - *Sagittaria lancifolia* Herbaceous Vegetation

Biotic Community: *Eleocharis rostellata* - *Rhynchospora colorata* -  
*Rhynchospora microcarpa* Herbaceous Vegetation

Biotic Community: *Eleocharis rostellata* - *Sagittaria lancifolia* Oligohaline  
Herbaceous Vegetation

**Biotic Group: Freshwater Tidal Marsh**

Tidally influenced riverine marshes with salinity levels less than 0.5, which are dominated by salt-intolerant, herbaceous species (e.g., *Juncus* sp., *Eleocharis* sp., and *Zizania* sp.). Non-tidal, palustrine, freshwater marshes are beyond the scope of CMECS. The list of Biotic Communities for this group is long: a few examples are provided below, and the complete list is available in Appendix F.

Biotic Community: *Acorus calamus* Tidal Herbaceous Vegetation

Biotic Community: *Eriocaulon parkeri* - *Polygonum punctatum* Herbaceous  
Vegetation

Biotic Community: *Hibiscus moscheutos* - *Polygonum punctatum* - *Peltandra virginica* Tidal Herbaceous Vegetation

Biotic Community: *Impatiens capensis* - *Peltandra virginica* - *Polygonum arifolium* - *Schoenoplectus fluviatilis* - *Typha angustifolia* Tidal  
Herbaceous Vegetation

Biotic Community: *Isoetes riparia* Tidal Herbaceous Vegetation

Biotic Community: *Juncus balticus* - *Carex obnupta* Herbaceous Vegetation  
[Provisional]

Biotic Community: *Juncus effusus* var. *brunneus* Pacific Coast Herbaceous  
Vegetation

Biotic Community: *Juncus falcatus* - *Trifolium wormskioldii* Herbaceous  
Vegetation

Biotic Community: *Juncus roemerianus* - *Pontederia cordata* Herbaceous  
Vegetation

Biotic Community: *Justicia americana* - *Peltandra virginica* Herbaceous  
Vegetation [Provisional]

Biotic Community: *Nelumbo lutea* Tidal Herbaceous Vegetation

Biotic Community: *Nuphar advena* Tidal Herbaceous Vegetation

Biotic Community: *Nuphar sagittifolia* Tidal Herbaceous Vegetation

Biotic Community: *Peltandra virginica* - *Pontederia cordata* Tidal Herbaceous  
Vegetation

Biotic Community: *Peltandra virginica* - *Schoenoplectus* (*pungens*,  
*tabernaemontani*) Tidal Herbaceous Vegetation

Biotic Community: *Phragmites australis* - (*Sagittaria platyphylla*, *Vigna*

luteola) Tidal Herbaceous Vegetation

Biotic Community: *Sagittaria lancifolia* - *Glottidium vesicarium* - *Solidago sempervirens* - *Lythrum lineare* Herbaceous Vegetation

Biotic Community: *Sagittaria lancifolia* Mississippi River Deltaic Plain Herbaceous Vegetation

Biotic Community: *Sagittaria latifolia* - *Sagittaria platyphylla* - (*Colocasia esculenta*) Deltaic Herbaceous Vegetation

Biotic Community: *Schoenoplectus californicus* Tidal Herbaceous Vegetation

Biotic Community: *Schoenoplectus pungens* - (*Osmunda regalis* var. *spectabilis*) Herbaceous Vegetation

Biotic Community: *Spartina cynosuroides* - *Panicum virgatum* - *Phyla lanceolata* Herbaceous Vegetation

Biotic Community: *Zizania aquatica* Gulf Coast Herbaceous Vegetation

Biotic Community: *Zizania aquatica* Tidal Herbaceous Vegetation

Biotic Community: *Zizaniopsis miliacea* - *Panicum hemitomon* Herbaceous Vegetation

Biotic Community: *Zizaniopsis miliacea* Tidal Herbaceous Vegetation

**Biotic Group: High Salt Marsh**

Salt marshes dominated by herbaceous, emergent vegetation and forb-like dwarf shrubs; areas are infrequently flooded by tides and characterized by distinctive patterns of halophytic vegetation (e.g., *Spartina patens*). Low shrubs may be present, but they are not dominant. Shrub-dominated portions of salt marshes are included in the Saltwater Tidal Scrub-Shrub Wetland Biotic Group. The list of biotic communities for this group is long; a few examples are provided below, and the complete list is available in Appendix F.

Biotic Community: *Argentina egedii* - *Juncus balticus* Herbaceous Vegetation

Biotic Community: *Argentina egedii* - *Symphiotrichum subspicatum* Herbaceous Vegetation

Biotic Community: *Carex lyngbyei* - *Argentina egedii* Herbaceous Vegetation

Biotic Community: *Deschampsia caespitosa* - *Argentina egedii* Herbaceous Vegetation

Biotic Community: *Deschampsia caespitosa* - *Sidalcea hendersonii* Herbaceous Vegetation

Biotic Community: *Eleocharis rostellata* - *Spartina patens* Herbaceous Vegetation

Biotic Community: *Festuca rubra* - (*Argentina egedii*) Herbaceous Vegetation

Biotic Community: *Juncus roemerianus* Herbaceous Vegetation



Biotic Community: *Panicum virgatum* - (*Cladium mariscus* ssp. *jamaicense*, *Juncus roemerianus*) Herbaceous Vegetation

Biotic Community: *Panicum virgatum* - *Spartina patens* Herbaceous Vegetation

Biotic Community: *Schoenoplectus americanus* - *Spartina patens* Herbaceous Vegetation

Biotic Community: *Schoenoplectus pungens* - *Eleocharis parvula* Herbaceous Vegetation

Biotic Community: *Spartina bakeri* - *Kosteletzkya virginica* Herbaceous Vegetation

Biotic Community: *Spartina bakeri* Herbaceous Vegetation

Biotic Community: *Spartina patens* - *Agrostis stolonifera* Herbaceous Vegetation

Biotic Community: *Spartina patens* - *Distichlis spicata* - (*Juncus roemerianus*) Herbaceous Vegetation

Biotic Community: *Spartina patens* - *Festuca rubra* - (*Spartina pectinata*) Herbaceous Vegetation

**Biotic Group: Low and Intermediate Salt Marsh**

Salt marshes that are regularly flooded by tides so as to support characteristic halophytic vegetation (e.g., *Spartina alterniflora*). In locations with appropriate topography and tidal exchange, extensive meadows may form. Shrubs are less common in these areas. The list of biotic communities for this group is long: a few examples are provided below, and the complete list is available in Appendix F.

Biotic Community: *Acrostichum aureum* - (*Acrostichum danaeifolium*) Tidal Herbaceous Vegetation

Biotic Community: *Carex lyngbyei* - (*Distichlis spicata*, *Triglochin maritima*) Herbaceous Vegetation

Biotic Community: *Carex lyngbyei* Herbaceous Vegetation

Biotic Community: *Deschampsia caespitosa* - (*Carex lyngbyei*, *Distichlis spicata*) Herbaceous Vegetation

Biotic Community: *Distichlis spicata* - (*Salicornia virginica*) Herbaceous Vegetation

Biotic Community: *Distichlis spicata* - *Ambrosia chamissonis* Herbaceous Vegetation

Biotic Community: *Salicornia* (*bigelovii*, *virginica*) Tidal Herbaceous Vegetation [Provisional]

- Biotic Community: *Salicornia virginica* - *Brassica nigra* Herbaceous Vegetation
- Biotic Community: *Salicornia virginica* - *Distichlis spicata* - *Jaumea carnosa* Tidal Herbaceous Vegetation
- Biotic Community: *Salicornia virginica* - *Distichlis spicata* - *Triglochin maritima* - (*Jaumea carnosa*) Herbaceous Vegetation
- Biotic Community: *Salicornia virginica* - *Frankenia salina* - *Suaeda californica* Herbaceous Vegetation
- Biotic Community: *Salicornia virginica* / Algae Herbaceous Vegetation
- Biotic Community: *Salicornia virginica* Herbaceous Vegetation
- Biotic Community: *Sesuvium portulacastrum* Tidal Herbaceous Vegetation [Placeholder]
- Biotic Community: *Spartina alterniflora* - *Distichlis spicata* - *Spartina patens* Mesohaline Tidal Herbaceous Vegetation
- Biotic Community: *Spartina alterniflora* - *Juncus roemerianus* - *Distichlis spicata* Louisianian Zone Salt Tidal Herbaceous Vegetation
- Biotic Community: *Spartina alterniflora* - *Distichlis spicata* Tidal Herbaceous Vegetation
- Biotic Community: *Spartina alterniflora* / (*Ascophyllum nodosum*) Acadian/Virginian Zone Herbaceous Vegetation
- Biotic Community: *Spartina alterniflora* Carolinian Zone Herbaceous Vegetation
- Biotic Community: *Spartina patens* - *Distichlis spicata* - (*Juncus gerardii*) Herbaceous Vegetation
- Biotic Community: *Spartina patens* - *Schoenoplectus (americanus, pungens)* - (*Distichlis spicata*) Herbaceous Vegetation
- Biotic Community: *Spartina foliosa* Herbaceous Vegetation
- Biotic Community: *Triglochin maritima* - (*Salicornia virginica*) Herbaceous Vegetation

**Biotic Subclass: Vegetated Tidal Flats**

Tidal Flats or Pannes (see GC for definition) colonized by herbaceous vegetation, usually with sparse cover. Cover is not sufficiently dense or raised to constitute a marsh.

**Biotic Group: Vegetated Freshwater Tidal Mudflat**

Tidal mudflats in freshwater riverine systems colonized by sparse, emergent, salt-intolerant vegetation.

**Biotic Group: Vegetated Salt Flat and Panne**

Tidal Salt Flats or Pannes (see GC for definition) colonized by sparse, emergent,

halophytic, herbaceous or woody forb vegetation. The list of biotic communities for this group is long; a few examples are provided below, and the complete list is available in Appendix F.

Biotic Community: *Batis maritima* - *Sarcocornia pacifica* Dwarf-shrubland

Biotic Community: *Batis maritima* Dwarf-shrubland

Biotic Community: *Distichlis spicata* - (*Sporobolus virginicus*) Herbaceous Vegetation

Biotic Community: *Monanthochloe littoralis* Herbaceous Vegetation

Biotic Community: *Salicornia* (*virginica*, *bigelovii*, *maritima*) - *Spartina alterniflora* Herbaceous Vegetation

Biotic Community: *Salicornia bigelovii* - *Triglochin maritima* Herbaceous Vegetation

Biotic Community: *Sarcocornia pacifica* - (*Batis maritima*, *Distichlis spicata*) Dwarf-shrubland

Biotic Community: *Spartina spartinae* - *Monanthochloe littoralis* - *Suaeda linearis* Herbaceous Vegetation

Biotic Community: *Spartina spartinae* - *Sporobolus virginicus* Tidal Herbaceous Vegetation

Biotic Community: *Sporobolus virginicus* - *Distichlis spicata* Herbaceous Vegetation

Biotic Community: *Sporobolus virginicus* - *Paspalum vaginatum* Herbaceous Vegetation

### **Biotic Class: Scrub-Shrub Wetland**

Emergent wetland areas dominated by woody vegetation that is generally less than 6 meters tall. Characteristic species include true shrubs, young trees, and trees or shrubs that are small or stunted due to environmental conditions. Scrub-Shrub Wetland includes the shrub-dominated portions of high salt marshes- as well as stunted or low mangrove communities. This CMECS Class is equivalent to the Scrub-Shrub Wetland Class of FGDC-STD-004; however, the palustrine and non-tidal riverine portions of FGDC-STD-004 class are beyond the scope of CMECS.

#### **Biotic Subclass: Tidal Scrub-Shrub Wetland**

Estuarine or tidal riverine areas dominated by shrub vegetation that has less than 10% tree cover. (The cutoff value is the standard employed by FGDC-STD-005-2008 for defining the Shrubland and Grassland Formation Class [FGDC 2008]).

#### **Biotic Group: Brackish Tidal Scrub-Shrub**

Tidal areas dominated by shrub or immature tree species that are less than 6 meters tall and have a range of salt tolerance. Salinity may range from 0.5-30 (PSS).

Biotic Community: *Lonicera involucrata* / *Argentina egedii* Tidal Shrubland  
[Provisional]

**Biotic Group: Freshwater Tidal Scrub-Shrub**

Tidal areas dominated by shrub or immature tree species that are less than 6 meters tall and are salt intolerant. Salinity levels are less than 0.5. The list of biotic communities for this group is long; a few examples are provided below, and the complete list is available in Appendix F.

Biotic Community: *Alnus* (*incana* ssp. *rugosa*, *serrulata*) - *Cornus amomum* Shrubland

Biotic Community: *Alnus maritima* / *Acorus calamus* Shrubland

Biotic Community: *Alnus serrulata* - *Salix nigra* / *Pilea* (*fontana*, *pumila*)  
Tidal Shrubland

Biotic Community: *Alnus serrulata* / (*Zizania aquatica*, *Zizaniopsis miliacea*)  
Shrubland

Biotic Community: *Amorpha fruticosa* Tidal Shrubland

Biotic Community: *Morella cerifera* - *Rosa palustris* / *Thelypteris palustris*  
var. *pubescens* Shrubland

Biotic Community: *Morella cerifera* - *Toxicodendron radicans* / *Spartina bakeri* Shrubland

**Biotic Group: Saltwater Tidal Scrub-Shrub**

Tidal areas dominated by halophytic shrubs or immature trees that are less than 6 meters tall. Vegetation is composed of halophytic species, chiefly shrubs and other herbaceous species. The vegetation is usually arranged in distinct zones of parallel patterns in response to gradients of tidal flooding frequency and duration, water chemistry, or other disturbances. The list of Biotic Communities for this group is long; a few examples are provided below, and the complete list is available in Appendix F.

Biotic Community: *Borrichia arborescens* Shrubland

Biotic Community: *Borrichia frutescens* / (*Spartina patens*, *Juncus roemerianus*) Shrubland

Biotic Community: *Borrichia frutescens* / *Spartina spartinae* Shrubland

Biotic Community: *Baccharis halimifolia* - *Iva frutescens* - *Morella cerifera* - (*Ilex vomitoria*) Shrubland

Biotic Community: *Baccharis halimifolia* - *Iva frutescens* / *Panicum virgatum* Shrubland

Biotic Community: *Iva frutescens* ssp. *frutescens* - *Baccharis halimifolia* / *Spartina spartinae* Shrubland

Biotic Community: *Iva frutescens* / *Spartina patens* Shrubland

Biotic Community: *Avicennia germinans* / *Spartina alterniflora* Shrubland

Biotic Community: *Morella cerifera* - *Baccharis halimifolia* / *Eleocharis fallax* Shrubland

Biotic Community: *Iva frutescens* / *Spartina cynosuroides* Tidal Shrubland

**Biotic Group: Tidal Mangrove Shrubland**

Tidally influenced, dense, tropical or subtropical areas dominated by dwarf or short mangroves (and associates) that are generally less than 6 meters in height. Commonly found on intertidal mud flats along the shores of estuaries. Tidal mangrove shrublands may include immature stands or stunted mature trees that indicate a harsh growing environment. Areas characterized by tall mangroves (> 6 meters) are placed in the Tidal Mangrove Forest Biotic Group.

Where tidal amplitude is relatively low, the vegetation forms narrow bands along the coastal plains, and it rarely penetrates inland more than several kilometers along rivers. Where tidal amplitude is greater, mangroves extend further inland along river courses, forming extensive stands in the major river deltas. Also, mangrove cays may occur within the lagoon complex of barrier reefs.

The list of biotic communities for this group is long: a few examples are provided below, and the complete list is available in Appendix F.

Biotic Community: *Rhizophora mangle* Shrubland

Biotic Community: *Rhizophora mangle* - *Avicennia germinans* - *Laguncularia racemosa* / *Batis maritima* Shrubland

Biotic Community: *Rhizophora mangle* - *Avicennia germinans* - *Laguncularia racemosa* Shrubland

Biotic Community: *Rhizophora mangle* - *Avicennia germinans* Shrubland

Biotic Community: *Avicennia germinans* / *Batis maritima* Shrubland

Biotic Community: *Avicennia germinans* / *Sarcocornia pacifica* Shrubland

**Biotic Class: Forested Wetland**

Areas in this class are characterized by woody vegetation that is generally 6 meters or taller. This CMECS class is equivalent to the Forested Wetland Class of FGDC-STD-004 (FGDC 1996b and the Forest/Woodland Class of FGDC-STD-005-2008); however, the palustrine and non-tidal riverine portions of the FGDC-STD-004 class are beyond the scope of CMECS.

**Biotic Subclass: Tidal Forest/Woodland**

FGDC (Federal Geographic Data Committee). 2008. FGDC-STD-005-2008. National Vegetation Classification Standard, Version 2. Reston, VA: U.S. Geological Survey.

**Biotic Group: Brackish Tidal Forest/Woodland**

Tidal areas dominated by tree species that are greater than 6 meters tall and have a range of salt tolerance. Salinities may range from 0.5-30.

Biotic Community: *Picea sitchensis* / *Lonicera involucrata* - *Malus fusca* Tidal

Woodland [Provisional]

**Biotic Group: Freshwater Tidal Forest/Woodland**

Tidal riverine areas dominated by salt-intolerant tree species that are greater than 6 meters tall. The list of Biotic Communities for this group is long; a few examples are provided below, and the complete list is available in Appendix F.

Biotic Community: *Juniperus virginiana* var. *silicicola* / *Morella cerifera* / *Kosteletzkya virginica* - *Bacopa monnieri* Woodland

Biotic Community: *Nyssa aquatica* Tidal Forest

Biotic Community: *Nyssa biflora* - *Nyssa aquatica* - *Taxodium distichum* / *Saururus cernuus* Forest

Biotic Community: *Pinus taeda* - *Nyssa biflora* - *Taxodium distichum* / *Morella cerifera* / *Osmunda regalis* var. *spectabilis* Forest

Biotic Community: *Nyssa biflora* - (*Taxodium distichum*, *Nyssa aquatica*) / *Morella cerifera* - *Rosa palustris* Tidal Forest

Biotic Community: *Taxodium distichum* / *Carex hyalinolepis* Woodland

Biotic Community: *Taxodium distichum* / *Typha angustifolia* Woodland

Biotic Community: *Taxodium distichum* / *Zizania aquatica* - *Carex canescens* ssp. *disjuncta* Woodland

Biotic Community: *Taxodium distichum* Tidal Woodland [Provisional]

Biotic Community: *Taxodium distichum* / *Pontederia cordata* - *Peltandra virginica* Tidal Woodland

Biotic Community: *Taxodium ascendens* - *Cliftonia monophylla* - *Pinus elliotii* var. *elliotii* - *Chamaecyparis thyoides* / *Hypericum nitidum* - *Cladium mariscus* ssp.

Biotic Community: *Taxodium distichum* - *Nyssa aquatica* - *Persea palustris* Forest

Biotic Community: *Taxodium distichum* - *Nyssa biflora* - *Magnolia virginiana* - *Fraxinus profunda* Forest

Biotic Community: *Nyssa biflora* - *Magnolia virginiana* / *Cyrilla racemiflora* Forest

Biotic Community: *Nyssa biflora* - *Magnolia virginiana* - *Sabal palmetto* - *Juniperus virginiana* var. *silicicola* Forest

Biotic Community: *Acer rubrum* - *Fraxinus pennsylvanica* / *Polygonum* spp. Forest

Biotic Community: *Acer rubrum* / *Sambucus canadensis* / *Ampelopsis arborea* - *Sicyos angulatus* Forest

**Biotic Group: Tidal Mangrove Forest**

Tidally influenced, dense, tropical or subtropical forest with a shore zone dominated by true mangroves (and associates) that generally are 6 meters or taller (Figure 8.17). Dwarf shrub and short mangroves are placed in the Tidal Mangrove Shrubland Biotic Group.

Mangrove Forests (e.g., mangal or mangle) occur along the sheltered coasts of tropical latitudes of the Earth, and are commonly found on the intertidal mud flats along the shores of estuaries, usually in the region between the salt marshes and seagrass beds and may extend inland along river courses where tidal amplitude is high. Also, mangrove cays may occur within the lagoon complex of barrier reefs.

The list of biotic communities for this group is long: a few examples are provided below, and the complete list is available in Appendix F.

Biotic Community: *Avicennia germinans* Forest

Biotic Community: *Conocarpus erectus* Forest

Biotic Community: *Rhizophora mangle* Basin Forest

Biotic Community: *Rhizophora mangle* Fringe Forest

Biotic Community: *Rhizophora mangle* Medium Island Forest

Biotic Community: *Rhizophora mangle* Overwash Island Forest

Biotic Community: *Rhizophora mangle* Tall Fringing Forest

Biotic Community: *Rhizophora mangle* - (*Avicennia germinans*, *Laguncularia racemosa*) Riverine Forest

Biotic Community: *Rhizophora mangle* - *Dalbergia ecastaphyllum* - *Pavonia paludicola* Forest

## Substrate Component

Substrate is defined in the Coastal and Marine Ecological Classification Standard (CMECS) as the non-living materials that form an aquatic bottom or seafloor, or that provide a surface (e.g., floating objects, buoys) for growth of attached biota. Substrate may be composed of any substance, natural or man-made. Describing the composition of the substrate is a fundamental part of any ecological classification scheme. Substrate provides context and setting for many aquatic processes, and it provides living space for benthic and attached biota.

The Substrate Component (Section 7, p. 98, FGDC-STD-018-2012) is a characterization of the composition and particle size of the surface layers of the substrate; this component is designed to be compatible with a range of sampling tools. The Substrate Component provides guidance to characterize the layers of substrate that support the majority of multicellular life (the upper layer of hard substrate, or (typically) the upper 15 centimeters of soft substrate) in a way that is consistent with a variety of past practices. The Substrate Component and the Biotic Component (Section 8, p. 119, FGDC-STD-018-2012) describe the non-living (Substrate) and living (Biotic) aspects of a plan-view perspective of the seafloor at comparable scales.

Substrate Component observational unit scales range from sediment corers or grabs, to sediment profile or plan-view photographs of the seafloor, to defined quadrats or transects, to video clips, to high-resolution acoustic images. At larger scales, the structure, shape, and surface pattern of the substrate are described by the Geoform Component (Section 6, p. 60, FGDC-STD-018-2012).

### Implementation Guidance for all Substrate Component Units

The Coastal and Marine Ecological Classification Standard (CMECS) does not prescribe metrics or methodologies for substrate analysis or interpretation at this time. Classifications throughout the Substrate Component may be based on visual percent cover for plan-view images or metrics such as percent weight, or percent composition for other approaches (e.g., retrieved samples).

CMECS components are intended to be scale-independent and method-independent; the reported scale of substrate “patchiness” is determined by the scale of observation, and so is somewhat method-dependent. To assist with comparability, practitioners should always report sampling gear, methods, units, scale of observation, and scale of reporting in project metadata. Data users should be aware of the methods that were used to collect and report data, and should make note of any data limitations that may exist.

Modifier terms (Section 7.6 and Section 10, FGDC-STD-018-2012) can be applied as needed to further describe substrate characteristics. Recommended modifiers for substrate units include: *Anthropogenic Impact, aRPD and RPD Depth, Benthic Depth Zones, Co-occurring Elements, Coral Reef Zone, Energy Intensity, Induration, Percent Cover (Fine), Mineral Precipitate, Percent Cover (Coarse), Seafloor Rugosity, Small-Scale Slope, Substrate Descriptor, Substrate Layering, Surface Pattern, Temporal Persistence.*

The Co-occurring Elements modifier (Section 10.6.2, p. 213, FGDC-STD-018-2012) may be used to describe the presence of secondary substrate units within the observational unit (i.e., image frame, sampling grid cell, etc.)

### Substrate Origin: Geologic Substrate

Benthic substrates where sufficient evidence shows that Geologic Substrate exceeds (is dominant over) both Biogenic and Anthropogenic Substrates, considered separately. Geologic Substrates are composed of consolidated igneous, metamorphic, or sedimentary rock or finer unconsolidated particles, and are classified according to particle size and mixes of particle sizes. When Geologic Substrate is present, but does not constitute the dominant substrate origin, it may be included as a Co-occurring Element.

*Substrate Origin describes the genesis of the substrate, not the process by which it is emplaced. If the Substrate Origin cannot be definitively determined, the analyst may opt to use “Indeterminate” in place of Origin type and use the Geologic Origin units for further classification.*

### Substrate Class: Consolidated Mineral Substrate

Igneous, metamorphic, or sedimentary rock with particle sizes greater than or equal to 4.0 meters (4,096 millimeters) in any dimension that cover 50% or greater of the Geologic



## Substrate surface.

*Depending on the sampling method used and scale of the observational unit, classifying larger features may require extrapolating information from surrounding observations or additional studies. The Geoform Component may also be used to extend the substrate classification for such features (p. 227, FGDC-STD-018-2012).*

### **Substrate Subclass: Bedrock**

Substrate with mostly continuous formations of bedrock that cover 50% or more of the Geologic Substrate surface.

### **Substrate Subclass: Megaclast**

Substrate where individual rocks with particle sizes greater than or equal to 4.0 meters (4,096 millimeters) in any dimension cover 50% or more of the Geologic Substrate surface.

### **Substrate Subclass: Tar**

Substrate dominated by tar, asphalt, or other hydrocarbon material that has extruded onto the seafloor. This material has cooled from a semi-liquid state and now forms a potential attachment surface for biota. This substrate is usually associated with seeps, tar mounds, or tar lily geoforms.

## **Substrate Class: Coarse Unconsolidated Mineral Substrate**

Geologic Substrate where Unconsolidated Mineral Substrate covers 50% or more of the surface area with  $\geq 5\%$  Gravel (2 millimeters to  $< 4,096$  millimeters in diameter).

*The CMECS Coarse and Fine Unconsolidated Mineral Substrate classes and subordinate units use Folk (1954) terminology to describe particle sizes of loose mineral substrates as shown in the ternary diagram in Figure 7.2 (revised version). Units with bracketed letters, e.g., [G], [(g)sM], correspond to the labeled polygons in Figure 7.2, using conventions from Folk (1954).*

### **Substrate Subclass: Gravel Substrate [G]**

Geologic Unconsolidated Mineral Substrate surface is  $\geq 80\%$  Gravel (particles 2 millimeters to  $< 4,096$  millimeters in diameter).

#### **Substrate Group: Very Coarse Gravel**

Geologic Unconsolidated Mineral Substrate surface is  $\geq 80\%$  Gravel particles 64 millimeters to  $< 4,096$  millimeters in diameter.

#### **Substrate Subgroup: Boulder**

Geologic Unconsolidated Mineral Substrate surface is  $\geq 80\%$  Gravel particles 256 millimeters to  $< 4,096$  millimeters in diameter.

## Getting Started

If Gravel particles make up  $> 80\%$  of the substrate, continue classifying using the Gravel Substrate subclass units.

If Gravel particles make up  $\geq 5\%$  but  $< 80\%$ , continue classifying using the Mixed Gravel subclass units.

If Gravel particles make up  $0.01\%$  to  $< 5\%$  continue classifying using the Trace Gravel subclass within the Fine Unconsolidated Mineral Substrate class.

**Substrate Subgroup: Cobble**

Geologic Unconsolidated Mineral Substrate surface is  $\geq 80\%$  Gravel particles 64 millimeters to  $< 256$  millimeters in diameter.

**Substrate Group: Moderately Coarse Gravel**

Geologic Unconsolidated Mineral Substrate surface is  $\geq 80\%$  Gravel particles 2 millimeters to  $< 64$  millimeters in diameter.

**Substrate Subgroup: Pebble**

Geologic Unconsolidated Mineral Substrate surface is  $\geq 80\%$  Gravel particles 4 millimeters to  $< 64$  millimeters in diameter.

**Substrate Subgroup: Granule**

Geologic Unconsolidated Mineral Substrate surface is  $\geq 80\%$  Gravel particles 2 millimeters to  $< 4$  millimeters in diameter.

### Implementation Guidance for Classification of Gravel in All Units

Due to the importance of different particle sizes of Gravel as habitat for many organisms, Gravel subgroup particle sizes (Boulder, Cobble, Pebble, Granule) **must be identified whenever particle sizes are known or can be estimated** within any mix and at any level of classification. *Examples:*

- *Gravel Mixes -> Pebble Mixes*
- *Muddy Sandy Gravel -> Muddy Sandy Cobble*
- *Gravelly Sand -> Bouldery Sand*

When classifying mixes of two different Gravel subgroup particle sizes, use combinations of the subgroup unit names with the overall dominant size first.

*Examples: Boulder-Cobble, Cobble-Boulder, Cobble-Granule, Pebble-Granule, Granule-Boulder.*

When classifying mixes, or when there is a need to identify specific particle sizes beyond the subgroup definitions, the subgroup terms for the Gravel group (Boulder, Cobble, Pebble, Granule), Sand group (Very Coarse Sand, Coarse Sand, Medium Sand, Fine, Sand, Very Fine Sand), and Mud group (Silt, Silt-Clay, Clay) may optionally be substituted for the group term.

*Examples:*

- *Muddy Sandy Gravel -> Silty Sandy Gravel*
- *Slightly Gravelly Sandy Mud -> Slightly Gravelly Sandy Clay*
- *Gravelly Muddy Sand -> Gravelly Muddy Coarse Sand*
- *Slightly Gravelly Sand -> Slightly Gravelly Medium Sand*

**Substrate Subclass: Mixed Gravels**

Geologic Unconsolidated Mineral Substrate surface is 5% to  $< 80\%$  Gravel (particles 2 millimeters to  $< 4,096$  millimeters in diameter) with the remaining mix composed of

Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) and/or Mud (particles < 0.0625 millimeters in diameter).

**Substrate Group: Gravel Mixes**

Geologic Unconsolidated Mineral Substrate surface is 30% to < 80% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) with the remaining mix composed of Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) and/or Mud (particles < 0.0625 millimeters in diameter).

Substrate Subgroup: Sandy Gravel [sG]

Geologic Unconsolidated Mineral Substrate surface is 30% to < 80% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), with Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) composing 90% or more of the remaining Sand-Mud mix.

Substrate Subgroup: Muddy Sandy Gravel [msG]

Geologic Unconsolidated Mineral Substrate surface is 30% to < 80% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), with Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) composing from 50% to < 90% of the remaining Sand-Mud mix.

Substrate Subgroup: Muddy Gravel [mG]

Geologic Unconsolidated Mineral Substrate surface is 30% to < 80% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), with Mud (particles < 0.004 millimeters in diameter) composing 50% or more of the remaining Mud-Sand mix.

**Substrate Group: Gravelly Mixes**

Geologic Unconsolidated Mineral Substrate surface is 5% to < 30% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) with the remaining mix composed of Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) and/or Mud (particles < 0.0625 millimeters in diameter).

Substrate Subgroup: Gravelly Sand [gS]

Geologic Unconsolidated Mineral Substrate surface is 5% to < 30% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), and the remaining Sand-Mud mix is 90% or more Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

Substrate Subgroup: Gravelly Muddy Sand [gmS]

Geologic Unconsolidated Mineral Substrate surface is 5% to < 30% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), and the remaining Sand-Mud mix is 50% to < 90% Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

Substrate Subgroup: Gravelly Mud [gM]

Geologic Unconsolidated Mineral Substrate surface is 5% to < 30% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), and the remaining

Sand-Mud mix is 50% or more Mud (particles < 0.004 millimeters in diameter).

**Substrate Class: Fine Unconsolidated Mineral Substrate**

Geologic Substrate where Unconsolidated Mineral Substrate covers 50% or more of the surface area with < 5% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter).

*The CMECS Coarse and Fine Unconsolidated Mineral Substrate classes and subordinate units use Folk (1954) terminology to describe particle sizes of loose mineral substrates as shown in the ternary diagram in Figure 7.2 (revised version). Units with bracketed letters, e.g., [G], [(g)sM], correspond to the labeled polygons in Figure 7.2, using conventions from Folk (1954).*

**Substrate Subclass: Trace Gravels**

Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel to < 5% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) with the remaining mix composed of Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) and/or Mud (particles < 0.0625 millimeters in diameter).

**Substrate Group: Sandy Mixes with Trace Gravel**

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) to < 5% Gravel, and the remaining Sand-Mud mix is 50% or more Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

**Substrate Subgroup: Slightly Gravelly Sand [(g)S]**

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) to < 5% Gravel, and the remaining Sand-Mud mix is 90% or more Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

**Substrate Subgroup: Slightly Gravelly Muddy Sand [(g)mS]**

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) to < 5% Gravel, and the remaining Sand-Mud mix is 50% to < 90% Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

**Substrate Group: Muddy Mixes with Trace Gravel**

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) to < 5% Gravel, and the remaining Sand-Mud mix is 50% or more Mud (particles < 0.0625 millimeters in diameter).

**Substrate Subgroup: Slightly Gravelly Sandy Mud [(g)sM]**

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel (particles 2 millimeters to < 4,096 millimeters in diameter) to < 5% Gravel (particles 2 millimeters to < 4,096 millimeters in diameter), and the remaining Sand-Mud mix is 50% to < 90% Mud (particles < 0.0625 millimeters in diameter).

**Substrate Subgroup: Slightly Gravelly Mud [(g)M]**

Geologic Unconsolidated Mineral Substrate surface is 0.01% (a trace) of Gravel

(particles 2 millimeters to < 4,096 millimeters in diameter) to < 5% Gravel, and the remaining Sand-Mud mix is 90% or more Mud (particles < 0.0625 millimeters in diameter).

**Substrate Subclass: Sandy Substrate**

Geologic Unconsolidated Mineral Substrate surface contains no trace of Gravel and is 50% Sand (particles 0.0625 millimeters to < 2 millimeters in diameter) with the remainder composed of Mud (particles < 0.0625 millimeters in diameter).

**Substrate Group: Sand [S]**

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

Substrate Subgroup: Very Coarse Sand

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand particles 1 millimeter to < 2 millimeters in diameter.

Substrate Subgroup: Coarse Sand

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand particles 0.5 millimeters to < 1 millimeter in diameter.

Substrate Subgroup: Medium Sand

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand particles 0.25 millimeters to < 0.5 millimeters in diameter.

Substrate Subgroup: Fine Sand

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand particles 0.125 millimeters to < 0.25 millimeters in diameter.

Substrate Subgroup: Very Fine Sand

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is ≥ 90% Sand particles 0.0625 millimeters to < 0.125 millimeters in diameter.

**Substrate Group: Muddy Sand [mS]**

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 50% to < 90% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remainder is Mud (particles less than 0.0625 millimeters in diameter).

Substrate Subgroup: Silty Sand [zS]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 50% to < 90% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Silt-Clay mix is 67% or more Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

Substrate Subgroup: Silty-Clayey Sand [zcS]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 50% to < 90% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Silt-Clay mix is 33% to < 67% Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

**Substrate Subgroup: Clayey Sand [cS]**

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 50% to < 90% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Clay-Silt mix is 67% or more Clay (particles < 0.0040 millimeters in diameter).

**Substrate Subclass: Muddy Substrate**

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is > 50% Mud (particles < 0.0625 millimeters in diameter) with the remainder composed of Sand (particles 0.0625 millimeters to 2 millimeters in diameter).

**Substrate Group: Sandy Mud [sM]**

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 50% to 90% Mud (particles < 0.0625 millimeters in diameter); the remainder is Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

**Substrate Subgroup: Sandy Silt [sZ]**

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 10% to < 50% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Silt-Clay mix is 67% or more Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

**Substrate Subgroup: Sandy Silt-Clay [sZC]**

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 10% to < 50% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Silt-Clay mix is 33% to < 67% Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

**Substrate Subgroup: Sandy Clay [sC]**

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 10% to < 50% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Clay-Silt mix is 67% or more Clay (particles < 0.004 millimeters in diameter).

**Substrate Group: Mud [M]**

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is 90% or more Mud (particles < 0.0625 millimeters in diameter); the remainder (< 10%) is Sand (particles 0.0625 millimeters to < 2 millimeters in diameter).

**Substrate Subgroup: Silt [Z]**

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is < 10% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Silt-Clay mix is 67% or more Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

**Substrate Subgroup: Silt-Clay [ZC]**

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is < 10% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the

remaining Silt-Clay mix is < 33% to 67% Silt (particles 0.0040 millimeters to < 0.0625 millimeters in diameter).

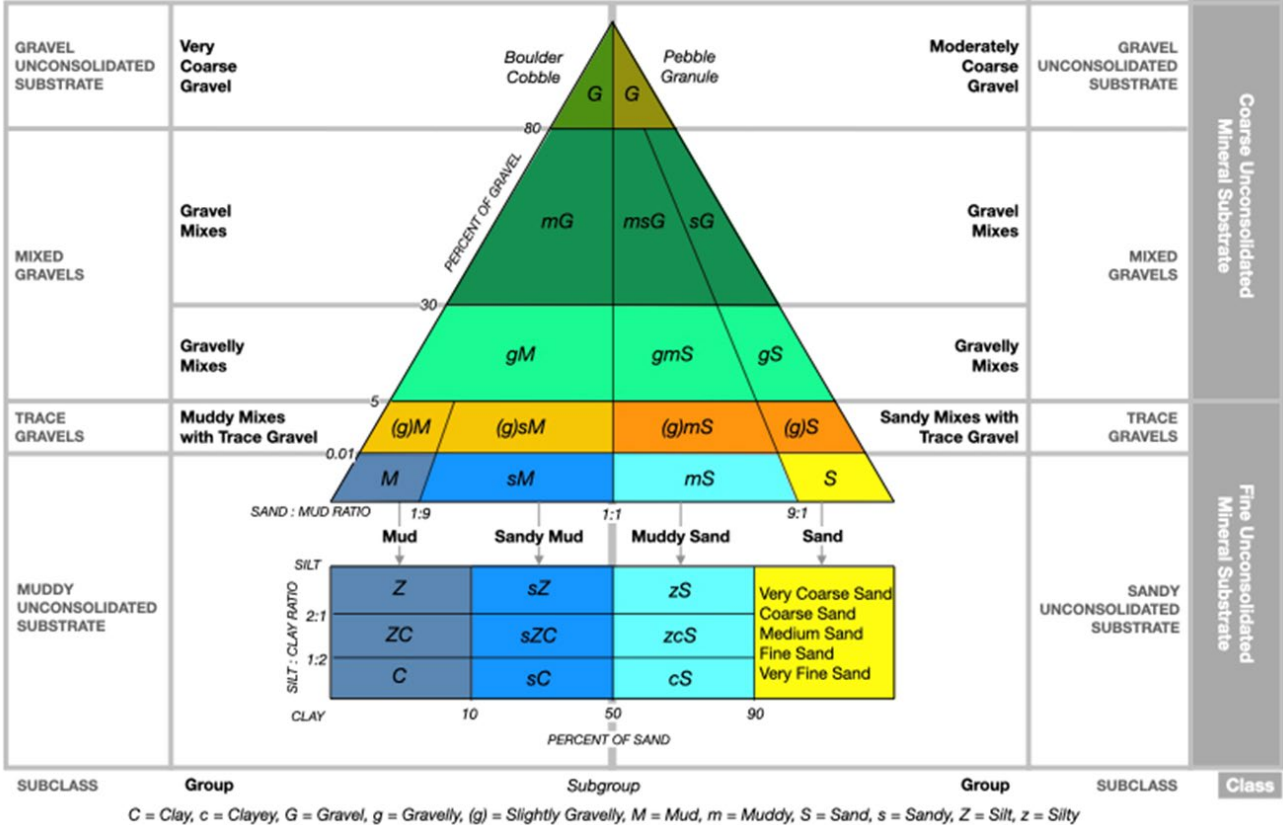
Substrate Subgroup: Clay [C]

Geologic Unconsolidated Mineral Substrate surface has no trace of Gravel and is < 10% Sand (particles 0.0625 millimeters to 2 millimeters in diameter); the remaining Clay-Silt mix is 67% or more Clay (particles < 0.004 millimeters in diameter).

**Figure 7.2 (Revised)**

**Figure 7.2 (revised)** Extended ternary diagram depicting the threshold values for Gravel-Sand-Mud combinations and Sand-Silt-Clay combinations (adapted from Folk, 1954) that define the CMECS Substrate Component's Subgroup and some Group units, and their placement within the higher-level units of the units of the Substrate Component framework.

The upper four rows of the ternary diagram and all sections of the rectangle contain the Subgroup units (see key to abbreviations below). The bottom row of the ternary diagram shows the Mud, Sandy Mud, Muddy Sand, and Sand Groups; their constituent Subgroups are shown in the rectangle sections. Colored sections represent the different Groups.



## Substrate Origin: Biogenic Substrate

Benthic substrates where sufficient evidence shows that Biogenic Substrate exceeds (is dominant over) that of both Geologic and Anthropogenic Substrates, when all are considered separately. Biogenic substrates are the non-living material that supports, intersperses, or overlays the living biota described in the Biotic Component (see Section 7.2), and are either generated by living biota, such as shells and tests, or are non-living remnants of living biota,



such as skeletons, dead wood, and detritus.

Biogenic substrates are classified at the class level by the level of consolidation, and at the subclass and group levels by particle size and biological source of the material. Subgroup units provide further descriptive detail where possible. Particle size bins at the Biogenic Substrate class, subclass, and group levels correspond to the Geologic Substrate units as follows:

- Class: Consolidated Biogenic Substrate is equivalent to the Geologic Origin class: Consolidated Mineral Substrate ( $\geq 4,096$  millimeters in any dimension)
- Subclass: Biogenic Rubble is equivalent to the Geologic Origin group: Very Coarse Gravel (64 millimeters to  $< 4,096$  millimeters in diameter)
- Subclass: Biogenic Hash is equivalent to the Geologic Origin group: Moderately Coarse Gravel (2 millimeters to  $< 64$  millimeters in diameter)
- Subclass: Biogenic Sand is equivalent to the Geologic Origin group: Sand (0.0625 millimeters to  $< 2$  millimeters in diameter)
- Group: Organic Mud is equivalent to the Geologic Origin group: Mud ( $< 0.0625$  millimeters in diameter)

These units are derived from Wentworth (1922), and they can be broken down into Wentworth grain size classes for greater precision, if desired.

*Substrate Origin describes the genesis of the substrate, not the process by which it is emplaced. If the Substrate Origin cannot be definitively determined, the analyst may opt to use "Indeterminate" in place of origin type and use the Geologic Origin units for further classification.*

### Implementation Guidance for all Biogenic Origin Units

CMECS does not prescribe metrics or methodologies for substrate analysis or interpretation at this time. The terms "dominant" and "primarily" in the Biogenic Substrate Origin describe the substrate type that is present in the greatest visual percent cover for plan-view images or metrics such as percent weight, or percent composition for other approaches (e.g., retrieved samples).

When two Biogenic Substrate types are present, "dominant" and "primarily" are equivalent to  $> 50\%$ . When three or more types exist, the dominant type may occur at a lower percent-of-total value. Biogenic Substrate types that are present, but do not constitute the dominant feature, may be included as a Co-occurring Element modifier (see Section 10).

### Substrate Class: Consolidated Biogenic Substrate

Non-living, consolidated material formed by living biota that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Biogenic Substrate surface. Examples include mounds, ridges, or pavements composed of calcium carbonate reef material generated by corals, cemented aggregations of shells and worm tubes, and very large woody particles.



**Substrate Subclass: Reef Substrate**

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is formed by living, reef-building biota such as scleratinian corals, molluscs, and worms.

**Substrate Group: Coral Reef**

Consolidated substrate that is formed and dominated by living or non-living hard coral reefs (bioherms). The material may be intact coral skeletons in relatively intact condition or may be formed from the agglomeration of coral rubble/hash or other particles into a fixed non-mobile surface.

**Substrate Group: Rhodolith Reef**

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by rhodoliths.

**Substrate Group: Shell Reef**

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by non-living cemented, conglomerated, or otherwise self-adhered shell reefs.

**Substrate Subgroup: Coquina Reef**

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by Shell Reef primarily composed of cemented or conglomerated Coquina shells.

**Substrate Subgroup: Crepidula Reef**

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by Shell Reef primarily composed of conglomerated Crepidula shells. While Crepidula are slowly mobile and do not cement their shells, the gregarious settlement of their larvae on conspecifics (Zhao and Qian 2002) can lead to very dense accumulations with a flat, reef-like texture as live shells build over dead shells.

**Substrate Subgroup: Mussel Reef**

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by Shell Reef primarily composed of self-

adhered or conglomerated mussel shells.

**Substrate Subgroup: Oyster Reef**

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by Shell Reef primarily composed of cemented or conglomerated oyster shells that form a stable substrate surface.

**Substrate Group: Worm Reef**

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by cemented or conglomerated calcareous or sandy tubes of polychaetes or other worm-like fauna.

**Substrate Subgroup: Sabellariid Reef**

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by Worm Reef primarily composed of cemented mineral-based or shell-based sabellariid worm tubes.

**Substrate Subgroup: Serpulid Reef**

Consolidated Biogenic Substrate area that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is dominated by Worm Reef that is primarily composed of cemented or conglomerated calcareous serpulid worm tubes.

**Substrate Subclass: Very Large Wood**

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, and is composed of non-living, very large wood fragments that cover 50% or greater of the Biogenic Substrate surface. These include rooted, partially buried, and sunken intact non-living woody plant structures, such as remnant trunks, branches, roots, and root networks.

**Substrate Group: Very Large Trunk or Root Substrate**

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of non-living trees, trunks, branches, roots, or root structures.

**Substrate Subgroup: Tree**

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated

Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of non-living trees.

Substrate Subgroup: Very Large Trunk or Branch

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of non-living, very large branches.

Substrate Subgroup: Very Large Wood Fragment

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of non-living, very large wood fragments.

Substrate Subgroup: Very Large Root or Root Network

Consolidated Biogenic Substrate that is greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of non-living, very large roots, root balls, or root networks.

#### **Substrate Subclass: Biogenic Pavement**

Consolidated Biogenic Substrate that is a relatively flat, continuous area of solid substrate greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of low-relief carbonate deposits formed by the cemented, remnant skeletons and tests of living biota.

#### **Substrate Group: Coralline Pavement**

Consolidated Biogenic Substrate that is a relatively flat, continuous area of solid substrate greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension, that covers 50% or greater of the Biogenic Substrate surface, and is composed of carbonate deposits formed by the cemented, remnant skeletons of corals.

#### **Substrate Class: Coarse Unconsolidated Biogenic Substrate**

Biogenic Unconsolidated Substrate that is dominated by Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface. Particles may be either loose whole or broken non-living biogenic fragments or, particularly in the larger Rubble sizes, particles may be cemented, conglomerated, or otherwise attached so as to form consolidated material. The Coarse Unconsolidated Biogenic Substrate subclass includes rubble of various origins, as well as woody debris.

#### **Substrate Subclass: Biogenic Rubble**

Unconsolidated Biogenic Substrate dominated by Biogenic Rubble particles (64

millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface. Particles may be either loose whole or broken non-living biogenic fragments or, particularly in the larger Rubble sizes, fragments may be cemented, conglomerated, or otherwise attached so as to form Boulders of consolidated material.

**Substrate Group: Algal Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living calcareous algae.

**Substrate Subgroup: Rhodolith Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living Rhodolith fragments.

**Substrate Group: Coral Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living coral fragments.

**Substrate Group: Shell Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living shells. Most (but not all) shell-builders are mollusks.

**Substrate Subgroup: Coquina Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of cemented or conglomerated Coquina shells. Note that Coquina shells are described in a separate substrate subgroup due to their distinctive features and special significance in many areas.

**Substrate Subgroup: Crepidula Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of conglomerated Crepidula shells. While Crepidula are slowly mobile and do not cement their shells, the gregarious settlement of their larvae on conspecifics (Zhao and Qian 2002) can lead to very dense accumulations as live shells build over dead shells, and sediments fill in to bind these areas into flat shelly masses.

**Substrate Subgroup: Mussel Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of self-adhered or conglomerated mussel shells.

**Substrate Subgroup: Oyster Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of cemented or conglomerated oyster shells.

**Substrate Group: Wood Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living woody material.

**Substrate Subgroup: Very Coarse Woody Debris**

Biogenic Rubble particles (256 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroup Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living, very coarse woody debris.

**Substrate Subgroup: Coarse Woody Debris**

Biogenic Rubble particles (64 millimeters to < 256 millimeters, equivalent to Geologic Origin subgroup Cobble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living, coarse woody debris.

**Substrate Group: Worm Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of the cemented or conglomerated calcareous or sandy tubes of polychaetes or other worm-like fauna.

**Substrate Subgroup: Sabellariid Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of sand and shell bits cemented with adhesive proteins into cohesive, clustered tubes by sabellariid worms (e.g., Sabellaria or Phragmatopoma).

**Substrate Subgroup: Serpulid Rubble**

Biogenic Rubble particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of cemented calcareous worm tubes produced by serpulid worms, e.g., Serpula.

**Substrate Class: Fine Unconsolidated Biogenic Substrate**

Biogenic Unconsolidated Substrate that is dominated by fine biogenic substrate particles (0.004 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble, and groups Sand and Mud) that cover 50% or greater of the Biogenic Substrate surface, including hash of various origins, as well as organic material and oozes.

**Substrate Subclass: Biogenic Hash**

Biogenic Unconsolidated Substrate dominated by Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface. Particles may be either loose whole or broken non-living biogenic fragments.

**Substrate Group: Algal Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living calcareous algae fragments.

**Substrate Subgroup: Rhodolith Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living Rhodolith fragments.

**Substrate Group: Coral Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living coral fragments.

**Substrate Subgroup: Acropora Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living Acropora fragments.

**Substrate Group: Shell Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living shells and shell bits. Most (but not all) shell-builders are mollusks.

**Substrate Subgroup: Coquina Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of cemented or conglomerated Coquina shells and shell bits.

**Substrate Subgroup: Crepidula Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic

Substrate surface and are primarily composed of loose *Crepidula* shells and shell bits.

**Substrate Subgroup: Mussel Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of loose mussel shells and shell bits.

**Substrate Subgroup: Oyster Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of loose oyster shells and shell bits.

**Substrate Group: Fine Woody Debris**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed non-living fine woody debris.

**Substrate Group: Worm Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of fragments of the cemented or conglomerated calcareous or sandy tubes of polychaetes or other worm-like fauna.

**Substrate Subgroup: Sabellariid Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of fragments of the sand-shell-protein matrix and tubes constructed by sabellariid worms.

**Substrate Subgroup: Serpulid Hash**

Biogenic Hash particles (2 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of fragments of the calcareous tubes of serpulid worms.

**Substrate Subclass: Biogenic Sand**

Biogenic Unconsolidated Substrate dominated by Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken down, non-living biogenic material. Shells or other remains are generally broken and difficult to identify. For this reason, only substrate-forming taxa that produce distinctive Sand types are listed as substrate subgroups.

*When the composition and origin of Sand is unclear, it is assumed to be mineral Sand,*

*and is classified as a Geologic Origin substrate.*

**Substrate Group: Algal Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down calcareous algae. This Sand may have a characteristic white color as it becomes bleached by the sun.

**Substrate Subgroup: Halimeda Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of recognizable, broken segment-like fronds of Halimeda, a green coralline alga.

**Substrate Subgroup: Rhodolith Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down Rhodolith material.

**Substrate Group: Coral Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down coral material.

**Substrate Subgroup: Diploria Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down Diploria coral.

**Substrate Group: Shell Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down shell material.

**Substrate Subgroup: Coquina Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down coquina shell.

**Substrate Subgroup: Mussel Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down mussel shell.

**Substrate Subgroup: Oyster Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down mussel shell.



**Substrate Group: Worm Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down mussel shell.

**Substrate Subgroup: Sabellariid Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down sand-shell-protein matrix and tubes constructed by sabellariid worms.

**Substrate Subgroup: Serpulid Sand**

Biogenic Sand particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin group Sand) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of broken-down calcareous tubes of serpulid worms.

**Substrate Subclass: Fine Organic Substrate**

Biogenic Unconsolidated Substrate dominated by Fine Organic Substrate particles (0.004 to < 0.625 millimeters, equivalent to Geologic Origin group Mud) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living organic material.

**Substrate Group: Peat**

Fine Organic Substrate particles that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of non-living peat deposits, from modern or prehistoric times.

**Substrate Group: Organic Detritus**

Fine Organic Substrate particles (0.004 to < 4 millimeters, equivalent to Geologic Origin group Mud) that cover 50% or greater of the Biogenic Substrate surface and are primarily composed of decomposing plant and animal tissues, often in an advanced state of utilization and decay. Organic Detritus may be produced in situ, deposited from above or transported horizontally, or may be remnant material.

**Substrate Group: Organic Mud**

Fine Organic Substrate particles (0.004 to < 0.625 millimeters, equivalent to Geologic Origin group Mud) that cover 50% or greater of the Biogenic Substrate surface with an organic carbon content of greater than 5%.

**Substrate Subclass: Ooze Substrate**

Deep sea substrates that are composed of > 30% tests, shells, or frustules of small plankton, including diatoms, radiolarians, pteropods, foraminifera, and other marine plankters. Oozes are common in deeper waters far from shore, where terrestrial inputs to the bottom sediments are very low, and where surface productivity is reasonably high.

*Based on common practice in the field, definition of a substrate as “ooze” requires a 30% or greater (but not necessarily “dominant”) ooze composition within the sediments. Once defined as an “ooze,” the type of ooze is determined by dominant percent composition.*

**Substrate Group: Carbonate Ooze**

Ooze Substrate that cover 50% or greater of the Biogenic Substrate surface and are dominated by calcium carbonate-based shells of foraminifera, coccolithophores, pteropods, or other calcareous plankton. These oozes are limited to seafloors shallower than the carbonate compensation depth (4-5 kilometers); calcium carbonate dissolves in the cold acidic waters deeper than this.

**Substrate Subgroup: Coccolithophore Ooze**

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is formed primarily from carbonate tests of phytoplanktonic coccolithophores.

**Substrate Subgroup: Foraminiferan Ooze**

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is formed primarily from carbonate tests of foraminiferans.

**Substrate Subgroup: Pteropod Ooze**

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is formed primarily from the shells of pteropods (a group of planktonic mollusks).

**Substrate Group: Siliceous Ooze**

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is dominated by silicate-based shells of diatoms, radiolarians, and other organisms. These oozes are limited to seafloors shallower than the carbonate compensation depth (4-5 kilometers); calcium carbonate dissolves in the cold acidic waters deeper than this.

**Substrate Subgroup: Diatomaceous Ooze**

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is formed primarily from the silica-based frustules or tests of phytoplanktonic diatoms.

**Substrate Subgroup: Radiolarian Ooze**

Ooze Substrate that covers 50% or greater of the Biogenic Substrate surface and is formed primarily from the silica-based tests of amoeba-like radiolarians.

**Substrate Origin: Anthropogenic Substrate**

Benthic substrates where sufficient evidence shows that Anthropogenic Substrate exceeds (is dominant over) that of both Geologic and Biogenic Substrates, when all are considered separately. Anthropogenic substrates are composed of material created by human physical, chemical, or other processes. Examples include metals, plastics, ceramics, cement, and construction aggregates. Wood, although it is biogenic in origin, is included here to describe

instances where it has been shaped, textured, treated, or otherwise altered from its natural condition and thus has different habitat suitability and/or function.

Anthropogenic substrates are classified at the class level by particle size and degree of stability in relation to the surrounding substrate, i.e., fixed (immobile and generally large structures or fragments) or unconsolidated (potentially mobile, of varying particle sizes); Subclass and group level units are further refined by particle size and composition. The Anthropogenic Origin does not include any subgroup units but users may provide further descriptive detail if desired. Particle size bins at the Anthropogenic Substrate class and subclass levels correspond to the Geologic Substrate units as follows:

- Class: Fixed Anthropogenic Substrate is equivalent to the Geologic Origin class Consolidated Mineral Substrate ( $\geq 4,096$  millimeters in any dimension)
- Class: Coarse Unconsolidated Anthropogenic Substrate is equivalent to the Geologic Origin group Very Coarse Gravel (64 millimeters to  $< 4,096$  millimeters in diameter)
- Class: Fine Unconsolidated Anthropogenic Substrate Hash is equivalent to the Geologic Origin groups Moderately Coarse Gravel (2 millimeters to  $< 64$  millimeters in diameter), Sand (0.0625 millimeters to  $< 2$  millimeters in diameter), and Mud ( $< 0.0625$  millimeters in diameter).

These units are derived from Wentworth (1922), and they can be broken down into Wentworth grain size classes for greater precision, if desired.

*Substrate Origin describes the genesis of the substrate, not the process by which it is emplaced. If the Substrate Origin cannot be definitively determined, the analyst may opt to use "Indeterminate" in place of origin type and use the Geologic Origin units for further classification.*

### Implementation Guidance for all Anthropogenic Origin Units

CMECS does not prescribe metrics or methodologies for substrate analysis or interpretation at this time. The terms "dominant" and "primarily" in the Anthropogenic Substrate Origin describe the substrate type that is present in the greatest visual percent cover for plan-view images or metrics such as percent weight, or percent composition for other approaches (e.g., retrieved samples).

When two Anthropogenic Substrate types are present, "dominant" and "primarily" are equivalent to  $> 50\%$ . When three or more types exist, the dominant type may occur at a lower percent-of-total value. Anthropogenic Substrate types that are present, but do not constitute the dominant feature, may be included as a Co-occurring Element modifier (see Section 10).

### Substrate Class: Fixed Anthropogenic Substrate

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Anthropogenic Substrate surface. Examples include man-made materials such as metal pipelines, concrete bulkheads, and treated-wood pilings that are either

fixed (adhered to, embedded in, or otherwise attached to) the environment.

**Substrate Subclass: Fixed Aggregate Substrate**

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Anthropogenic Substrate surface are consolidated or fixed in the surrounding environment and are dominated by aggregate, primarily construction, materials. This includes concrete, asphalt, brick, porcelain, or similar materials. Examples of features that form anthropogenic substrates include boat ramps, piers, and seawalls.

**Substrate Subclass: Fixed Metal Substrate**

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Anthropogenic Substrate surface are consolidated or fixed in the surrounding environment and are composed of metal. Examples include sheet metal, ship hulls/parts, metallic walls/bulkheads, pipes, valves, mooring chains, or other infrastructural objects.

**Substrate Subclass: Fixed Trash/Plastic Substrate**

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Anthropogenic Substrate surface are consolidated or fixed in the surrounding environment and composed of plastic, trash, or other disposed materials. Examples include PVC piping, valves, or other infrastructural objects.

**Substrate Subclass: Fixed Anthropogenic Wood Substrate**

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Anthropogenic Substrate surface are consolidated or fixed in the surrounding environment and are composed of wood that has been shaped, textured, treated, or otherwise altered, and forms a stable surface in the environment. Examples include pilings, posts, daymarks, docks or other infrastructural objects.

**Substrate Group: Pilings**

Anthropogenic Substrates that are greater than or equal to 4.0 meters (4,096 millimeters, equivalent to the Geologic Substrate class Consolidated Mineral Substrate) in any dimension and cover 50% or greater of the Anthropogenic Substrate surface, are consolidated or fixed in the surrounding environment and are composed of wood, such as pilings or other support structures.

**Substrate Class: Coarse Unconsolidated Anthropogenic Substrate**

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface. Particles may be

either loose whole or broken fragments of man-made material or in the case of wood, biogenic but significantly altered.

**Substrate Subclass: Coarse Unconsolidated Aggregate Substrate**

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of aggregate pieces, or fragments.

**Substrate Group: Aggregate Rubble**

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of rubble-sized aggregate particles/fragments.

**Substrate Subclass: Coarse Unconsolidated Metal Substrate**

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of metal pieces or fragments.

**Substrate Group: Metal Rubble**

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of metal particles.

**Substrate Subclass: Coarse Unconsolidated Trash/Plastic Substrate**

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of plastic or trash pieces or fragments.

**Substrate Group: Trash/Plastic Rubble**

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface trash or plastic pieces or fragments.

**Substrate Subclass: Coarse Unconsolidated Anthropogenic Wood Substrate**

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface and are composed of wood pieces or fragments. Examples include pallets, boards, framing, or other human constructed/processed wooden objects. Smaller pieces of anthropogenic wood may be interspersed with the dominant larger fragments.

**Substrate Group: Wood Rubble**

Unconsolidated Anthropogenic Substrate that is dominated by Coarse Anthropogenic particles (64 millimeters to < 4,096 millimeters, equivalent to Geologic Origin subgroups Cobble and Boulder) that cover 50% or greater of the Anthropogenic Substrate surface composed of wood pieces or fragments.

**Substrate Class: Fine Unconsolidated Anthropogenic Substrate**

Unconsolidated Anthropogenic Substrate that is dominated by fine Anthropogenic Substrate particles (0.004 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble, and groups Sand and Mud) that cover 50% or greater of the Anthropogenic Substrate surface.

**Substrate Subclass: Fine Unconsolidated Aggregate Substrate**

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (0.004 to < 64 millimeters, equivalent to Geologic Origin subgroups Granule and Pebble, and groups Sand and Mud) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of aggregate material.

**Substrate Group: Aggregate Hash**

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (2 millimeters to < 64 millimeters, equivalent to Geologic Origin subgroups Granule) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of aggregate particles or fragments.

**Substrate Group: Aggregate Fines**

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin subgroup Sand) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of aggregate particles or fragments.

**Substrate Subclass: Fine Unconsolidated Metal Substrate**

Anthropogenic unconsolidated substrate that is dominated by metal material with particle sizes ranging from 0.0625 millimeters to < 64 millimeters (size of sand to hash) and is composed of metal.

**Substrate Group: Metal Hash**

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (2 millimeters to < 64 millimeters, equivalent to Geologic Origin subgroup Granule) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of metal.

**Substrate Group: Metal Fines**

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin subgroup Sand) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of metal.

**Substrate Subclass: Fine Unconsolidated Trash/Plastic Substrate**

Anthropogenic unconsolidated substrate that is dominated by metal material with particle sizes ranging from 0.0625 millimeters to < 64 millimeters (size of sand to hash) and is composed of trash/plastic.

**Substrate Group: Trash/Plastic Hash**

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (2 millimeters to < 64 millimeters, equivalent to Geologic Origin subgroups Granule) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of trash/plastic.

**Substrate Group: Trash/Plastic Fines**

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin subgroup Sand) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of trash/plastic.

**Substrate Subclass: Fine Unconsolidated Anthropogenic Wood Substrate**

Anthropogenic unconsolidated substrate that is dominated by metal material with particle sizes ranging from 0.0625 millimeters to < 64 millimeters (size of sand to hash) and is composed of wood.

**Substrate Group: Wood Hash**

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (2 millimeters to < 64 millimeters, equivalent to Geologic Origin subgroups Granule) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of wood.

**Substrate Group: Wood Fines**

Unconsolidated Anthropogenic Substrate that is dominated by Fine Anthropogenic particles (0.0625 millimeters to < 2 millimeters, equivalent to Geologic Origin subgroup Sand) that cover 50% or greater of the Anthropogenic Substrate surface and that is composed of wood.

## Modifiers

Modifiers are physicochemical, spatial, geological, biological, anthropogenic, and temporal variables with defined categorical values and ranges that are used to describe CMECS units. Modifiers can be applied when additional information is needed to further characterize an identified unit for individual applications. Modifiers provide additional environmental, structural, or biological information about the ecosystem; modifiers are useful for description and application—but they are not required for classification according to the CMECS schema. Modifiers are a dynamic component of the CMECS in the sense that users are free to apply additional local modifiers for their project needs as long as these are reported and do not conflict with modifiers outlined in this section.



## **Anthropogenic Modifiers**

### **Anthropogenic Impact**

#### **Aquaculture**

Areas and structures where shellfish or finfish are being raised or confined for harvest. This may also include fish traps and ponds or enclosures.

#### **Contaminated**

Areas affected by past or present anthropogenic discharge of unnatural or excessive amounts of compounds (such as nutrients, sewage, metals, pesticides, or other materials) to waters or substrates, which results in concentrations significantly higher than those attributable to natural loading.

#### **Developed**

Coastal or marine areas that have been modified by durable and persistent human construction (e.g., artificial reef, pier, seawall, marina, residence, or drilling platform).

#### **Dredged**

Landscape that is mechanically altered by the removal of sediments or other materials (e.g., shell) in order to deepen or widen channels (e.g., for navigation or alteration to hydrology).

#### **Exotic**

Areas affected by human-mediated introduction of exotic species.

#### **Filled Deposition Site**

Areas where materials (such as sand or shell) have been placed on (or in) an area of coast or a water body.

#### **Impounded/Diverted**

Areas where artificial construction impedes, redirects, or retains hydrological flow by building or placing barriers (e.g., dams, levees, dikes, berms, seawalls, or piers); these structures are designed to either retain water or to prevent inundation.

#### **Restored**

Areas where restoration activities have been conducted; may include planted areas.

#### **Scarred**

Areas of scarring by natural or anthropogenic activities other than trawling or harvesting. Examples include ice scouring, vessel grounding, prop scarring, or other industrial activities.

#### **Trawled/Harvested**

Areas affected by past or present trawling or shellfish harvesting.

#### **Constructed**

Artificially built-up material that is either natural or man-made.

## **Biogeographic Modifiers**



### **Primary Water Source**

The Primary Water Source Modifier refers to the provenance of water flowing through or into a location. This can range from freshwater inputs (from watersheds and sloughs) to seawater exchanges through tidal passes.

#### **Estuary**

Plume flow that is from the estuary.

#### **Local Estuary Exchange**

Tidal exchange that is primarily estuarine water.

#### **Local Ocean Exchange**

Tidal exchange that is primarily marine water at the marine end member interface.

#### **Marine**

Unidirectional flow that is primarily marine water.

#### **River**

Tidal exchange or plume flow that is primarily river water.

#### **Watershed**

Flowing freshwater from the upstream watershed.

### **Biological Modifiers**

#### **Associated Taxa (Descriptive: Taxa Name)**

The Associated Taxa Modifier is used in the Biotic Component to denote the presence of biota that are not a classification unit in CMECS; e.g., portunid crabs, groupers, gadids, barracuda, herring, all nekton, and other rapidly moving fauna. Further discussions on the use of Associated Taxa (as well as examples) are given under Co-occurring Elements, Section 10.6.2.

#### **Community Successional Stage**

In the ecological literature, successional stage is a concept used to characterize identifiable points along a continuum of sequential—and somewhat predictable—replacements of taxa following a major disturbance which opens up a relatively large space. These stages are based in part on the differing organism life-history strategies of biota, and in part on their resulting modifications to the physical environment (Odum 1969; Ritter, Montagna, and Applebaum 2005). Rosenberg (1976) pointed out that the same basic pattern of succession is seen in soft-sediment environments in many different parts of the world, in response to various stressors (e.g., organic input, temperature stress, or low oxygen), noting that species composition (but not the basic pattern) differs among settings. Early work on infaunal marine succession recognized that this process is a complex and continually varying response to a history of disturbance, and that “there is a complete spectrum in nature” (Johnson 1972). Nonetheless, there is (along this spectrum) a predictable pattern to benthic community structure that follows levels of stress and disturbance, and this is a very useful construct in understanding the environment (Rosenberg 2001). CMECS provides four modifiers for Community Stage in soft-sediment areas; these have been described previously (Pearson and Rosenberg 1976, 1978; Rhoads and Germano 1982, 1986; Nilsson and Rosenberg 1997, 2000) and are shown in Figure

10.1.

**Stage 0**

These oligozoic soft-sediment areas show little evidence of multi-cellular life; however, benthic samples that are retrieved and processed under magnification from Stage 0 stations will generally produce low numbers of small macrofauna or meiofauna. Multicellular fauna will not be obvious to the unassisted eye when examining sediment, and it will not be obvious in high-resolution images of the seafloor. Bacterial mats may be present. If examining sediment profile images, guidelines from Rhoads and Germano (1982, 1986) can be followed or the Nilsson-Rosenberg BHQ metrics (Nilsson and Rosenberg 1997, 2000) can be used (BHQ values for Stage 0 will range from 0 to 1.99). No evidence of active bioturbation exists, and aRPD depths are typically < 2 millimeters.

**Stage 1**

These associations are inhabited by small opportunistic fauna (e.g., capitellids and spionids) in the upper centimeter of sediment. Larger fauna are not present, although juvenile individuals of larger species may occur. Names of small, opportunistic local species typical of Stage 1 are available in the regional literature. Surface expressions include small tubes (< 2 millimeters in diameter) of polychaetes or other fauna, or evidence of oligochaete burrowing activities. Subsurface evidence of either small worms or small burrow structures will primarily occur in the upper centimeter of sediment. If examining sediment profile images, guidelines from Rhoads and Germano (1982, 1986) can be followed or the Nilsson-Rosenberg BHQ metrics (Nilsson and Rosenberg 1997, 2000) can be used (Stage 1 BHQ values will range from 2 to < 5). Bioturbation depths will be shallow, with an aRPD depth typically > 2 millimeters to < 2 centimeters.

**Stage 2**

Communities are characterized by fauna of intermediate sizes typically inhabiting the upper 2-4 centimeters of sediment. This stage is considered transitional and is often variable; in a percentage of samples it will be difficult to clearly distinguish Stage 2 from other stages within the continuous spectrum presented by natural environments. Regional literature identifying species typical of Stage 2 may be referenced. Surface evidence of Stage 2 communities includes openings to small burrows (defined as excavations with a lumen width < 1 centimeter) and the presence of mid-sized tube dwelling fauna (e.g., robust *Ampelisca* tube mats; tubes > 2 millimeters in diameter; or tubes longer than 30 millimeters if very thin). Subsurface evidence includes burrows of polychaetes or other fauna in the upper 2-4 centimeters of sediment, small shallow-dwelling opportunistic bivalves, and small feeding voids in the upper 4 centimeters of sediment. If examining sediment profile images, guidelines from Rhoads and Germano (1982, 1986) can be followed or the Nilsson-Rosenberg BHQ metrics (Nilsson and Rosenberg 1997, 2000) can be used (BHQ for Stage 2 will range from 5 to 10).

**Stage 3**

These communities are identified by larger, long-lived, deep burrowing fauna or by evidence of the activities of those fauna; burrowing activities typically extend deeper than 5 centimeters. Characteristic species vary among localities and among

environments; species can be identified through regionally appropriate literature. Common surface expression may include very large tube-building fauna (> 3 millimeters in diameter or > 30 mm in length), larger fecal mounds, burrowing urchins or ophiuroids, pits or tunnel openings (e.g., crustacean excavations with a lumen width of > 1 centimeter), or large digging spoils associated with pits or tunnels. Subsurface characteristics include oxygenated or active faunal feeding voids at 5 centimeters or deeper, active tunnels (subsurface excavations with a lumen width of > 1 centimeter) at depth, or presence of large polychaetes or other fauna. Frequently, evidence of smaller, opportunistic fauna will also be present in Stage 3 communities; these fauna are not necessarily eliminated by larger fauna. If evaluating sediment profile images, guidelines from Rhoads and Germano (1982, 1986) can be followed, or the Nilsson-Rosenberg Benthic Habitat Quality (BHQ) metric (Nilsson and Rosenberg 1997, 2000) can be used (Stage 3 will have BHQ > 10). Extensive bioturbation will be evidenced by deep RPD and aRPD depths.

### **Invertebrate Community Organism Size**

The Invertebrate Community Organism Size modifier is intended for use in the Biotic Component, Faunal Bed Class. Ecological theory of community succession and disturbance posits that less frequently disturbed environments will provide the stability to support longer-lived communities of larger organisms, while frequently disturbed environments will be characterized by smaller and shorter-lived organisms. Faunal Bed communities are often complex, with a wide range of individual organisms and species occurring in many sizes to fill a variety of ecological niches. CMECS provides a coarse set of Organism Size Modifiers to describe Faunal Bed communities through sizes of the larger organisms that are evident in an observational unit. Many different methods have historically been proposed to distinguish macrofauna from megafauna—ranging from “visible to the unassisted eye,” to retention on various screen sizes, to inclusion only of much larger organisms. The CMECS criterion used to identify megafauna is a body size > 1 cm (in the smallest dimension). Importantly, this modifier describes the defining, significant, or dominant organisms that best characterize a community, recognizing that most communities include a variety of organisms that occur in both large and small individual sizes.

#### **Large Megafauna**

Benthic invertebrate communities that are dominated by organisms that typically reach a body size of > 3 to 10 centimeters in the smallest dimension (e.g., height, width), with this measurement not to include the length of slender, lateral protrusions (such as arms or tentacles).

#### **Megafauna**

Benthic invertebrate communities that are dominated by organisms that typically reach a body size of > 1 to 3 centimeters in the smallest dimension (e.g., height, width), with this measurement not to include the length of slender, lateral protrusions (such as arms or tentacles). These communities may be identified by evidence of these fauna (e.g., large mounds or pit or tunnel openings of > 1 to 3 centimeters).

#### **Large Macrofauna**

Benthic invertebrate communities that are dominated by organisms with a body width (smallest dimension) of > 2 millimeters to 1 centimeter; living organisms larger than this size range are rare in these infaunal or epifaunal associations.

**Small Macrofauna**

Benthic invertebrate communities that are dominated by organisms with a body width (smallest dimension) of > 0.5 to 2 millimeters; living organisms larger than this size range are rare in these infaunal or epifaunal associations.

**Meiofauna**

Benthic invertebrate communities that are dominated by organisms with a body width (smallest dimension) of 0.5 mm or less, that would typically pass through an 0.5 mm sieve but be retained on an 0.25 mm sieve. Living organisms larger than this size range are rare in the infaunal or epifaunal association; the modifier may be applied to any classification unit within Faunal Bed.

**Phytoplankton Productivity**

Productivity is a general categorization of the level of primary productivity—that is, the photosynthetic activity of autotrophs, including plankton, benthic microalgae, macroalgae, and vascular vegetation. The density of phytoplankton can be estimated by measuring the level of chlorophyll a in the water column, since all phytoplankton contain this fluorescent pigment enabling the harvesting of light. This measure also indirectly reflects the abundance of dissolved labile macronutrients (DIN and DIP), which phytoplankton use in photosynthetic processes. In broad terms, chlorophyll a content reflects net productivity, giving an indication of the trophic status of the system or the balance of primary production; secondary consumption by zooplankton, fish, and predators; and export from the system. Productivity is indicated by chlorophyll a concentration in water columns and by total biomass in macroalgal and rooted vascular plant communities. For water column phytoplankton communities, the modifier categories were derived, with modification, from the NOAA Estuarine Eutrophication Survey (NOAA 1997).

**Oligotrophic (Phytoplankton Productivity)**

Less than 5 µg/L chlorophyll a

**Mesotrophic (Phytoplankton Productivity)**

5 to less than 50 µg/L chlorophyll a

**Eutrophic (Phytoplankton Productivity)**

Greater than or equal to 50 µg/L chlorophyll a

**Macrovegetation Productivity**

Productivity is a general categorization of the level of primary productivity—that is, the photosynthetic activity of autotrophs, including plankton, benthic microalgae, macroalgae, and vascular vegetation. The density of phytoplankton can be estimated by measuring the level of chlorophyll a in the water column, since all phytoplankton contain this fluorescent pigment enabling the harvesting of light. This measure also indirectly reflects the abundance of dissolved labile macronutrients (DIN and DIP), which phytoplankton use in photosynthetic processes. In broad terms, chlorophyll a content reflects net productivity, giving an indication of the trophic

status of the system or the balance of primary production; secondary consumption by zooplankton, fish, and predators; and export from the system. Productivity is indicated by chlorophyll a concentration in water columns and by total biomass in macroalgal and rooted vascular plant communities. For water column phytoplankton communities, the modifier categories were derived, with modification, from the NOAA Estuarine Eutrophication Survey (NOAA 1997).

**Oligotrophic (Macrovegetation Productivity)**

Less than 50 mg dry wt/m<sup>2</sup> biomass

**Mesotrophic (Macrovegetation Productivity)**

50 to less than 1,000 mg dry wt/m<sup>2</sup> biomass

**Eutrophic (Macrovegetation Productivity)**

Greater than or equal to 1,000 mg dry wt/m<sup>2</sup> biomass

## **Temporal Modifiers**

### **Temporal Persistence**

The Temporal Persistence Modifier describes the permanency or variability of a hydromorphic, geomorphic, or biological feature.

**Hours**

**Days**

**Weeks**

**Months**

**Years**

**Decades**

**Centuries**

## **Physical Modifiers**

### **Energy Direction**

Energy can be classified according to its principal direction of travel or influence. In the case of tidal energy, this is generally an oscillation between onshore and offshore motions. In the case of currents and waves, the energy is usually directional.

**Baroclinic Energy Direction**

Motion along lines of equal pressure within the water column.

**Circular Energy Direction**

Motion in a closed, circular form.

**Downward Energy Direction**

Descending and perpendicular to the sea surface or bottom.

**Horizontal Energy Direction**

Parallel to the sea surface or bottom.

**Mixed Energy Direction**

Combination of more than one of above directions.

**Seaward Energy Direction**

On land, water currents following a topographic gradient toward the sea.

**Upward Energy Direction**

Ascending and perpendicular to the sea surface or bottom.

**Energy Intensity**

Energy Intensity is classified into four categories as shown on Table 10.8.

**Very Low Energy**

Area experiences little current motion under most conditions.

**Low Energy**

Area typically experiences very weak currents (0-1 knots).

**Moderate Energy**

Area regularly experiences moderate tidal currents (> 1-3 knots).

**High Energy**

Area regularly experiences strong currents (> 3 knots).

**Energy Type**

The Energy Type Modifier is adapted from Dethier (1990) and Zacharias et al. (1998) with type categories as described in Table 10.9.

**Current (Energy Type)**

Coherent directional motion of the water.

**Internal Wave (Energy Type)**

Vertical and transverse oscillating water motion- below the surface- due to seismic energy or a pressure differential.

**Surface Wave (Energy Type)**

Vertical and transverse oscillating surface water motion due to wind or seismic energy.

**Tide (Energy Type)**

Periodic, horizontally oscillating water motion.

**Wind (Energy Type)**

Coherent directional motion of the atmosphere.

**Induration**

The stability of the substrate is a strong determinant of the suitability of an area for colonization by sessile organisms, and for feeding or burrowing activities by benthic epifauna and infauna. The Induration Modifier can be used to describe the hardness or amount of consolidation of bottom sediments (Substrate Component units). Induration is often measured with acoustic tools. The following categories are adopted from Greene et al. (2007).

**Hard Induration**

Strongly consolidated fine sediment with low water content, or rock outcrop, or bedrock.

**Mixed Induration**

A blend of hard and soft substrate materials.

**Soft Induration**

Loose, fine, unconsolidated, or sediment-covered substrate with a high water content.

**Mineral Precipitate**

A substrate or deposit formed by the oxidation and precipitation of minerals from a body of water. Mineral precipitate substrates may form nodules, crusts and geoforms.

**Crust**

A layer of consolidated substrate overlying other consolidated or unconsolidated material. Crusts may be composed of chemical precipitates (e.g. ferromanganese, salt), calcareous or crustose algae, or may form via sediment diagenesis, resulting in surficial lithification.

**Nodules**

Round or spherical concretions that form by accreting in concentric layers around a fragment of some other mineral or biological material, called a nucleus.

**Patina**

A thin or patchy layer of consolidated substrate overlying other consolidated or unconsolidated material. Patina may be composed of chemical precipitates (e.g. ferromanganese, salt), calcareous or crustose algae, or may form via sediment diagenesis, resulting in surficial lithification.

**Seafloor Rugosity**

Seafloor Rugosity, a measure of surface "roughness", is applicable at several scales using different measures (e.g., bathymetric x-y-z data, measured transect data, video data). Rugosity is derived as the ratio of surface area to planar (flat) area for a grid cell, or as the ratio of surface area to linear area along transects, and is calculated as follows:  $fr = Ar / Ag$  where  $Ar$  is the real (true, actual) surface area and  $Ag$  is the geometric surface area (IUPAC 1997). Values for Seafloor Rugosity are taken from Greene et al. 2007. The five rugosity types and their associated numeric values are given in Table 10.11.

**Very Low (Rugosity)**

1.0 to less than 1.25

**Low (Rugosity)**

1.25 to less than 1.50

**Moderate (Rugosity)**

1.50 to less than 1.75

**High (Rugosity)**

1.75 to less than 2.00

**Very High (Rugosity)**

Greater than or equal to 2.00

**Small Scale Slope**

The Slope Modifier refers to the angle of the substrate at a scale appropriate for the feature being described; Greene et al.'s (2007) geological classification is followed here to characterize slope.

**Flat (Small Scale Slope)**

0 to less than 5 degrees

**Sloping (Small Scale Slope)**

5 to less than 30 degrees

**Steeply Sloping (Small Scale Slope)**

30 to less than 60 degrees

**Vertical (Small Scale Slope)**

60 to less than 90 degrees

**Overhang (Small Scale Slope)**

Greater than or equal 90 degrees

**Substrate Descriptor**

The Substrate Component describes substrate size and composition, considering substrate origin as Geologic, Biogenic, and Anthropogenic. The Geologic classifications follow Wentworth (1922) and Folk (1954) to describe particle sizes and mixes, but do not consider geologic composition or several other important attributes. Substrate descriptors provide consistent terminology to meet these needs. Certain substrate descriptors may be used for other applications as well, e.g., Well-Mixed, Patchy, and Well-Sorted can be used to describe biotic communities or other units.

**Carbonate (Substrate)**

Geologic Origin particles or substrates composed mainly of carbonate minerals, e.g., limestone, dolostone.

**Compacted (Substrate)**

Unconsolidated sediments with very little water content and a hard, packed form that resists penetration and resuspension. This is one of several terms that are used in CMECS to describe the fluid consistency of substrates.

**Floc (Substrate)**

A layer of very fine particles suspended in the water column just above firmer sediment. This is often most apparent with visual or imaging techniques, and may appear as a turbid or cloudy layer above a more defined sediment surface. This is one of several terms that are used in CMECS to describe the fluid consistency of substrates.

**Fluid (Substrate)**

Substrate with high water content. When a palmful of sediment is squeezed in the hand, most or all flows through the fingers after full pressure (Schoeneberger et al. 2002). This



is one of several terms that are used to describe the fluid consistency of substrates in CMECS.

**Gas (Substrate)**

Subsurface bubbles of gas, possibly resulting from methanogenesis or other biogeochemical processes, are present. Escaping gas may or may not express at the sediment surface.

**Mobile (Substrate)**

Bedded sediments which regularly resuspend and/or move with local hydrodynamics due to the density, grain size, shape, and/or high water content of the sediment, or due to the higher hydrodynamic energy experienced in the local area. This term is used in CMECS to describe or predict behavior of substrates.

**Non-Mobile (Substrate)**

Bedded sediments which do not regularly resuspend and/or move with local hydrodynamics due to the density, grain size, shape, and/or compaction (low water content) of the sediment particles, or due to the lower hydrodynamic energy experienced in the local area. This term is used in CMECS to describe or predict behavior of substrates.

**Mud Clasts (Substrate)**

Compacted or consolidated fragments (clumps, lumps, balls, shards, etc.) of mud or clay, typically occurring at the sediment surface, with diameters of millimeters to < 1 meter.

**Patchy (Substrate)**

Different elements within a sample, observational unit, or reporting unit are grouped into clusters or patches at the scale of the sample or unit. "Patchy" implies that clusters of elements or particles are arranged in a haphazard manner, as clusters of pebbles scattered on sand. This is one of several terms used in CMECS to describe unit variability.

**Pelagic Clay (Substrate)**

Deep sea Geologic Substrates composed primarily of aeolian deposits, volcanic ash, and other non-biogenic materials that sink into the very deep oceans, or may be generated in the deep oceans. Pelagic Clays contain less than 30% ooze materials (tests, shells, and frustules of plankters) and are found in areas of low surface productivity.

**Red Clay (Substrate)**

A type of Pelagic Clay composed primarily of aeolian dust, with various marine-generated particles mixed in (fish bones, teeth, authigenic mineral deposits). Red clays are distinguished by their characteristic bright red or brown color and are found in the deepest and most remote ocean areas. Red Clay contains less than 30% ooze materials.

**Siliciclastic (Substrate)**

Geologic Substrate Origin particles or substrates composed primarily of silicate minerals e.g., quartz, sandstone, siltstone.

**Sulfidic (Substrate)**

Substrate in which bacterial sulfate reduction is an important biogeochemical process; this generally occurs in anaerobic environments and is often identifiable by a very low reflectance black or blue color, and a characteristic "rotten egg" odor when sediments are examined in air.

**Volcaniclastic (Substrate)**

Geologic Origin particles or substrates composed primarily of volcanic rock, crystals, glassy pumice, ash, or other volcanic products.

**Volcanic Ash (Substrate)**

A substrate or substrate layer composed primarily of volcanic dust and volcanic ash, often with various aeolian or marine-generated particles mixed in. In areas of the deep sea, where terrigenous input and bioturbation are limited, Volcanic Ash may be present in distinct layers at depth in the substrate matrix (see the "Layers" modifier).

**Well-Mixed (Substrate)**

Different elements within a sample, observational unit, or reporting unit are well-mixed or poorly-sorted at the scale of the sample or unit. Well-mixed implies that elements or particles are completely and relatively evenly intermingled, e.g., Granule/Sand/Mud particles in an area with high bioturbation. This is one of several terms used in CMECS to describe unit variability. Note that CMECS does not use the equivalent geological term "Poorly-Sorted", because the descriptor may be used to describe distributions of non-geological features (such as biological communities or Geoform Component structures).

**Well-Sorted (Substrate)**

Different elements within a sample, observational unit, or reporting unit are separated into different areas at the scale of the sample or unit. Well-sorted implies that elements or particles are (or have been) separated and arranged in a non-haphazard manner, as an area of Coarse Sand adjacent to an area of Clay. This is one of several terms used in CMECS to describe unit variability.

**Porous**

Containing voids, pores, or interstices, which may or may not connect.

**Surface Pattern**

The surface of the seafloor may be flat (on a scale of centimeters or meters), or it may be characterized by roughness or pattern. The Substrate Component describes substrate size and composition, while the Geoform Component describes texture or shape—including the Surface Pattern Modifier. These roughness patterns may have physical origins (e.g., caused by wave or current action) or biological origins (due to activities of life forms, e.g., mounds or tunnels). Physically influenced bedforms may appear as regularly spaced "sand ripples" (with a wavelength on the order of centimeters), which may be indicative of wave oscillations or of current flows. Physical energy in soft-sediment areas may occur through riverine flow or tidally driven flow, leading to erosion and deposition of mobile sediment layers.

**Biological (Surface Pattern)**

Roughness appears due to bioturbation, fecal mounds, tunneling, feeding or locomotory activities of megafauna, or other faunal activities. Further characterization of biological

features is described in the Biotic Component.

**Irregular (Surface Pattern)**

Sediment surface has a perceptible roughness or texture that is non-regular in either frequency, direction, or amplitude.

**Physical (Surface Pattern)**

Roughness appears due to water motion, but the nature of the roughness is other than Rippled.

**Rippled (Surface Pattern)**

Closely spaced, regular, repeating, vertical variations in the height of a sandy or muddy bottom, with a very short wavelength on the order of centimeters. A rippled substrate is generally caused by the physical processes of water motion.

**Scarred (Surface Pattern)**

Roughness appears due to localized sediment disturbance resulting either from natural causes (e.g., slumps) or anthropogenic causes (e.g., anchor scars, propeller scars, trawl scars, or other fishing gear scars), but not as an artifact of camera or sampling gear deployment.

**Smooth (Surface Pattern)**

No perceptible roughness or texture to sediment surface at scales of less than 1 meter.

**Tidal Regime (Amplitude)**

The Tidal Regime Modifier refers to the height difference between mean high tide and mean low tide at the coast. The mean range gives a proxy for the energy and flow associated with tidal motions. Tidal Regime is shown in Table 10.15.

**Atidal**

Less than 0.1 meter

**Microtidal**

0.1 to less than 0.3 meter

**Minimally Tidal**

0.3 to less than 1 meter

**Moderately Tidal**

1 to less than 4 meters

**Macrotidal**

4 to less than 8 meters

**Megatidal**

Greater than or equal to 8 meters

**Wave Regime (Amplitude)**

This modifier is intended to quantify intensity of wave energy by amplitude, and can be applied on any time scale, as specified by the user.

**Quiescent**

Less than 0.1 meter

**Very Low Wave Energy**

0.1 to less than 0.25 meter

**Low Wave Energy**

0.25 to less than 1.0 meter

**Moderate Wave Energy**

1.0 to less than 2.0 meters

**Moderately High Wave Energy**

2.0 to less than 4.0 meters

**High Wave Energy**

4.0 to less than 8.0 meters

**Very High Wave Energy**

Greater than or equal to 8.0 meters

## **Physicochemical Modifiers**

### **Oxygen Regime**

Oxygen concentration is an important water column modifier. Oxygen is critical to aerobic organisms and to aerobic processes (such as chemical oxidation and microbial respiration). Dissolved oxygen levels change daily in a dramatic way in systems such as estuaries, where they often go from hypoxic (at night) to saturated (during the day). The Oxygen Regime Modifier is intended for use in reporting persistent oxygen conditions, or can be used to explain variable regimes as described by the user. Oxygen levels are determined according to the following ranges, for the time scales and durations specified by the user; practitioners may specify, e.g., “oxygen varies from highly oxic during daylight hours to severely hypoxic at night”. Furthermore, practitioners should note that oxygen saturation varies with temperature and pressure.

**Anoxic**

0 to less than 0.1 mg/L

**Severely Hypoxic**

0.1 to less than 2 mg/L

**Hypoxic**

2 to less than 4 mg/L

**Oxic**

4 to less than 8 mg/L

**Highly Oxic**

8 to less than 12 mg/L

**Very Oxic**

Greater than or equal to 12 mg/L

## **Photic Quality**

Photic quality is a highly variable parameter. In many cases, water is clear and downwelling light penetration extends the photic zone to the bottom of the water column. In cases of reduced water clarity, light is highly attenuated. Photic exposure depends on the depth, sun angle, cloud cover, time of year, and other factors. Moreover, the depth of the shift from photic to aphotic occurs at different points in the water column, depending on the ecosystem, watershed, and suspended substances reducing water clarity.

Vertical zones are evaluated relative to the penetration of light (photic and aphotic) for both water column and benthic components. The depth of the photic zone can also be calculated from ocean color imagery using satellite algorithms (Lee et al. 2007).

### **Aphotic**

Region of the water column where no ambient light penetrates, no photosynthesis occurs, and animals cannot make use of visual cues based on even reduced levels of ambient light. In oceans, this zone typically lies below 500-1,000 meters of depth. In turbid estuaries, this zone may be very shallow.

### **Dysphotic**

Region of the water column, below the compensation depth, that receives less than 2% of the surface light; plants and algae cannot achieve positive photosynthetic production in this region, but some ambient light does penetrate such that animals can make use of visual cues based on reduced levels of ambient light.

### **Photic**

Region of the water column where ambient light is > 2% of surface light and phototrophic organisms can photosynthesize.

### **Seasonally Photic**

An area that regularly varies between photic and dysphotic/aphotic.

## **Physicochemical Modifiers**

### **aRPD and RPD Depth**

The apparent Redox Potential Discontinuity (aRPD) is a measurement of the depth of the “color break,” that is, the maximum color difference below the sediment-water interface at which lighter-colored (tan, brown, beige, yellow, or red), more-oxidized surface sediments transition into darker-colored (grey, black, or blue-black), more-reduced deeper sediments. The depth of the aRPD is easily measured, and it has been found to be an extremely useful parameter in characterizing certain biogeochemical aspects of the sedimentary environment. For instance, the aRPD represents the depth at which iron exists as colored, insoluble, ferric hydroxides, which dissolve into solution as iron monosulfides in a reducing environment, e.g., in the presence of sulfate reduction (Teal et al. 2009).

The aRPD is strongly correlated to the true RPD depth (Grizzle and Penniman 1991; Rosenberg et al. 2001), which is the depth where Eh (measured sediment reduction/oxidation potential) is zero. Both values are very useful as proxies for

bioturbation (because the values are extended deeper by the effects of bioturbating fauna), and both are correlated to bottom-water dissolved-oxygen concentration (Rosenberg 1977; Diaz, Cutter, and Rhoads 1994; Cicchetti et al. 2006). The aRPD can be measured with a variety of techniques including retrieval of cores, sediment profile imaging, and direct observation. The RPD can be measured using microelectrodes, either in retrieved cores or *in situ*.

RPD (centimeters) – The RPD is measured with electrodes, and is reported in centimeters.

aRPD depth (centimeters), muddy sediments – The aRPD depth is measured at the color transition based on direct observation or from images, and it can be reported in centimeters or following the terms defined below (from Nilsson and Rosenberg 1997). These modifier terms apply only to sediments that contain some mud; aRPD depths manifest differently in sand sediments that are dominated by different diffusional processes and rates.

**Zero (aRPD and RPD Depth)**

0.0 cm depth

**Diffusional (aRPD and RPD Depth)**

Greater than 0.0 to 1.0 cm depth

**Shallow Infralittoral (aRPD and RPD Depth)**

Greater than 1.0 to 2.0 cm depth

**Moderate (aRPD and RPD Depth)**

Greater than 2.0 to 3.5 cm depth

**Deep (aRPD and RPD Depth)**

Greater than 3.5 to 5.0 cm depth

**Very Deep (aRPD and RPD Depth)**

Greater than 5 cm depth

**Salinity Regime (Modifier)**

Salinity is considered a classifier for the Water Column Component, i.e., it is an essential parameter for measurement in order to effectively classify the water column. However, users may wish to apply the CMECS terminology for salinity within other components when the water column itself is not being classified. The salinity ranges are repeated here in the modifier section to allow this convenience for users.

**Oligohaline**

Less than 5

**Mesohaline**

5 to less than 18

**Lower Polyhaline**

18 to less than 25

**Upper Polyhaline**

25 to less than 30

**Euhaline**

30 to less than 40

**Hyperhaline**

Greater than or equal to 40

**Temperature Range**

As with salinity, temperature is considered a classifier for the Water Column Component, i.e., it is an essential parameter for measurement in order to effectively classify the water column. Likewise, users may wish to apply the CMECS terminology for temperature within other components when the water column itself is not being classified. The temperature ranges are repeated here in the modifier section to allow this convenience for users.

**Frozen/Superchilled (Temperature Range)**

Less than or equal to 0 °C

**Very Cold (Temperature Range)**

0 to less than 5 °C (liquid)

**Cold (Temperature Range)**

5 to less than 10 °C

**Cool (Temperature Range)**

10 to less than 15 °C

**Moderate (Temperature Range)**

15 to less than 20 °C

**Warm (Temperature Range)**

20 to less than 25 °C

**Very Warm (Temperature Range)**

25 to less than 30 °C

**Hot (Temperature Range)**

30 to less than 35 °C

**Very Hot (Temperature Range)**

Greater than or equal to 35 °C

**Turbidity**

Turbidity is a factor of the suspended solids and color within the water column, and it affects light attenuation and the depth to which light penetrates in the water column. This is critically important for autotrophs that convert light to photosynthetic products. Turbidity also has important effects on visual hunting and predation avoidance. While turbidity is frequently reported in Nephelometric Turbidity Units (NTUs), CMECS establishes categories for turbidity based on Secchi disk depth; it would be difficult to standardize turbidity by NTUs due to regional variations in background measurements. Secchi disk observations are commonly used

in the marine environment.

**Extremely Turbid**

Less than 1 m Secchi depth

**Highly Turbid**

1 to less than 2 m Secchi depth

**Moderately Turbid**

2 to less than 5 m Secchi depth

**Clear**

5 to less than 20 m Secchi depth

**Extremely Clear**

Greater than or equal to 20 m Secchi depth

**Turbidity Type**

The provenance of the attenuating substance, whether the reduced water clarity is derived from chlorophyll pigments (e.g., phytoplankton blooms), from color due to dissolved substances in the water (e.g., gelbstoff or tannins), from imported mineral terrigenous sediments, or from carbonate particulates in resuspension, is an important qualitative characteristic of turbidity. This qualitative assessment can be used in addition to a qualitative or quantitative evaluation of the degree of turbidity in the water column.

**Carbonate Particulates**

Attenuation produced by suspended precipitated  $\text{CaCO}_3$  in the water column, generally creating an opaque "milky" appearance.

**Chlorophyll**

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

**Colloidal Precipitates**

Dispersed particulates that precipitate out of the water to form aggregations such as marine snow.

**Mineral Precipitates**

Attenuation produced by suspended inorganic sediments derived from soil and rock weathering.

**Detritus**

Attenuation due to larger particles of organic detritus in suspension.

**Dissolved Color**

Substances dissolved in water that have color.

**Mixed Turbidity Type**

Attenuation due to a variety of the above sources and substances.

**Turbidity Provenance**

The provenance of the attenuating substance—whether the reduced water clarity is derived



from chlorophyll pigments (e.g., phytoplankton blooms), from color due to dissolved substances in the water (e.g., gelbstoff or tannins), from imported mineral terrigenous sediments, or from carbonate particulates in resuspension—is an important qualitative characteristic of turbidity. This qualitative assessment can be used in addition to a qualitative or quantitative evaluation of the degree of turbidity in the water column.

**Allochthonous**

Originating outside of the system and transported into the system.

**Autochthonous**

Generated *in situ* by biogenic processes (e.g., phytoplankton bloom).

**Marine Origin**

Materials, water, or energy originating in the ocean.

**Precipitated**

Solutes such as calcium carbonate that precipitate out of solution.

**Resuspended**

Deposited materials mixed into the water column by currents (e.g., bottom sediments).

**Terrigenous Origin**

Materials, water, or energy in a water body resulting from land drainage or wind deposits.

**Water Column Stability Regime**

Water column stability can be characterized as stratified, partially mixed, and well-mixed. This structure is defined by density differentials from bottom to surface, as shown in the table below. Water Column Stability is assessed using the more universally applied delta Sigma-t to calculate stability, which incorporates salinity, temperature into the calculation of density and adjusts for adiabatic effects (Pond and Pickard 1983). The Stability Regime modifier compares the calculated delta Sigma-t, or the relative density of two water parcels by subtraction of the density of the surface layer from the density of the deeper layer. If the density difference equals or exceeds 0.125, the water column is considered to be vertically stable; if it differs by less than 0.125, and density is homogeneous between the upper and lower layers, the water column is classified as well-mixed. If the density difference is less than 0.125 and variable between the two layers, the water column is classified as partially mixed.

**Partially Stratified**

Less than 0.125 delta Sigma-t and variable

**Stratified**

Greater than or equal to 0.125 delta Sigma-t

**Well-Mixed**

Less than 0.125 delta Sigma-t and homogeneous

**Spatial Modifiers**

**Benthic Depth Zone**

The depths of benthic zones vary depending on regional geology and turbidity. It is often useful to describe a specific depth or range of depths for the bottom, and the CMECS Benthic Depth Zone Modifiers represent the major divisions in a gradient from land to the deep ocean bottom. They are generally based on the zones in which surf or ocean swell influences bottom communities, lower limits of vegetation (such as kelp), overall photic availability, and temperature. The zones within this category are drawn or adapted from Greene et al. (2007) and Connor (1997).

**Littoral**

Intertidal

**Shallow Infralittoral**

0 to less than 5 meters

**Deep Infralittoral**

5 to less than 30 meters

**Circalittoral**

30 to less than 200 meters

**Mesobenthic**

200 to less than 1,000 meters

**Bathybenthic**

1,000 to less than 4,000 meters

**Abyssalbenthic**

4,000 to less than 6,000 meters

**Hadalbenthic**

Greater than or equal to 6,000 meters

**Co-occurring Elements (Descriptive)**

Nature is inherently a mixture or a continuum. CMECS provides an ecologically meaningful methodology to classify nature into discrete environmental types using consistent threshold values that define primary classification units. However, in natural coastal and marine settings, less abundant, co-occurring (or secondary) features are frequently mixed into these primary classification types at some level beneath a classification threshold. Therefore, these co-occurring features are not recognized in the syntax of the primary classification. In some situations, project goals may require identification of these co-occurring features and associated taxa. In other situations, identification of co-occurring materials, taxa, or mixes may detract from project goals.

CMECS provides a modifier, Co-occurring Elements, for identification of secondary CMECS classification units that are mixed into a primary classification unit at a level below the classification threshold. Co-occurring Elements are used in the hierarchical Biotic and Substrate Components when the primary feature and the co-occurring feature are both units in that same Component. More information and examples of Co-occurring Elements can be found on page 213.

## **Coral Reef Zone**

All coral reef environments contain distinct horizontal and vertical zones created by differences in depth, morphology, wave and current energy, temperature, and light. The following zones are commonly present on shallow and mesophotic reefs (Zitello et al. 2009).

### **Back Reef (Coral Reef Zone)**

Area between the seaward edge of a lagoon floor and the landward edge of a reef crest. This zone is present only when a reef crest exists.

### **Bank/Shelf (Coral Reef Zone)**

Deeper water area (usually > 30 meters) extending offshore from the seaward edge of the fore reef (or shoreline) to the beginning of the bank/shelf escarpment where the insular shelf drops off into deep, oceanic water.

### **Bank/Shelf Escarpment (Coral Reef Zone)**

The edge of the bank/shelf where depth increases rapidly into deep oceanic water. This zone begins at approximately 20-30 meters depth, near the depth limit of features visible in aerial images. This zone extends well into depths exceeding those that can be seen on aerial photos, and this zone is intended to capture the transition from the bank/shelf to deep waters of the open ocean.

### **Fore Reef (Coral Reef Zone)**

Area from the seaward edge of the reef crests (which slopes into deeper water) to the landward edge of the bank/shelf platform. Features not forming an emergent reef crest- but still having a seaward-facing slope that is significantly greater than the slope of the bank/shelf- are also designated as forereef.

### **Lagoon (Coral Reef Zone)**

Shallow area (relative to the deeper water of the bank/shelf) between the shoreline intertidal zone and a back reef or barrier island. This zone is protected from the high-energy waves commonly experienced on the bank/shelf and reef crest. If no reef crest is present, there is no lagoon zone.

### **Reef Crest (Coral Reef Zone)**

The flattened, emergent (especially during low tides) or nearly emergent segment of a reef. This zone lies between the back reef and fore reef zones. In aerial images, breaking waves will often be visible at the seaward edge of this zone.

### **Reef Flat (Coral Reef Zone)**

Shallow (semi-exposed) area between the shoreline intertidal zone and the reef crest of a fringing reef. This zone is protected from the high-energy waves commonly experienced on the shelf and reef crest. Reef flat is typically not present if there is a lagoon zone.

### **Ridges and Swales (Coral Reef Zone)**

An area of numerous thin, narrow, discontinuous bands of coral ridges and leeward sand- and sediment-filled swales. Debris and reef-rubble fields behind many of the reefs may obscure these margin-parallel seabed features. In Florida, for example, this zone

extends for an estimated 200 kilometers along the Florida shelf (from Key Largo to Halfmoon Shoal), and it is discontinuous due to (a) topography, (b) inconsistent responses of coral reefs to changing sea levels, and (c) varying effects of the physical environment on reefs and sediments.

**Shoreline/Intertidal (Coral Reef Zone)**

Area between the mean high water line (or the landward edge of emergent vegetation- such as Red Mangrove- when present) and the lowest spring tide level (excluding emergent segments of barrier reefs).

**Vertical Wall (Coral Reef Zone)**

Area with near-vertical slope from the shore to the shelf (or shelf escarpment). This zone is typically narrow and may not be distinguishable in remotely gathered imagery; however, it is included because it is recognized as a biologically important feature.

**Enclosure**

Enclosure represents the degree of isolation of a water body from other waters because of enclosure by a land mass. In estuaries, enclosure determines the degree of exchange of water, materials, energy, and biota between the estuary and the sea. More enclosed water bodies have longer water residence times, can tend to be more evaporative and hypersaline, and can more readily trap and retain materials within them.

**Unenclosed**

Greater than or equal to 150-degree angular gap from landward end of water body to seaward opening; no confining land masses (e.g., islands) within or just outside water body.

**Partially enclosed**

90-degree to less than 150-degree angular gap from landward end of water body to seaward opening.

**Significantly enclosed**

45-degree to less than 90-degree angular gap from landward end of water body to seaward opening.

**Very enclosed**

10-degree to less than 45-degree angular gap from landward end of water body to seaward opening.

**Enclosed**

Essentially separated from the ocean; waters are completely surrounded by land or with a narrow channel connection to the sea. This category includes perched estuaries and lagoonal estuaries.

**Intermittent**

Class of water bodies that regularly close due to low flow, opening seasonally during high flow. Also called ICOLL (Intermittently Closed and Open Lake or Lagoon).

**Percent Cover Range**

To classify a unit to the class and subclass level of the Biotic Component, a user needs to know the relative percent cover of each of the components of the substrate. The degree of substrate cover for each biotic feature is assessed using the following ranges. These categories can also be used as a modifier to describe the density of vegetation (such as seagrasses) or other substrate components, and are useful in the Substrate component as well. Coarse Percent Cover can be described using one of five coarse descriptors, e.g., "Sparse", or, if greater detail is needed, Fine Percent Cover can be described using one of eleven range categories, e.g., "10 to less than 20%".

#### **Fine Percent Cover Range**

Fine Percent Cover can be described using one of eleven range categories, e.g., "10 to less than 20 percent".

**Less than 1%**

**1 to less than 10%**

**10 to less than 20%**

**20 to less than 30%**

**30 to less than 40%**

**40 to less than 50%**

**50 to less than 60%**

**60 to less than 70%**

**70 to less than 80%**

**80 to less than 90%**

#### **Coarse Percent Cover Range**

Coarse Percent Cover can be described using one of five coarse descriptors, e.g., "Sparse".

**90 to 100%**

**Trace (< 1%)**

**Sparse (1 to < 30%)**

**Moderate (30 to < 70%)**

**Dense (70 to < 80%)**

**Complete (90 to 100%)**

#### **Elevation Profile**

The Profile Modifier refers to the elevation of a feature relative to the surrounding level of the water or bed.

#### **None (Elevation Profile)**

0 meters

**Low (Elevation Profile)**

0.1 to less than 2 meters

**Medium (Elevation Profile)**

2 to less than 5 meters

**High (Elevation Profile)**

Greater than or equal to 5 meters

**Substrate Layering (Descriptive)**

Although certain large fauna may penetrate several meters below the surface in soft sediments, CMECS generally considers the uppermost 15 centimeters of fine substrates, recognizing that evidence of very-deep burrowing fauna will also be present in the top 15 centimeters. The upper 15 centimeters of substrate may present as a set of horizontal layers constituting a three-dimensional matrix. A basic identification of horizontal substrate layers can be accomplished by describing the characteristics of these layers and recording the mean thickness in centimeters together with the ordering of each layer below the sediment surface.

The structuring of distinctly layered sediments is captured in CMECS as a modifier using any SC classifiers, modifiers, or descriptors in the following format, with measurements indicating thickness or depth of the examined layers (as specified): "Modifier: Layering – 4 centimeters (thick) Coarse Sand Layer over > 11 centimeters (thick) Sandy Silt-Clay Layer". More examples can be found on page 219.

The term “veneer” may be used to describe a thin (< 1 centimeter thick) covering of one sediment type over another sediment type, ex. "Modifier: Layering – Mud veneer over Cobbles".

## Deprecated Units

### Substrate Component

**Geologic Substrate**

Unconsolidated Mineral Substrate (CMECS Substrate Component: Substrate Class)

Slightly Gravelly (CMECS Substrate Component: Substrate Group)

**Biogenic Substrate**

Algal Substrate (CMECS Substrate Component: Substrate Class)

Rhodolith Substrate (CMECS Substrate Component: Substrate Subclass)

Coral Substrate (CMECS Substrate Component: Substrate Class)

Organic Substrate (CMECS Substrate Component: Substrate Class)

Organic Debris (CMECS Substrate Component: Substrate Subclass)

Woody Debris (CMECS Substrate Component: Substrate Group)

*Globigerina* Ooze (CMECS Substrate Component: Substrate Subgroup)

Shell Substrate (CMECS Substrate Component: Substrate Class)

Clam Reef Substrate (CMECS Substrate Component: Substrate Group)

Clam Rubble (CMECS Substrate Component: Substrate Group)

Clam Hash (CMECS Substrate Component: Substrate Group)

Worm Substrate (CMECS Substrate Component: Substrate Class)

Sabellariid Substrate (CMECS Substrate Component: Substrate Subclass)

Serpulid Substrate (CMECS Substrate Component: Substrate Subclass)

### **Anthropogenic Substrate**

Anthropogenic Rock (CMECS Substrate Component: Substrate Class)

Anthropogenic Rock Reef Substrate (CMECS Substrate Component: Substrate Subclass)

Anthropogenic Rock Rubble (CMECS Substrate Component: Substrate Subclass)

Anthropogenic Rock Hash (CMECS Substrate Component: Substrate Subclass)

Anthropogenic Rock Sand (CMECS Substrate Component: Substrate Subclass)

Anthropogenic Rock Mud (CMECS Substrate Component: Substrate Subclass)

Anthropogenic Wood (CMECS Substrate Component: Substrate Class)

Construction Materials (CMECS Substrate Component: Substrate Class)

Metal (CMECS Substrate Component: Substrate Class)

Trash (CMECS Substrate Component: Substrate Class)

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