Classification of Marine Sublittoral Habitats with Application to the Northeastern North America Region

Page C. Valentine[1], Brian J. Todd[2], and Vladimir E. Kostylev[2]

[1]U.S. Geological Survey, 384 Woods Hole Road, Woods Hole, MA 02543
[2]Geological Survey of Canada (Atlantic), PO Box 1006, Dartmouth, NS B2Y 4A2

Abstract

Habitats are defined as spatially recognizable areas where the physical, chemical, and biological environment is distinctly different from surrounding environments. A habitat can be delimited as narrowly or as broadly as the data and purpose permit, and this flexibility of scale influences the development of habitat classification schemes. Recent habitat classifications focus on a wide range of habitats that occur in European, American, and worldwide sea floor environments. The proposed classification of marine sublittoral habitats is based on recent studies in the American and Canadian parts of northeastern North America using multibeam and sidescan sonar surveys, video and photographic transects, and sediment and biological sampling. A guiding principle in this approach to habitat classification is that it be useful to scientists and to managers of fisheries and the environment. The goal is to develop a practical method to characterize the marine sublittoral (chiefly the subtidal continental shelf and shelf basin) habitats in terms of (1) their topographical, geological, biological, and oceanographic attributes, and (2) the natural and anthropogenic processes that affect the habitats. The classification recognizes eight seabed *themes* (informal units) that are the major subject elements of the classification. They are seabed topography, dynamics, texture, grain size, roughness, fauna and flora, habitat association and usage, and habitat recovery from disturbance. Themes include one to many *classes* of habitat characteristics related to seabed features, fauna and flora, and processes that we view as fundamental for recognizing and analyzing habitats. Below the classes, a sequence of *subclasses, categories*, and *attributes* addresses habitat characteristics with increasing detail. Much of the classification is broadly applicable worldwide (excluding some low latitude environments), but faunal and floral examples are representative of the northeastern North America region. In naming habitats, the classification emphasizes seabed substrate dynamics, substrate type, and seabed physical and biological complexity. The classification can accommodate new classes, subclasses, categories, and attributes, and it can easily be modified or expanded to address habitats of other regions. It serves as a template for a database that will provide a basis for organizing and comparing habitat information and for recognizing regional habitat types.

Valentine, P.C., Todd, B.J., and Kostylev, V.E. In press. Classification of marine sublittoral habitats with application to the northeastern North America region. In P.W. Barnes and J.P. Thomas, editors. *Benthic habitats and the effects of fishing.* American Fisheries Society Symposium, Bethesda, Maryland.

Page Valentine: tel 508-457-2239; pvalentine@usgs.gov
Brian Todd: tel 902-426-3407; brian.todd@nrcan.gc.ca
Vladimir Kostylev: tel 902-426-8590; vkostyle@nrcan.gc.ca

Introduction

The recent increased interest in the management and conservation of marine environments and species has stimulated efforts to produce large-scale maps of the sea floor, and by extension, of habitats. Sea floor surveys using modern multibeam sonar and laser technology can generate topographic imagery of seabed features with vertical and horizontal resolutions of centimeters to tens of centimeters, respectively. Sea floor reflectance (backscatter) imagery collected at the same time shows the distribution of seabed materials and reveals patterns that are related to the origin of the materials and their responses to modern processes of erosion, transport, and deposition. These images depict broad geological environments well, and they provide an excellent framework for identifying and classifying habitats at a scale that is useful for scientific research and for environmental management.

Habitats are defined as spatially recognizable areas where the physical, chemical, and biological environment is distinctly different from surrounding environments. Although modern sea floor imagery is a solid foundation for the study of habitats, the classification of habitats requires additional information in the form of video and photographic imagery and geologic and biologic samples of the seabed. Habitat *characterization* produces descriptions of habitats based on geological, biological, chemical, and oceanographic observations. Habitat *classification* produces a set of habitat types based on a suite of standard descriptors of topographical, geological, biological, and natural and anthropogenic features and processes. Habitat *mapping* is the spatial representation of described and classified habitat units.

The goal of the habitat classification scheme proposed here is to develop a practical method to define marine sublittoral (chiefly subtidal continental shelf and shelf basin) habitats in terms of (1) their geological, biological, and oceanographic attributes, and in terms of (2) the natural and anthropogenic processes that affect the habitats. The classification is based on recent observations in the American and Canadian parts of northeastern North America using multibeam and sidescan sonar surveys, video and photographic transects, and sediment and biological sampling (Figure 1). The structure of the classification serves as a template for a database. It is designed so that it can easily be modified to classify habitats of other regions.

Recent Habitat Classification Schemes

Several recent classifications have focused on a range of habitats that occur in European land and water environments (Connor, et al., 2003; EUNIS, European Environment Agency, EEA, 2002), in American marine, estuarine, and wetland environments (Cowardin et al., 1979; Allee et al., 2000), and in worldwide deep (subtidal) marine environments (Greene et al., 1999). These five schemes are accessible online (see websites in References section). Dethier (1992), who is a co-author of the Allee et al. (2000) classification, proposed in 1992 an alternative to the Cowardin et al. (1979) system. It is not the purpose of this paper to exhaustively compare and contrast all of the structural details of these classifications with the scheme proposed here (see Allee et al., 2000, for a review of recent classifications and for a comparison of that classification with the EUNIS classification). All habitat classifications are, for the most part, based on observations of similar kinds of habitat characteristics (e.g. topography, bottom type, and fauna, among others). Classifications are designed by ranking kinds of characteristics so as to coherently describe habitat structure and function. However, it is somewhat difficult to compare the various schemes in detail because some kinds of habitat characteristics are placed at different levels in the classification hierarchies. There probably is not a right or wrong method for classifying habitats. The differences in classification structure reflect the ways the designers have chosen to organize, understand, and rank the structures and functions of natural systems.

The Cowardin et al. (1979) classification is a hierarchy of five levels that range from systems at the highest level (marine, estuarine, and others) to dominance types at the lowest levels (plant or animal forms). The marine sublittoral is treated sparingly in the classification. The Allee et al. (2000) classification also is a hierarchy that ranges from coarse-scale life zones at the top to fine-scale eco-units at the bottom; and marine sublittoral environments are addressed in levels 5 to 13. The EUNIS (EEA, 2002) classification also is a hierarchy that addresses an exceptionally wide range of land and water environments, including the marine sublittoral environment (A3 and A4). The Connor et al. (2003) classification treats the littoral and sublittoral environments of Britain and Ireland. It is a hierarchy of six levels, of which habitat levels 2 and 3 are comparable to the same levels of the EUNIS classification.

In a somewhat different approach, the Greene et al. (1999) classification uses the concept of area as a major criterion for describing habitats, and it recognizes four habitat sizes that include megahabitats (kilometers to 10s of kilometers), mesohabitats (10s of meters to a kilometer), macrohabitats (1 meter to 10 meters), and microhabitats (centimeters to a meter). The top level of this partly hierarchical classification is a system (marine benthic), followed by a subsystem (for mega- and mesohabitats), a class (for meso- and macrohabitats), two subclasses (for macro- and microhabitats), and modifiers that describe seabed characteristics and processes found in the various habitats. It is a notable improvement on other classifications in that it emphasizes the importance of geological characteristics of seabed habitats.

Regional Approach to Habitat Classification

The classifications discussed above address a broad range of habitats over geographic areas of continental size or larger, except for the Connor et al. (2003) scheme that focuses on the Britain and Ireland region. Our focus is on the marine sublittoral environments of the American and Canadian parts of North America that extend northward from the continental shelf off New Jersey (Figure 1). We found it most practical to develop a habitat classification scheme that is tailored to the region under study and to the level of detail we required, and that is based on extensive seabed observations from there. However, the classification incorporates concepts that are applicable worldwide.

The marine sublittoral zone as defined in most classifications lies below the intertidal zone and extends to the continental shelf edge at a water depth of approximately 200 m. We include in the marine sublittoral the continental shelf basins of the Gulf of Maine region that reach depths of approximately 400 m and the submarine canyon heads that incise the continental shelf and reach depths of up to 800 m. The marine sublittoral encompasses by far the major portion of the offshore area of northeastern North America that is valued and managed for its fisheries resources, marine mammal habitats, sensitive environments, and industrial uses such as transportation, petroleum extraction and cable and pipeline routes.

By necessity, habitat classification schemes utilize many common concepts and terminology, and in this regard we have drawn freely from the schemes described above. Our classification addresses characteristics and processes that are key components of habitats in general, while focusing specifically on marine sublittoral environments (Table 1). It recognizes eight seabed *themes* (informal units) that are the major subject elements of the classification and that emphasize the geological characteristics of habitats. Themes include one to many *classes* of habitat characteristics related to seabed features, fauna and flora, and processes that we view as fundamental for recognizing and analyzing habitats (Table 1). The *classes* of this scheme are unique formal units, and all reside at the top level (are not hierarchical) and are applied to the classification of each site. Below the classes, a sequence of *subclasses*, *categories*, and *attributes* addresses habitat characteristics with increasing detail. The observations that are the basis for classifying habitats are collected at sites that generally fall into the size range of the mesohabitats (10s of meters to a kilometer) of Greene et al. (1999). The process of classifying habitats involves the documentation of suites of habitat characteristics at individual sites and the identification of standard descriptors that together represent habitat types at an appropriate scale.

The classification is designed to be a template for a database that will allow the habitat characteristics of a site to be entered easily by selecting terms from lists. The database will (1) be an archive of habitat observations, (2) produce a summary report of the habitat characteristics of individual sites, and (3) export characteristics in spreadsheet format suitable for multivariate statistical analysis, which will aid in the recognition of the basic habitat types, biological communities, and functional groups of the region. The habitat database can be searched for any habitat type or characteristic, and it can provide habitat information for areas of interest to scientists and managers (see the Appendix and Figures 2-5 for four examples of habitat site descriptions based on the proposed scheme).

We expect that a well-designed regional habitat classification can be expanded to incorporate new kinds of observations (e.g. classes for seabed chemistry, and water column structure and productivity). The classification also can be expanded into other environments simply by incorporating applicable terminology. For example, the classification as applied to northeastern North America now does not address low latitude carbonate environments but could easily be modified for that purpose. As regional classifications of this nature develop, it will be possible to compare habitats of different regions and, ultimately, to merge them if that proves useful.

Habitat Classification Structure

The classification proposed for marine sublittoral habitats has a four-level (*class, subclass, category, attribute*), partly hierarchical structure in which many of the levels have a broad geographic application (Table 1). However, categories that address fauna and flora in Classes 14-17 are regional in nature. Classes are grouped into eight seabed *themes* that address major geological, biological, and oceanographic characteristics of habitats and the natural and human processes that create and modify the seabed. The themes, which contain one to many classes, are: (1) topographic setting; (2) seabed dynamics and currents; (3) seabed texture, hardness, and layering in the upper 5-10 cm; (4) seabed grain size analysis; (5) seabed roughness; (6) fauna and flora; (7) habitat association and usage; and (8) habitat recovery from disturbance.

Theme 1, Class 1 – Topographic setting addresses the location of the habitat in terms of seabed slope and major sea floor features and industrial structures. The marine sublittoral is subdivided into two depth subclasses: Class 1, shallow photic; and Class 2, deep aphotic. The shallow photic zone encompasses depths in which epifaunal macrophyte algae occur. Categories and attributes are descriptors of features and structures (physiographic, biogenic, and anthropogenic).

Theme 2, Class 2 – Seabed dynamics and currents addresses the stability and mobility of seabed materials in response to current types and their strength and frequency of flow. This class recognizes the fundamental role of seabed dynamics in determining the structure and function of habitats. Three subclasses are recognized at present: Class 1, mobile substrate; Class 2, immobile substrate; and Class 3, intermixed mobile and immobile substrates (e.g. boulders on mobile sand). The mobility (or immobility) of the seabed is a major characteristic that influences habitats in terms of sediment texture, the presence and kinds of bedforms and shell deposits, the erosion and transport of sediment, the presence of biogenic structures, and the presence of many benthic species.

Theme 3, Class 3 – Seabed texture, hardness, and layering in the upper 5-10 cm describes the sediment texture and relative hardness of the seabed by using visual observations of seabed character. Four subclasses include: Class 1, fine-grained sediment composed of mud, very fine (4 phi), and fine (3 phi) sand; Class 2, coarse-grained sediment composed of medium (2 phi), coarse (1 phi), and very coarse (0 phi) sand, and gravel; Class 3, mixed fine-grained and coarse-grained sediment composed of mud, sand, and gravel mixtures; and Class 4, rock or other hard seabed (with or without mud, sand, or gravel). Each of these four subclasses also incorporates terminology that describes visible sediment layering in the upper 5-10 cm (e.g. sand partial veneer on pebbles, mud partial veneer on clay, pebble gravel on rock outcrop).

Theme 4, Classes 4, 22, 23 – Grain size analysis provides the results of sediment texture analysis as follows: Class 4, a general sediment description that includes texture classes (e.g. silty sand, gravelly mud), sorting, skewness, kurtosis, and particle shape; Class 22, major Wentworth size classes (e.g. sand, gravel, silt, clay, mud) in weight percent; and Class 23, Phi and all Wentworth size classes (e.g. fine sand, coarse silt) in weight percent.

Theme 5, Classes 5-13, 24 – Seabed roughness describes the three-dimensionality of the seabed surface in terms of physical and biological structures and the percent of the seabed covered by them. Seven classes of physical structures are: Class 5, bedforms; Class 6, shell materials; Class 7, rough sediments and hard seabeds (features composed variously of pebbles, cobbles, boulders, and rock outcrops that are smaller than the topographic features treated in Class 1); Class 8, biogenic structures (burrows, depressions, mounds); Class 12, anthropogenic marks (trawl and dredge tracks); Class 13, anthropogenic structures (minor structures such as lost fishing gear); and Class 24, physical structures combined. Three classes of biological structures are: Class 9, attached epifauna; Class 10, emergent epifauna; and Class 11, biological structures combined. Seabed roughness classes address a wide range of characteristics that are produced by mobile sediments, immobile hard materials, and biogenic structures and epifauna.

Theme 6, Classes 14-17 – Fauna and flora enumerates the dominant and typical biological elements that characterize habitats. Four classes are: Class 14, faunal groups (e.g. attached anemones, erect sponges, polychaetes, flounder); Class 15, faunal species (e.g. Atlantic cod *Gadus morhua*, red hake *Urophycis chuss*, sea scallop *Placopecten magellanicus*); Class 16, floral groups (e.g. calcareous algae); and Class 17, floral species. Fauna and flora are subdivided into *groups* and *species* to accommodate and keep separate the varying levels of identification that can be achieved when analyzing habitats with video and photographic imagery and with collected specimens. Many important faunal and floral groups can be identified from visual observations. Some faunal and floral species also can be identified using visual methods, but others need to be collected in order to obtain an accurate identification.

Theme 7, Classes 18, 19 – Habitat association and usage describes habitats in terms of faunal association, human usage, and state of disturbance. Two subclasses are: Class 18, faunal association and essential fish habitat (EFH) that documents spawning, juvenile, and adult habitats; and Class 19, human usage of habitat in terms of activities that impact the seabed such as fishing, waste disposal, construction, and extraction of minerals, among others.

Theme 8, Classes 20, 21 – Habitat recovery from disturbance describes the time required for the recovery of physical and biological structures from fishing disturbance (Class 20) and from natural disturbance (Class 21). These classes acknowledge the role of habitats in the life cycles of important fisheries species, the alteration of the seabed that might hinder the habitats' natural function, and the resilience and ability of habitats to resume their natural function. Classes 20 and 21 are included in the classification to address the growing importance of the effects of habitat disturbance to the management of fisheries and environments.

The Question of Scale

A habitat can be delimited as narrowly or as broadly in a geographic sense as the data and the purpose permit. This flexibility of scale necessarily influences the design and development of habitat classification schemes. Scale is particularly important when classifying subaqueous environments where observations generally are far more limited in number than they are in terrestrial environments. Several important questions related to scale should be addressed. What kinds and quantities of data are needed to achieve the required level of detail? What is the appropriate size and complexity of easily recognizable marine sublittoral habitats? Is it possible to define habitats too narrowly for practical application? A guiding principle in this approach to habitat classification is that it be useful to scientists and to managers of fisheries and the environment.

Habitat characteristics used in the proposed scheme are based on seabed geomorphology, video and photographic imagery, and on geologic and biologic sampling. For the most part, physical and biological structures, major faunal and floral groups, and many dominant species that are exposed on the seabed can be adequately observed using video imagery, and it probably is the most common form of seabed data collected. Photographs and biological sampling add a higher level of detail to habitat analysis and are especially helpful for the identification of species that are difficult to identify in video images. Sampling also can provide information on infaunal species that cannot be observed with visual methods. Geological sampling provides materials for grain size analysis that cannot be matched by estimates from video imagery, but sampling with conventional small volume samplers is a poor estimator of the presence of large gravel particles and other materials that are difficult to sample. A practical protocol for "standardizing" seabed observations and therefore habitat classification might be to rely chiefly on video imagery. As it often is not feasible to determine the abundances of individual structures and organisms by counting, this classification scheme allows for the inclusion of visual estimates of the percent of the seabed covered by habitat characteristics (e.g. percent of seabed covered by epifauna, by sea scallops, by cobbles and boulders on rippled sand, among others).

Our experience in the marine sublittoral of northeastern North America has shown that short video transects of 100 to 200 m often are adequate to characterize areas where habitats are relatively large and homogeneous; whereas transects of 500 to 1,000 m in length or longer are required to evaluate areas where habitats are relatively small and/or complex. The appropriate transect length (and number of transects) will vary from region to region, and should be determined by the variability of seabed characteristics, by the level of detail required, and by a habitat mapping scale that is suitable for practical applications.

The proposed classification need not be based on sonar or laser imagery of the seabed, although imagery has become an almost indispensable basis for the sampling and high-resolution mapping of habitats. The availability of seabed imagery allows video and sampling transects to be conducted across environmental gradients that are expressed in topographic and backscatter images.

We suggest that an appropriate scale for the mapping of sublittoral habitats lies in the range of 1:25,000 to 1:100,000 (1 cm on the map represents 250 to 1,000 m on the seabed, respectively) and depends in large part on the data and imagery available. Mappable habitats therefore lie in the size range of the mesohabitats and megahabitats of Greene et al. (1999).

Habitat Names

Classified habitats require names in order to facilitate communication among the management, science, and industry communities. However, it is exceedingly difficult to design habitat names (and codes) that are concise, highly descriptive, and decipherable. Cowardin et al. (1979) use a list of five or more descriptors to name habitats. Allee et al. (2000) name habitats by combining an ecotype term (e.g. salt marsh habitat) with a list of descriptors. The EUNIS (EEA, 2002) classification uses short descriptive names for habitats that include faunal, sediment, and oceanographic terms supplemented by a numerical code. For example, a sequence of habitats and codes is: *sublittoral muds A4.3; shallow fully marine mud communities A4.31; semi-permanent tube-building amphipods and polychaetes in sublittoral mud or muddy sand, A4.311*. Connor et al., (2003) employ habitat names and codes that are based on habitat factors (physical characteristics of habitats), taxon groups (e.g. brittlestars), community features (e.g. tube-building), and species names. For example, the habitat code *LS.LSa.MoSa.AmSco* describes a habitat characterized by: *littoral sediment (LS); littoral sand (LSa); mobile sand (MoSa); amphipods (Am); Scolelepsis species (Sco).* Greene et al. (1999) describe habitats by combining a code with an areal size term (e.g. megahabitat, mesohabitat) and a list of descriptors. For example, the large-scale habitat with the code Shp_d1D is named: c*ontinental shelf megahabitat (S); flat (1); highly complex (D); hard sea floor (h); with pinnacles (p); differentially eroded* $(_d)$. There is a separate code for small-scale habitats (Greene et al. 1999). Although habitat name codes can be cumbersome and require some effort to decipher, they are necessary shorthand for communication in situations where long text descriptions are inappropriate.

We have developed habitat-naming conventions for the marine sublittoral classification proposed here. Habitat names (and codes) are descriptive and can incorporate up to three kinds of information including (1) seabed substrate type from Class 3, (2) seabed substrate dynamics from Class 2, and (3) the degree of physical and biological complexity of the seabed from Classes 24 and 11, respectively (Table 1). The least descriptive habitat name is based on seabed substrate type only (e.g. *mud; M*). A more descriptive name links a seabed dynamics term with the substrate type (e.g. *immobile; mud; I_M*). Seabed dynamics are expressed as mobile (M), immobile (I), and intermixed mobile and immobile (IMI) substrates.

The most descriptive habitat name has three components that include a seabed dynamics term, the seabed substrate type, and seabed structural complexity terms that describe both physical structure and biological structure of the seabed. Structural complexity of habitats is based on the percent of the seabed covered by physical structures and by biological structures. The *percent of the seabed covered* by structures is determined by visual observations (Table 2) and is estimated in nine semi-quantitative intervals that range from 0 to 100 percent (0, <1, 1-5, 5-10, 10-25, 25-50, >50, >90, and 100 percent). These percent intervals are reasonably easy to estimate from video and photographic imagery. The percent of the seabed covered is determined separately for physical and biological structures, and it is possible that the total percent of the seabed covered by physical and biological structures combined could be greater than 100 percent (e.g. in the case of abundant attached epifauna on a pebble, cobble, boulder substrate). The *degree of structural complexity* of the seabed is described in terms of the percent of the seabed that is covered separately by physical and biological structures in seven qualitative intervals that range from none to very high (Table 2). Wherever >50 percent of the seabed is covered by structures, the structural complexity is considered to be very high. An example of a three-component habitat name and code is: *immobile; mud; physical structural complexity low; biological structural complexity very very low; I_M_ps5-10L_bs<1VVL*. In this example, physical structures (ps) cover 5-10 percent of the seabed and complexity is low, and biological structures (bs) cover <1 percent of the seabed and complexity is very very low (see Table 3 and Appendix for other examples of habitat name construction).

It must be emphasized that names and codes, by definition, do not fully describe a habitat. For example, a habitat name can indicate the degree of structural complexity present, but to gain a full understanding of the nature of a habitat's complexity, it is necessary to examine the supporting observational data to determine the kinds and functions of the physical and biological structures present. Habitat names can be made more descriptive by appending a list of major habitat characteristics such as dominant physical and biological structures, faunal and floral groups and species, biological communities, and functional groups to the kinds of habitat names discussed above (Table 3).

Probable Marine Sublittoral Habitat Types

This classification characterizes habitats by emphasizing seabed dynamics (Class 2), seabed texture (Class 3), and seabed structural complexity (Classes 11 and 24). The number of probable habitat types that can occur in the marine sublittoral can be determined by combining the characteristics of these classes. For purposes of illustration, we will combine the seabed dynamics characteristics of Class 2 with some of the seabed texture characteristics of Class 3 to identify a representative suite of habitats (Table 4). We are leaving out the structural complexity characteristics of Classes 11 and 24 for simplicity.

Among the representative suite of 90 habitats (Table 4), 45 are likely to occur in marine sublittoral environments. Habitats that are not likely to occur are those that combine seabed dynamics and substrate types that generally are not compatible in nature (although some of these might occur under certain conditions such as in high energy coastal environments). Examples would include: mobile mud (mud is not likely to be mobile in sublittoral environments); mobile sandy gravel (the gravel component, depending on size, is not likely to be mobile); mobile muddy gravel (mud and gravel components are not likely to be mobile); intermixed mobile/immobile gravel on rock (rock is immobile and the gravel component is not likely to be mobile). The number of habitats that will be recognized and classified in a region depends on the dynamism and physical and biological heterogeneity of the seabed, on the kinds and distribution of data available, and on the scale chosen for habitat analysis.

Summary

The marine sublittoral habitat classification proposed here is designed to describe and classify habitats in terms of geological, biological, and oceanographic attributes and in terms of the effects of natural and anthropogenic processes on them. The classification emphasizes the importance of seabed substrate type, substrate dynamics, and seabed physical and biological complexity in characterizing and naming sublittoral habitats. The classification is applied to the northeastern North America region. The purpose of the classification is to provide a foundation for scientific research and environmental management of sea floor habitats in a relatively large region. A database will allow data from individual study sites to be summarized, archived, and used to perform statistical analyses for identifying the major habitat types of the region. The information in the database, together with seabed imagery, will be a basis for habitat mapping. The proposed habitat classification serves as a template both for a database and for the development of classifications for other regions. The merging of separate regional classifications that follow the same principles could lead to an integrated national habitat classification for the marine sublittoral and other seabed environments.

Acknowledgments

We wish to thank the officers, crews, and scientists who have collaborated with us on many cruises over the years to study the seabed of northeastern North America. We especially wish to thank our shipmates aboard the *CCGS Hudson* for their support on the June 2002 cruise to Georges and German Banks. Observations and discussions with colleagues on that cruise played a major role in the development of the classification scheme presented here. We also benefited greatly from insightful reviews of the manuscript by H. Josenhans and E. King of the Geological Survey of Canada, K. Scanlon of the U.S. Geological Survey, B. Barr of the National Marine Sanctuary Program, T. Noji of the National Marine Fisheries Service, and G. Greene of Moss Landing Marine Laboratories.

References

Allee, R.J., M. Dethier, D. Brown, L. Deegan, R.G. Ford, T.F. Hourigan, J. Maragos, C. Schoch, K. Sealey, R. Twilley, M.P. Weinstein, and M. Yoklavich. 2000. Marine and estuarine ecosystem and habitat classification. National Oceanic and Atmospheric Administration, NOAA Technical Memorandum NMFS-F/SPO-43, 43 p. Available at: http://www.nmfs.noaa.gov/habitat/watershed/habitat.htm (May 2003).

Connor, D.W., J.H. Allen, N. Golding, L.M. Lieberknecht, K.O. Northen, and J.B. Reker. 2003. The national marine habitat classification for Britain and Ireland, version 03.02. Joint Nature Conservation Committee (JNCC), United Kingdom. Available at: http://www.jncc.gov.uk/marine/biotopes/ (May 2003).

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Department of Interior, FWS/OBS-79/31, 131 p. Available at: http://wetlands.fws.gov/Pubs_Reports/Class_Manual/class_titlepg.htm (May 2003).

Dethier, M.N. 1992. Classifying marine and estuarine natural communities: an alternative to the Cowardin system. Natural Areas Journal 12(2):90-100.

European Environment Agency (EEA). 2002. EUNIS (European Nature Information System) habitat classification, version 2.3. Available at: http://mrw.wallonie.be/dgrne/sibw/EUNIS/ (May 2003).

Greene H.G., M.M. Yoklavich, R.M. Starr, V.M. O'Connell, W.W. Wakefield, D.E. Sullivan, J.E. McRea Jr., and G.M. Cailliet. 1999. A classification scheme for deep seafloor habitats. Oceanologica Acta 22:663-678. Available at: http://www.elsevier.com/locate/oceanact (May 2003). Note: See the following site for an addendum to this reference that contains a detailed explanation of habitat name codes. http://www.mlml.calstate.edu/groups/geooce/images.htm (May 2003).

Appendix

Habitat Descriptions

Example 1: Habitat name: mobile; coarse-grained sand; physical structural complexity very high; biological structural complexity none (M_cgS_ps100VH_bs0N). Further habitat characteristics: sand ripples and dunes; scallop depressions; sea scallops; flounder; skate; monkfish; silver hake; red hake; sculpin; sea stars (Figures 1, 2).
Station information: Eastern Georges Bank; CCGS Hudson cruise 2002-026; station 26; water depth 96 m; June 10, 2002; JD 161; visual observations; Campod video/photo station.

Marine sublittoral environment.
Class 1, Topographic setting: deep aphotic; shelf; flat (0-5 degrees).
Class 2, Seabed dynamics and currents: mobile substrate; tidal and storm wave currents.
Class 3, Seabed texture, hardness and layering in the upper 5-10 cm: coarse-grained sediment; coarse-grained sand.
Classes 4, 22, 23, Seabed grain sizes: no analysis.
Class 5, Seabed roughness; bedforms: sand ripples; sand ripple crests fresh; sand dunes low; sand dune asymmetry NW; ripples on dune crests and in troughs; mobile sand dune troughs and crests.
Class 6, Seabed roughness; shell materials: shell fragments; shell materials in sand dune troughs; fine shell fragments in sand ripple troughs.
Class 7, Seabed roughness; rough sediments and hard seabeds: none.
Class 8, Seabed roughness; biogenic structures: scallop depressions.
Class 9, Seabed roughness; attached epifauna: none
Class 10, Seabed roughness; emergent epifauna: none.
Class 11, Seabed roughness; biological structures combined: none.
Class 12, Seabed roughness; anthropogenic marks: none.
Class 13, Seabed roughness; anthropogenic structures: none.
Class 24, Seabed roughness; physical structures combined: sand ripples, sand dunes, and scallop depressions cover 100 percent of the seabed.
Class 14, Faunal groups: flounder; sea stars; skate; sculpin; bivalves (sea scallops); no sand dollars.
Class 15, Faunal species: red hake (*Urophycis chuss*); monkfish (*Lophius americanus*); silver hake (*Merluccius bilinearis*); sea star (*Asterias* sp.); sea scallops (*Placopecten magellanicus*) cover 10-25 percent of the seabed.
Class 16, Floral groups and *Class 17, Floral species*: none.
Class 18, Faunal habitat association: essential fish habitat for adult monkfish, silver hake, red hake, skate, flounder, and sea scallops.
Class 19, Human usage of habitat: unknown.
Class 20, Habitat recovery from fishing disturbance: habitat is undisturbed by fishing
Class 21, Habitat recovery from natural disturbance: unknown.

Example 2: Habitat name: intermixed mobile and immobile; pebbles and cobbles in sand; physical structural complexity very high; biological structural complexity low (IMI_pciS_ps100VH_bs5-10L). Further habitat characteristics: sand ripples; pebbles; cobbles; boulders; attached epifauna; colonial tube worms; sea stars; sponges; brachiopods; anemones; bryozoans (Figures 1, 3).
Station information: Eastern Georges Bank; CCGS Hudson cruise 2002-026; station 35; water depth 152 m; June 11, 2002; JD 162; visual observations; Campod video/photo station.

Marine sublittoral environment.
Class 1, Topographic setting: deep aphotic; shelf edge; sloping (5-30 degrees).
Class 2, Seabed dynamics and currents: intermixed mobile and immobile substrates; tidal currents.
Class 3, Seabed texture, hardness and layering in the upper 5-10 cm: coarse-grained sediment; rippled sand partial veneer on pebbles and cobbles; pebbles and cobbles in rippled sand. Comment: rippled sand migrating through pebble and cobble pavement.
Classes 4, 22, 23, Seabed grain sizes: no analysis.
Class 5, Seabed roughness; bedforms: sand ripples; sand ripple crests fresh.
Class 6, Seabed roughness; shell materials: shell fragments.
Class 7, Seabed roughness; rough sediments and hard seabeds: pebbles and cobbles in patches; boulders in depressions with pebbles.
Class 8, Seabed roughness; biogenic structures: none.
Class 9, Seabed roughness; attached epifauna: brachiopods; erect sponges; anemones; erect bryozoans; calcareous worm tubes. Comment: epifauna attached to pebbles, cobbles, and boulders.
Class 10, Seabed roughness; emergent epifauna: none.
Class 11, Seabed roughness; biological structures combined: attached epifauna covers 10-25 percent of hard substrates and 5-10 percent of the seabed in total.
Class 12, Seabed roughness; anthropogenic marks: none.
Class 13, Seabed roughness; anthropogenic structures: none.
Class 24, Seabed roughness; physical structures combined: sand ripples, pebbles, cobbles, boulders, and boulder depressions cover 100 percent of the seabed.
Class 14, Faunal groups: sea stars; brachiopods; colonial tube worms; erect sponges; juvenile fish; attached anemones; erect bryozoans; no sand dollars.
Class 15, Faunal species: calcareous colonial tube worms (*Filograna implexa*); yellow erect sponge (*Myxilla* spp.); yellow erect sponge (*Suberites* spp.); sea star (*Hippasterias* sp.); no sea scallops (*Placopecten magellanicus*).
Class 16, Floral groups and *Class 17, Floral species*: none.
Class 18, Faunal habitat association: essential fish habitat for unidentified juvenile fish species.
Class 19, Human usage of habitat: unknown.
Class 20, Habitat recovery from fishing disturbance: habitat is undisturbed by fishing
Class 21, Habitat recovery from natural disturbance: unknown.

Example 3: Habitat name: immobile; pebble gravel; physical structural complexity very high; biological structural complexity very very low (I_pG_ps100VH_bs<1VVL). Further habitat characteristics: pebble gravel; broken shells; disturbed; scallop dredge tracks (Figures 1, 4).
Station information: Eastern Georges Bank; CCGS Hudson cruise 2002-026; station 42; water depth 70 m; June 12, 2002; JD 163; visual observations; Campod video/photo station.

Marine sublittoral environment.
Class 1, Topographic setting: deep aphotic; shelf; flat (0-5 degrees).
Class 2, Seabed dynamics and currents: immobile substrate; tidal currents.
Class 3, Seabed texture, hardness and layering in the upper 5-10 cm: coarse-grained sediment; pebble gravel; cobbles on pebble gravel.
Classes 4, 22, 23, Seabed grain sizes: no analysis.
Class 5, Seabed roughness; bedforms: none.
Class 6, Seabed roughness; shell materials: shells partly broken; sea scallop shell debris.
Class 7, Seabed roughness; rough sediments and hard seabeds: pebble pavement.
Class 8, Seabed roughness; biogenic structures: none.
Class 9, Seabed roughness; attached epifauna: colonial calcareous tube worms.
Class 10, Seabed roughness; emergent epifauna: none.
Class 11, Seabed roughness; biological structures combined: attached epifauna covers <1 percent of the seabed.
Class 12, Seabed roughness; anthropogenic marks: scallop dredge tracks.
Class 13, Seabed roughness; anthropogenic structures: none.
Class 24, Seabed roughness; physical structures combined: pebble gravel and broken shells cover 100 percent of the seabed.
Class 14, Faunal groups: sea stars; colonial tube worms; no sand dollars.
Class 15, Faunal species: lobster (*Homarus americanus*); sea star (*Crossaster* sp.); sea star (*Solaster* sp.); calcareous colonial tube worms (*Filograna implexa*); no sea scallops (*Placopecten magellanicus*).
Class 16, Floral groups and *Class 17, Floral species*: none.
Class 18, Faunal habitat association: essential fish habitat for adult lobster.
Class 19, Human usage of habitat: scallop dredging.
Class 20, Habitat recovery from fishing disturbance: habitat is disturbed by fishing. Comment: this habitat lies adjacent to an undisturbed, mussel-encrusted, pebble gravel habitat with abundant epifauna, including calcareous tube worms (*Filograna implexa*).
Class 21, Habitat recovery from natural disturbance: unknown.

Example 4: Habitat name: immobile; pebbles, cobbles, boulders on rock outcrop; physical structural complexity very high; biological structural complexity very high (I_pcboR_ps>90VH_bs>50VH). Further habitat characteristics: Rock outcrop; pebbles; cobbles; boulders; attached epifauna; sponges; tunicates; hydrozoans; bryozoans; soft corals; anemones; brachiopods (Figures 1, 5).
Station information: German Bank; CCGS Hudson cruise 2002-026; station 49; water depth range 73-103 m; June 13, 2002; JD 164; visual observations; Campod video/photo station.

Marine sublittoral environment.
Class 1, Topographic setting: deep aphotic; bank edge; steep (30-45 degrees).
Class 2, Seabed dynamics and currents: immobile substrate; tidal currents.
Class 3, Seabed texture, hardness and layering in the upper 5-10 cm: rocks or other hard seabed (with or without mud, sand, gravel); bedrock outcrop; pebble gravel on bedrock outcrop; pebbles and cobbles and boulders on bedrock outcrop; cobbles and boulders in sand on bedrock outcrop.
Classes 4, 22, 23, Seabed grain sizes: no analysis.
Class 5, Seabed roughness; bedforms: none.
Class 6, Seabed roughness; shell materials: shell fragments; fine shell fragments on sand.
Class 7, Seabed roughness; rough sediments and hard seabeds: pebbles in patches; pebbles and cobbles in patches; cobbles and boulders in patches; piled cobbles and boulders with voids between; piled cobbles and boulders with sand between; smooth bedrock; irregular bedrock; stepped bedrock.
Class 8, Seabed roughness; biogenic structures: none.
Class 9, Seabed roughness; attached epifauna: anemones; erect bryozoans; erect hydrozoans; brachiopods; soft corals; erect sponges; encrusting sponges; stalked tunicates; encrusting tunicates. Comment: epifauna attached to pebbles, epifauna attached to cobbles and boulders, epifauna attached to bedrock.
Class 10, Seabed roughness; emergent epifauna: none.
Class 11, Seabed roughness; biological structures combined: attached epifauna covers >50 percent of the seabed.
Class 12, Seabed roughness; anthropogenic marks: none.
Class 13, Seabed roughness; anthropogenic structures: none.
Class 24, Seabed roughness; physical structures combined: pebbles, cobbles, boulders, stepped and irregular bedrock cover >90 percent of the seabed.
Class 14, Faunal groups: attached anemones; soft corals; brachiopods; erect bryozoans; erect hydrozoans; hermit crabs; flounder; sculpin; eel; sea stars; encrusting sponges; erect sponges; palmate sponges; stalked tunicates; encrusting tunicates; no sand dollars.
Class 15, Faunal species: redfish (*Sebastes fasciatus*); monkfish (*Lophius americanus*); yellow erect sponge (*Myxilla* sp.); yellow erect sponge (*Suberites* sp.); tunicate (*Mogula* sp.); stalked tunicate (*Boltenia* sp.); soft coral (*Gersemia* sp.); erect sponge (*Isodyctia palmata*); breadcrumb sponge (*Halichondria* sp.); sea star (*Leptasterias* sp.); attached anemone (cf. *Tealia* sp.); attached anemone (*Metridium* sp.); sea star (*Asterias* sp.); sea star (*Hippasterias* sp.); no sea scallops (*Placopecten magellanicus*).
Class 16, Floral groups and *Class 17, Floral species*: none.
Class 18, Faunal habitat association: essential fish habitat for adult redfish, monkfish, and flounder.
Class 19, Human usage of habitat: unknown.
Class 20, Habitat recovery from fishing disturbance: undisturbed habitat.
Class 21, Habitat recovery from natural disturbance: undisturbed habitat.

Table 1. Outline of the marine sublittoral habitats classification structure. The classification includes Classes, Subclasses, Categories, and Attributes. It is designed as a template for a database. Class numbers are unique. Themes (*in italics*) are the major subject elements of the classification and can include one to many Classes. Themes are informal units and are not incorporated into the habitats database. Observations from Classes 2, 3, 11, and 24 are used to compile habitat names (see Table 3 for examples). Category and Attribute terms in parentheses are not a complete list. The complete classification structure with all Category and Attribute terms will be available after publication online at http://woodshole.er.usgs.gov/project-pages/stellwagen/.

Theme 1, Topographic Setting

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

[Note: All Categories and Attributes apply to Subclasses 1 and 2.]

Theme 2, Seabed Dynamics and Currents

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

[Note: All Categories and Attributes apply to Subclasses 1-3.]

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

Class 3	Seabed texture, hardness, and layering in the upper 5-10 cm
Subclass 1	Fine-grained sediment: mud, very fine (4 phi), and fine (3 phi) sand
Subclass 2	Coarse-grained sediment: medium (2 phi), coarse (1 phi), and very coarse (0 phi) sand, and gravel

[Note: Gravel is composed of granules (>1, <2 mm), pebbles (<64 mm), cobbles (<256 mm), boulders (>256 mm).]

Subclass 3	Mixed fine-grained and coarse-grained sediment: mud, sand, and gravel mixtures
Subclass 4	Rock or other hard seabed (with or without mud, sand, gravel)
Categories	Descriptive sediment and hard seabed types (e.g. mud veneer on clay, gravel pavement, cobbles in muddy sand, sand veneer on rock outcrop)
Attributes	Percentage of seabed covered by sediment and hard seabed types

[Note: Categories apply to appropriate Subclasses; all Attributes apply to Subclasses 1-4.]

Theme 4, Seabed Grain Size Analysis

Class 4	Seabed grain sizes: general description
Subclass 1	General sediment description
Categories	Descriptive texture classification, sorting, grain size distribution, and particle shape
Attributes	Major descriptive texture classes (e.g. silty sand, gravelly mud), degree of sorting (e.g. well sorted), skewness (e.g. symmetrical), kurtosis (e.g. mesokurtic), and particle shape (e.g. rounded)

Class 22	Seabed grain sizes: major Wentworth size classes
Subclass 1	Major Wentworth grain size classes, weight percent
Categories	Major Wentworth grain size classes (e.g. sand, gravel, silt, clay, mud)
Attributes	Weight percent of major Wentworth grain size classes

Class 23	Seabed grain sizes: Phi and all Wentworth size classes
Subclass 1	Phi and all Wentworth grain size classes, weight percent
Categories	Phi and all Wentworth size classes (e.g. fine sand, coarse silt)
Attributes	Weight percent of Phi and all Wentworth size classes

Table 1 (continued)

Theme 5, Seabed Roughness	
Class 5	Seabed roughness: bedforms
Subclass 1	Bedforms (physical structures)
Categories	Bedform types (e.g. ripples, sand dunes)
Attributes	Percentage of seabed covered by bedform types
Class 6	Seabed roughness: shell materials
Subclass 1	Shell materials (physical structures)
Categories	Types of shell materials and deposits (e.g. shell fragments, shell deposits)
Attributes	Percentage of seabed covered by shell material and deposit types
Class 7	Seabed roughness: rough sediments and hard seabeds
Subclass 1	Rough sediments and hard seabeds (physical structures)
Categories	Associations of sediment particles, sediment type, seabed structures, and rock outcrops (e.g. cobbles in patches, piled boulders, pebbles in sand dune troughs, irregular rock outcrop)
Attributes	Percentage of seabed covered by rough sediment and hard seabed types
Class 8	Seabed roughness: biogenic structures
Subclass 1	Biogenic structures (physical structures)
Categories	Types of biogenic modifications of the seabed (e.g. crab depressions, fish burrows)
Attributes	Percentage of seabed covered by types of biogenic structures
Class 12	Seabed roughness: anthropogenic marks
Subclass 1	Anthropogenic marks (physical structures)
Categories	Types of marks made on the seabed by human activities (e.g. trawl marks, anchor marks)
Attributes	Percentage of seabed covered by types of anthropogenic marks
Class 13	Seabed roughness: anthropogenic structures
Subclass 1	Anthropogenic structures (physical structures)
Categories	Types of minor man-made structures and equipment on the seabed (e.g. types of fishing gear)
Attributes	Percentage of seabed covered by types of anthropogenic structures
Class 24	Seabed roughness: physical structures combined
Subclass 1	Extent of physical structures
Categories	Types of physical structures
Attributes	Percentage of seabed covered by physical structures by type and all combined
[Note: Class 24 summarizes observations for Classes 5-8, 12, 13.]	
Class 9	Seabed roughness: attached epifauna
Subclass 1	Attached epifauna (biological structures)
Categories	Epifaunal groups attached to the seabed surface (e.g. erect sponges, tunicates, brachiopods)
Attributes	Percentage of seabed covered by types of attached epifauna
Class 10	Seabed roughness: emergent epifauna
Subclass 1	Emergent epifauna (biological structures)
Categories	Epifaunal groups emergent from below the seabed surface (e.g. burrowing anemones, sea pens)
Attributes	Percentage of seabed covered by types of emergent epifauna
Class 11	Seabed roughness: biological structures combined
Subclass 1	Extent of biological structures
Categories	Types of biological structures
Attributes	Percentage of seabed covered by biological structures by type and all combined
[Note: Class 11 summarizes observations for Classes 9, 10.]	

Table 1 (continued)

Theme 6, Fauna and Flora	
Class 14	Faunal groups
Subclasses 1-6	Faunal groups (in several subclasses based on different methods of data collection; e.g. visual observations and/or specimens from various sampler types)
Categories	Faunal groups (e.g. erect sponges, burrowing anemones, sea stars, attached anemones)
Attributes	Presence/absence or percentage of seabed covered by individual faunal groups
[Note: All Categories and Attributes apply to Subclasses 1-6.]	
Class 15	Faunal species
Subclasses 1-6	Faunal species (in several subclasses based on different methods of data collection; e.g. visual observations and/or specimens from various sampler types)
Categories	Faunal species (e.g. Atlantic cod, *Gadus morhua*)
Attributes	Presence/absence or percentage of seabed covered by individual faunal species
[Note: All Categories and Attributes apply to Subclasses 1-6.]	
Class 16	Floral groups
Subclasses 1-6	Floral groups (in several subclasses based on different methods of data collection; e.g. visual observations and/or specimens from various sampler types)
Categories	Floral groups (e.g. calcareous algae, kelp)
Attributes	Presence/absence or percentage of seabed covered by individual floral groups
[Note: All Categories and Attributes apply to Subclasses 1-6.]	
Class 17	Floral species
Subclasses 1-6	Floral species (in several subclasses based on different methods of data collection; e.g. visual observations and/or specimens from various sampler types)
Categories	Floral species
Attributes	Presence/absence or percentage of seabed covered by individual floral species
[Note: All Categories and Attributes apply to Subclasses 1-6.]	
Theme 7, Habitat Association and Usage	
Class 18	Faunal habitat association: Essential Fish Habitat
Subclasses 1-6	Faunal EFH (in several subclasses based on different methods of data collection; e.g. visual observations and/or specimens from various sampler types)
Categories	Faunal species (e.g. Atlantic cod, haddock, yellowtail flounder)
Attributes	Types of Essential Fish Habitat by species (e.g. adult, spawning, juvenile habitat)
[Note: All Categories and Attributes apply to Subclasses 1-6.]	
Class 19	Human usage of habitat
Subclass 1	Human usage of habitat
Categories	Disturbed, undisturbed, or recovering habitat; kinds of disturbance (e.g. fishing, extraction)
Attributes	Types of disturbance activities (e.g. otter trawling, minerals mining)
Theme 8, Habitat Recovery from Disturbance	
Class 20	Habitat recovery from fishing disturbance
Subclass 1	Fishing disturbance
Categories	Recovery of physical structures and biological structures (e.g. bedforms, attached epifauna)
Attributes	Time required for recovery (e.g. months, year, decades)
Class 21	Habitat recovery from natural disturbance
Subclass 1	Natural disturbance
Categories	Recovery of physical structures and biological structures (e.g. fish burrows, emergent epifauna)
Attributes	Time required for recovery (e.g. months, year, decades)

Table 2. Structural complexity of habitats. The *percent of the seabed covered* by physical structures (Class 24) and by biological structures (Class 11) is based on visual observations and is estimated in nine semi-quantitative intervals that range from 0 to 100 percent. The *degree of structural complexity* of habitats is described in terms of the percent of seabed covered separately by physical and biological structures in seven qualitative intervals that range from none to very high. Wherever >50 percent of the seabed is covered by structures, the structural complexity is considered to be very high. The percent of the seabed covered by physical and biological structures combined can be greater than 100 percent (e.g. in the case of abundant epifauna on a rough seabed). See Table 3 and Appendix for examples showing how structural complexity is incorporated into habitat names.

Estimate of percent of seabed covered by physical (or biological) structures	Degree of structural complexity	Code
0	None	N
<1	Very very low	VVL
1-5	Very low	VL
5-10	Low	L
10-25	Medium	M
25-50	High	H
>50	Very high	VH
>90	Very high	VH
100	Very high	VH

Table 3. Habitat names. Three levels of descriptive habitat names (and codes) are based on seabed substrate dynamics from Class 2, seabed substrate type from Class 3, and the degree of physical and biological structural complexity of the seabed from Classes 24 and 11, respectively (Tables 1, 2). The least descriptive habitat name is based on seabed substrate type only (e.g. mud). More descriptive names incorporate a seabed dynamics term (e.g. immobile; mud) and a seabed structural complexity term (e.g. immobile; mud; physical structural complexity low; biological structural complexity very low). For further habitat description, a list of major habitat characteristics (dominant physical and biological structures, faunal and floral species, biological communities, functional groups) can be appended to a habitat name. Three examples are given below. See Note on structural complexity at the bottom of the table.

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

Explanation:
C. Habitat name is based on seabed dynamics, on seabed substrate type, and on physical and biological structural complexity. Immobile (I); mud (M); physical structures cover 5-10 percent of the seabed (ps5-10), physical complexity is low (L); biological structures cover <1 percent of the seabed (bs<1), biological complexity is very very low (VVL).
Further habitat characteristics: fish and crab burrows, flounder, ocean pout, cancer crabs.

Example 2.		
A. Coarse-grained sand (cgS)	B. Immobile; coarse-grained sand (I_cgS)	C. Immobile; coarse-grained sand; physical structural complexity very high; biological structural complexity medium (I_cgS_ps>50VH_bs10-25M)

Explanation:
C. Habitat name is based on seabed dynamics, on seabed substrate type, and on physical and biological structural complexity. Immobile (I); coarse-grained sand (cgS); physical structures cover >50 percent of the seabed (ps>50), physical complexity is very high (VH); biological structures cover 10-25 percent of the seabed (bs10-25), biological complexity is medium (M).
Further habitat characteristics: fish and scallop depressions, amphipod tubes, sea scallops, erect sponges, red hake.

Example 3.		
A. Sandy gravel (sG)	B. Intermixed mobile/immobile; sandy gravel (IMI_sG)	C. Intermixed mobile/immobile; sandy gravel; physical structural complexity very high; biological structural complexity low (IMI_sG_ps>90VH_bs5-10L)

Explanation:
C. Habitat name is based on seabed dynamics, on seabed substrate type, and on physical and biological structural complexity. Intermixed mobile/immobile (IMI); sandy gravel (sG); physical structures cover >90 percent of the seabed (ps>90), physical structure complexity is very high (VH); biological structures cover 5-10 percent of the seabed (bs5-10), biological structural complexity is low (L).
Further habitat characteristics: pebble and cobble gravel, sand ripples, erect sponges, hydrozoa, skate.

Note: Structural complexity of habitats is described in terms of the percent of the seabed covered by physical structures (Class 24) and by biological structures (Class 11). Based on visual observations, the percent of seabed cover is estimated in nine intervals (0, <1, 1-5, 5-10, 10-25, 25-50, >50, >90, and 100 percent). No structural complexity (N), 0 percent of seabed covered. Very very low (VVL), <1 percent. Very low (VL), 1-5 percent. Low (L), 5-10 percent. Medium (M), 10-25 percent. High (H), 25-50 percent. Very high (VH), >50 percent of seabed covered.

Table 4. Probable marine sublittoral habitat types. The dynamic aspects of seabed substrates (mobile substrate, immobile substrate, and intermixed mobile and immobile substrates) are found in Class 2, Subclasses 1-3. Seabed substrate types are found in Class 3, Subclasses 1-4 (Table 1). The number of probable habitats is determined by combining the three dynamic aspects of substrates from Class 2 with a number of seabed types selected from Class 3. Among the representative suite of 90 habitats shown here (more are possible), 45 are likely to occur in marine sublittoral environments. Habitats shown in *italics* are not likely to occur (although some might occur under certain conditions such as in high energy coastal environments). The structural complexity component of habitats is not considered here, but it would increase markedly the number of probable habitat types (see Table 2). The four examples from Georges Bank (see Appendix and Figures. 2-5) are listed below in Subclass 2, nos. 11, 26, and 6, and in Subclass 4, no. 7, respectively. See Notes below.

Habitat name (code) based on dynamic seabed types		Comments
Class 3. Seabed Texture, Hardness, and Layering in the Upper 5-10 cm		
Subclass 1. Fine-grained sediment: mud, very fine (4 phi), and fine (3 phi) sand.		
1. Immobile; mud (I_M)		
2.	Immobile; sandy mud (I_sM)	
3.	Immobile; fine-grained sandy mud (I_fgsM)	
4. Immobile; sand (I_S), also occurs in Subclass 2		
5.	Immobile; fine-grained sand (I_fgS)	
6.	Immobile; muddy sand (I_mS)	
7.	Immobile; muddy fine-grained sand (I_mfgS)	
8. *Mobile; mud (M_M)*		Note 1
9.	*Mobile; sandy mud (M_sM)*	Note 2
10.	*Mobile; fine-grained sandy mud (M_fgsM)*	“
11. Mobile; sand (M_S), also occurs in Subclass 2		
12.	Mobile; fine-grained sand (M_fgS)	
13.	*Mobile; muddy sand (M_mS)*	Note 3
14.	*Mobile; muddy fine-grained sand (M_mfgS)*	“
15. *Intermixed mobile/immobile; mud (IMI_M)*		Note 1
16.	*Intermixed mobile/immobile; sandy mud (IMI_sM)*	Note 2
17.	*Intermixed mobile/immobile; fine-grained sandy mud (IMI_fgsM)*	“
18. Intermixed mobile/immobile; sand (IMI_S), also occurs in Subclass 2		Note 4
19.	Intermixed mobile/immobile; fine-grained sand (IMI_fgS)	“
20.	*Intermixed mobile/immobile; muddy sand (IMI_mS)*	Note 3
21.	*Intermixed mobile/immobile; muddy fine-grained sand (IMI_mfgS)*	“
Subclass 2. Coarse-grained sediment: medium (2 phi), coarse (1 phi), and very coarse (0 phi) sand, and gravel.		
1. Immobile; sand (I_S), also occurs in Subclass 1		
2.	Immobile; coarse-grained sand (I_cgS)	
3.	Immobile; gravelly sand (I_gS)	
4.	Immobile; gravelly coarse-grained sand (I_gcgS)	
5. Immobile; gravel (I_G)		
6.	Immobile; pebble gravel (I_pG)	
7.	Immobile; cobble and boulder gravel (I_cbG)	
8.	Immobile; sandy gravel (I_sG)	
9.	Immobile; coarse-grained sandy gravel (I_cgsG)	
10. Mobile; sand (M_S), also occurs in Subclass 1		
11.	Mobile; coarse-grained sand (M_cgS)	
12.	*Mobile; gravelly sand (M_gS)*	Note 5
13.	*Mobile; gravelly coarse-grained sand (M_gcgS)*	“
14. *Mobile; gravel (M_G)*		“
15.	*Mobile; cobble and boulder gravel (M_cbG)*	Note 6
16.	*Mobile; sandy gravel (M_sG)*	Note 5
17.	*Mobile; coarse-grained sandy gravel (M_cgsG)*	“

Table 4 (continued)

Habitat name (code) based on dynamic seabed types		Comments
18. Intermixed mobile/immobile; sand (IMI_S), also occurs in Subclass 1		Note 4
19.	Intermixed mobile/immobile; coarse-grained sand (IMI_cgS)	“
20.	Intermixed mobile/immobile; gravelly sand (IMI_gS)	Note 7
21.	Intermixed mobile/immobile; gravelly coarse-grained sand (IMI_gcgS)	“
22. *Intermixed mobile/immobile*; *gravel (IMI_G)*		Note 5
23.	*Intermixed mobile/immobile*; *cobble and boulder gravel (IMI_cbG)*	Note 6
24.	Intermixed mobile/immobile; sandy gravel (IMI_sG)	Note 7
25.	Intermixed mobile/immobile; coarse-grained sandy gravel (IMI_cgsG	“
26.	Intermixed mobile/immobile; pebbles and cobbles in sand (IMI_pciS)	“
Subclass 3. Mixed fine-grained and coarse-grained sediment: mud, sand, and gravel mixtures.		
1. Immobile; mud, sand, gravel (I_MSG)		
2.	Immobile; mud, gravel (I_MG)	
3.	Immobile; muddy gravel (I_mG)	
4.	Immobile; gravelly mud (I_gM)	
5.	*Immobile*; *fine-grained sandy gravel (I_fgsG)*	Note 8
6.	*Immobile*; *gravelly fine-grained sand (I_gfgS)*	“
7.	Immobile; muddy coarse-grained sand (I_mcgS)	
8.	Immobile; coarse-grained sandy mud (I_cgsM)	
9. *Mobile*; *mud, sand, gravel (M_MSG)*		Note 9
10.	*Mobile*; *mud, gravel (M_MG)*	“
11.	*Mobile*; *muddy gravel (M_mG)*	“
12.	*Mobile*; *gravelly mud (M_gM)*	“
13.	*Mobile*; *fine-grained sandy gravel (M_fgsG)*	Notes 5, 8
14.	*Mobile*; *gravelly fine-grained sand (M_gfgS)*	“
15.	*Mobile*; *muddy coarse-grained sand (M_mcgS)*	Note 3
16.	*Mobile*; *coarse-grained sandy mud (M_cgsM)*	Note 2
17. *Intermixed mobile/immobile*; *mud, sand, gravel (IMI_MSG)*		Note 1
18.	*Intermixed mobile/immobile*; *mud, gravel (IMI_MG)*	“
19.	*Intermixed mobile/immobile*; *muddy gravel (IMI_mG)*	“
20.	*Intermixed mobile/immobile*; *gravelly mud (IMI_gM)*	“
21.	*Intermixed mobile/immobile*; *fine-grained sandy gravel (IMI_fgsG)*	Note 8
22.	*Intermixed mobile/immobile*; *gravelly fine-grained sand (IMI_gfgS)*	“
23.	*Intermixed mobile/immobile*; *muddy coarse-grained sand (IMI_mcgS)*	Note 3
24.	*Intermixed mobile/immobile*; *coarse-grained sandy mud (IMI_cgsM)*	Note 2
Subclass 4. Rock or other hard seabed (with or without mud, sand, gravel).		
1. Immobile; rock (I_R)		
2.	Immobile; mud on rock (I_MoR)	
3.	Immobile; sand on rock (I_SoR)	
4.	Immobile; fine-grained sand on rock (I_fgSoR)	
5.	Immobile; coarse-grained sand on rock (I_cgSoR)	
6.	Immobile; sand and gravel on rock (I_SGoR)	
7.	Immobile; pebbles, cobbles, boulders on rock (I_pcboR)	
8.	Immobile; gravel on rock (I_GoR)	
9. *Mobile*; *rock (M_R)*		Note 10
10.	*Mobile*; *mud on rock (M_MoR)*	“
11.	*Mobile*; *sand on rock (M_SoR)*	“
12.	*Mobile*; *fine-grained sand on rock (M_fgSoR)*	“
13.	*Mobile*; *coarse-grained sand on rock (M_cgSoR)*	“
14.	*Mobile*; *sand and gravel on rock (M_SGoR)*	“
15.	*Mobile*; *gravel on rock (M_GoR)*	“
16. *Intermixed mobile/immobile*; *rock (IMI_R)*		“

Table 4 (continued)

Habitat name (code) based on dynamic seabed types		Comments
17.	*Intermixed mobile/immobile*; *mud on rock (IMI_MoR)*	Notes 1, 10
18.	Intermixed mobile/immobile; sand on rock (IMI_SoR)	Note 7
19.	Intermixed mobile/immobile; fine-grained sand on rock (IMI_fgSoR)	“
20.	Intermixed mobile/immobile; coarse-grained sand on rock (IMI_cgSoR)	“
21.	Intermixed mobile/immobile; sand and gravel on rock (IMI_SGoR)	“
22.	*Intermixed mobile/immobile*; *gravel on rock (IMI_GoR)*	Notes 5,10

Notes:

1. Mud not likely mobile
2. Sandy mud not likely mobile
3. Muddy sand not likely mobile
4. Can occur in environments with large bedforms
5. Gravel particles >1 cm not likely mobile
6. Cobbles and boulders not likely mobile
7. Sand component is mobile
8. Gravel and fine-grained sand usually do not co-occur
9. Mud and gravel not likely mobile
10. Rock not mobile

Gravel is composed of granules (>1, <2 mm), pebbles (<64 mm), cobbles (<256 mm), boulders (>256 mm).

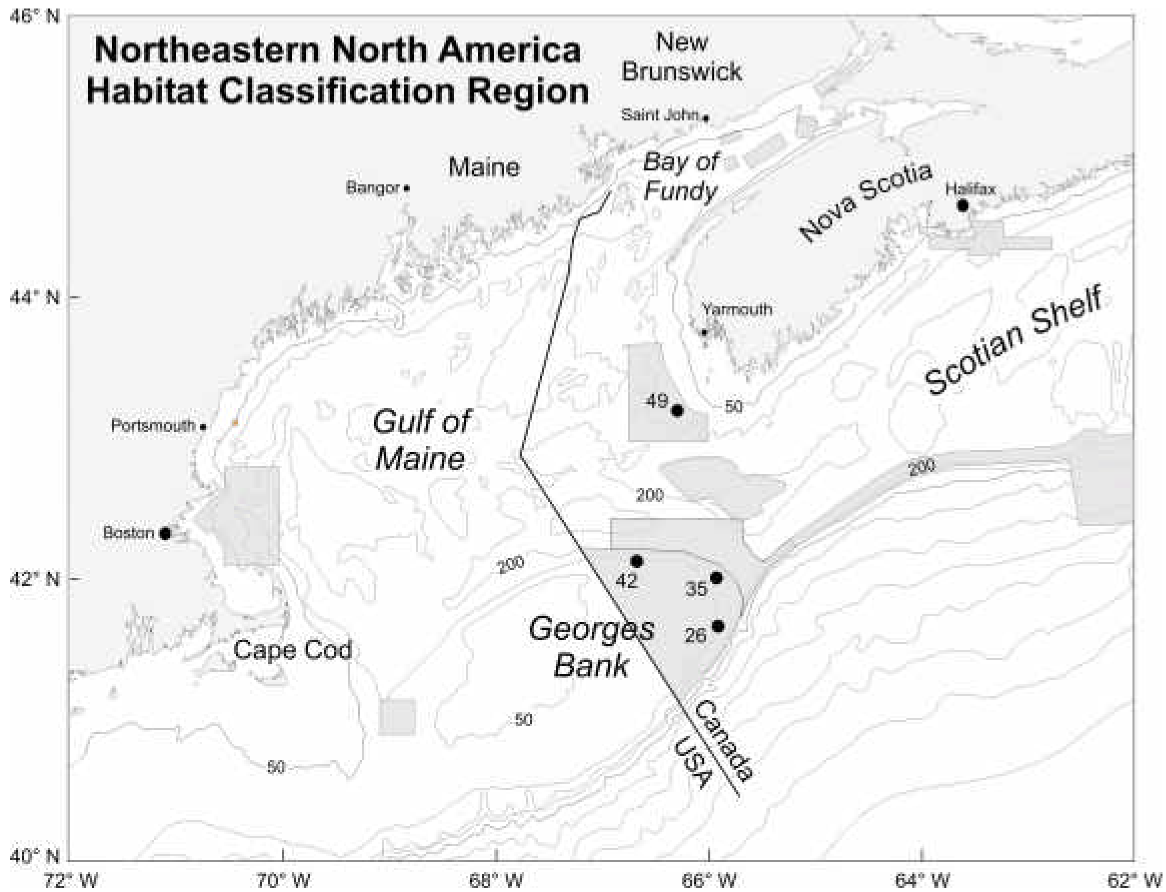

Figure 1. Map showing the geographic region that is the focus of the northeastern North America marine sublittoral habitat classification. The region is characterized by a wide variety of environments in continental shelf, deep bank and basin, and submarine canyon head settings. Shaded offshore areas have been surveyed using multibeam sonar mapping technology to produce high resolution topographic and backscatter imagery of the sea floor. Numbered dots indicate locations of stations 26, 35, 42, and 49 that are described as examples 1-4, respectively, in the Appendix and shown in Figures 2-5. Depth contours in meters.

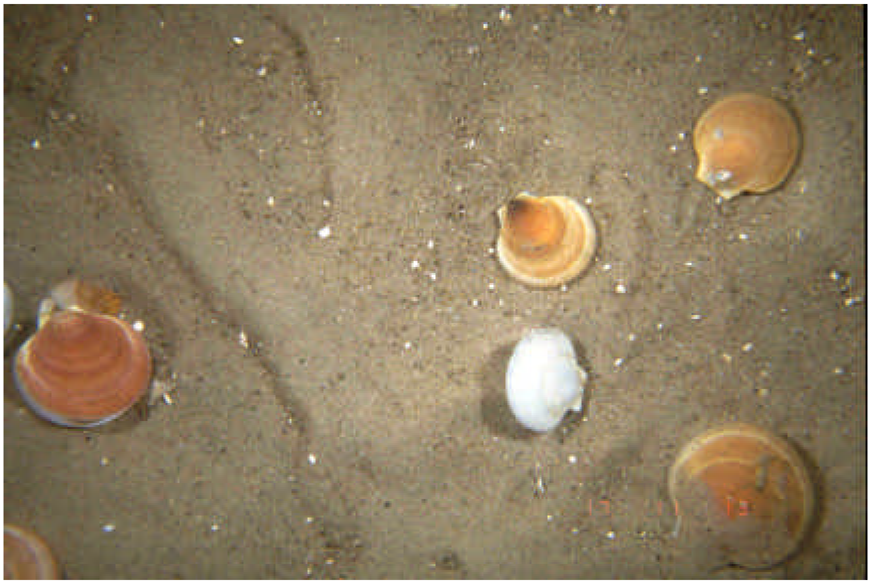

Figure 2. Mobile coarse-grained sand habitat (Example 1) with sea scallops (*Placopecten magellanicus*); eastern Georges Bank; water depth 96 m; image size approximately 51 x 76 cm (20 x 30 inches).

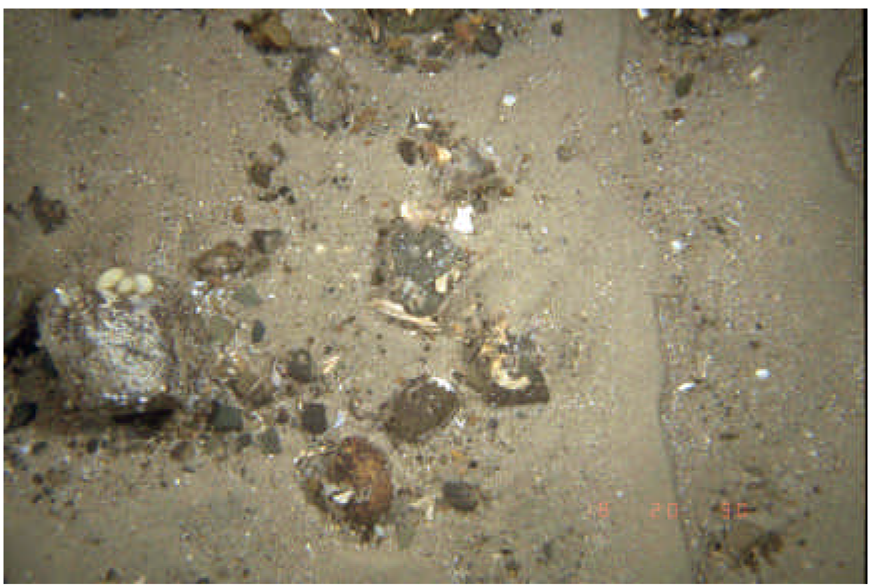

Figure 3. Intermixed mobile sand and immobile gravel habitat (Example 2) with epifauna (brachiopods, calcareous worm tubes) attached to gravel; eastern Georges Bank; water depth 152 m; image size approximately 51 x 76 cm (20 x 30 inches).

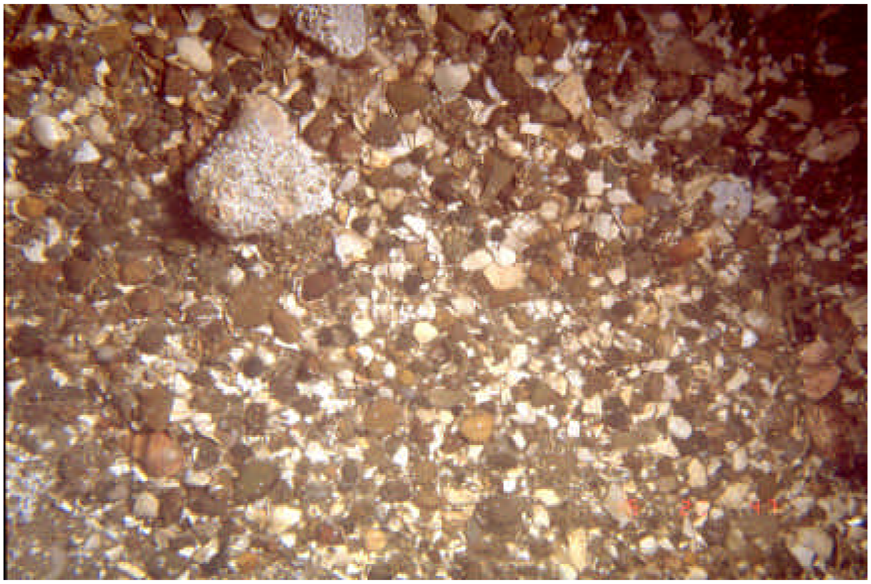

Figure 4. Immobile pebble gravel habitat (Example 3) with broken mollusk shells; epifauna (calcareous worm tubes) attached to cobbles; habitat disturbed by scallop dredging; this habitat lies adjacent to an undisturbed, mussel-encrusted, pebble gravel habitat with abundant epifauna; eastern Georges Bank; water depth 70 m; image size approximately 51 x 76 cm (20 x 30 inches).

Figure 5. Immobile rock outcrop habitat (Example 4) covered by attached epifauna (sponges, bryozoa, hydrozoa, calcareous worm tubes); German Bank; water depth 75-80 m; image size approximately 51 x 76 cm (20 x 30 inches).