Final Report

Essential Fish Habitat Characterization and Mapping of the California Continental Margin

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Introduction

This report briefly describes the procedures and methods that were used to characterize and map Essential Fish Habitats (EFH) for offshore California. The habitats characterized are an expanded version of those defined in the Magnuson-Stevens Act (16 USC 1801 *et seq.* 1996) because the original definition essentially encompassed two-thirds of the planet (Bax and Williams, 2001). As stated by these and other authors, vague or variable habitat definitions make if difficult to determine environmental effects of fishing and make management decisions problematic without further qualification. Our intent was to better define deep-water marine benthic habitats so that constructive management decisions can be made.

The National Marine Fisheries Service (NMFS) of NOAA approached the Center for Habitat Studies (CHS) of Moss Landing Marine Laboratories (MLML) in June 2001 to request assistance to characterize and map EFH in order to address legal concerns. A time frame of approximately 2 months (from June 20 to August 30, 2002) was initially established for the work, although the extent of the project was difficult to calculate at that time. It was agreed that this work would be coordinated with similar work being conducted for the Oregon and Washington offshore area so that a standardized habitat map would be produced for the west coast of the contiguous United States.

Statement of Work

The statement of work agreed upon for this project is as follows:

The Center for Habitat Studies (CHS) of Moss Landing Marine Laboratories (MLML) will synthesize all available analog and digital data to construct a marine benthic habitat map of the California Continental margin (to the 200 mile EEZ limit where data allows) that can be used to determine the areas and locations of interpreted seafloor habitat types. Seven 1:250,000-scale offshore geologic and marine benthic habitat maps that span the length of California, smaller scale industry and government data, bathymetric and side-scan sonar mosaics, and recently acquired multibeam bathymetric and backscatter images will be utilized to meet the above criteria and incorporated into an overall GIS. Habitat types will be interpreted by H. Gary Greene and attributed using a version of the deep-water marine benthic habitat scheme of Greene et al. (1999) that was modified to facilitate use in GIS programs. Area analyses of all delineated habitat types will be conducted and digital products will be produced as polygon shapefiles in ArcView® 3.2 or ArcGIS®. The project goals are to develop habitat maps in a GIS that can be queried to relate seafloor substrate type (hard, soft, mixed), approximate slope (or slope analyses where data allows), major geomorphic features such as submarine canyons, seamounts or prominent banks, and depth (bathymetry) for specific coordinates (represented in Latitude and Longitude or in UTM, as specified) or regions. The final products of this project are intended to provide biologists and resource managers with a starting point for habitat studies of commercially landed fishes and invertebrates and as a basis to determine future mapping efforts.

Procedures and Methods

Source materials for habitat interpretations in the region of interest (from the Oregon border to the Mexican border) consisted of digital multibeam, artificial sunshaded bathymetry and backscatter data, side-scan sonar, and hard copy geologic maps. This region was initially mapped for the California Department of Fish and Game (CDFG) under Contract #FG8293MR – "California nearshore marine habitats: Mapping and characterization" (2001). The habitat interpretation resulting from the CDFG project was used as the basemap for this work and was updated through the incorporation of new data sources. Habitat interpretations based on these sources were facilitated primarily through funding from the National Sea Grant Program (Grant #R/F-181A, 2002) and from supplemental funding provided by the Pacific States Marine Fisheries Commission.

Using digital imagery or hard copy maps as source materials, layouts were created in ArcView® and exported as georeferenced .tif files using the extension ArcPress. For digital data, this process was repeated at different scales until a final scale, most appropriate to the data quality, was chosen for habitat interpretations. Hard copy maps were scanned, resized to 36" x 42", and printed for interpretation. If multibeam imagery was used, backscatter data were printed at the same scale. Mylar sheets were affixed over the final printed layouts and coordinate tic marks were copied onto the Mylar sheets for later georeferencing. For this project, all files were projected in either Universal Transverse Mercator (UTM) Zone 10 (north of Point Conception) or Zone 11 (south of Point Conception) with a World Geodetic System (WGS) 84 datum and spheroid.

A coding system was established to standardize attributes used during habitat interpretations and to facilitate ease of use and queries in GIS and other database programs (Table I). This code was modified from the deep-water habitat characterization scheme developed by Greene et al. (1999) and based on interpretations of seafloor geology, morphology, and biology. A copy of the most recent habitat attribute code and a corresponding explanation are included as Appendices I and II and can also be found on the MLML Center for Habitat Studies web site: www.mlml.calstate.edu/groups/geooce/habcent.htm

Seafloor imagery was interpreted and habitat types were outlined (mapped), based on knowledge of the geology and seafloor processes in a particular study area, as the first steps in map production. Interpretations were made on a light table by drawing polygons on a Mylar overlay of the source image around distinct habitat features based on geological processes, structure and morphology. Geologic and sediment maps were modified and reclassified into habitat types. Multibeam and backscatter data provided a general picture of the location of bedrock and unconsolidated sediment. Resolution of the interpretations varied with the quality and scale of the images. However, on most images, we could easily identify such seafloor features as bedrock types (e.g., sedimentary rocks, crystalline rocks, and carbonate mounds), structures (e.g., faults, folds, and landslides), and bedforms of unconsolidated sediment such as sand waves.

Once interpretations were finalized, Mylar overlays were scanned using the WideImage® program, with the scan preset on Mylar, georeferenced to 0.5m (when possible), and processed in GIS programs (TNT Mips® and ArcView®). Scanned Mylars were then printed and used to attribute habitats. Individual polygons were color-coded on printed Mylar copies. This served to check the habitat interpretations and to assist in final editing. Processed files (rasters) were edited in the Spatial Data Editor within TNT Mips®. Unwanted features such as speckles, attribute numbers and text from within the interpreted polygons, and tick marks were erased during this process. Dashed lines were connected and missing lines were re-drawn using a drawing tool. The final raster file was then converted to a vector file using the Auto Trace method in TNT Mips®. Several tests were run before the final conversion in order to check the results of the line editing and tracing.

After raster to vector conversion, the vector file was edited to either delete or add nodes and lines and to correct the shape of polygons. During vector editing the original georeferenced .tif files were used for reference. These files were imported into TNT Mips® and then projected as layers beneath the vector file in the Spatial Data Editor. The edited vector was then warped to create an implied georeference with the output projection set, as appropriate. If necessary, smoothing of the warped vector file was performed with the Vector Filtering tool. If the lines were too angular, the smoothing process was used to better round the curves. Several tests were run before the final smoothing to ensure that no features were omitted during processing.

If more than one interpreted Mylar sheet existed for an area, the warped (and filtered) vector files were merged. Final cleaning was done with the Spatial Data Editor. The original georeferenced .tifs were once again projected as layers beneath the vector file and used as references. Special attention was paid to the overlapping areas to make sure that all of the lines met and all polygons closed. Once final cleaning changes were made, the file was exported as a shapefile (.shp). Shapefiles were opened in ArcView® where a legend (explanation) file was added and any additional attribute fields were included in the attribute table. The file was checked for proper georeferencing and for overlapping polygons, and area analysis was performed on each habitat type using the feature geometry calculator extension in ArcView®.

Due to the breadth of this project, the offshore region of California was subdivided into three regions (Northern, Central, and Southern California) for data compilation and interpretation. From one to three CHC graduate students and staff members worked to locate and assimilate all available data from each region into a GIS. All data for each region were then synthesized and plotted for interpretation as described above. Transitions between regions were edited to insure continuity and three final habitat maps were submitted to TerraLogic GIS, Inc. as final products. After troubleshooting, these maps were then merged to form one contiguous habitat map of offshore California.

The senior author of this report, who performed the original interpretations, was available during all stages and consulted when questions arose. In this way, we were able to provide consistency within and among the various areas and regions. As additional data becomes available, this habitat interpretation of the region of interest can be further refined and updated in the same manner outlined above.

Data Sources and Quality

Extensive public and private holdings of offshore geologic and deep-water marine benthic habitat data sets were compiled and incorporated into this work. These data sets can be subdivided into two main types: 1) those that were incorporated into a general basemap for this work and were therefore created from data sources that extended throughout the California offshore region, 2) those that were derived from smaller areas and based on imagery collected and interpreted at higher resolution. These higher resolution habitat maps were integrated into the lower resolution basemap to improve and update it, where possible. Footprint maps depicting data type and quality for all interpreted geophysical datasets are included as Appendix III.

Basemap

The California Marine Benthic Habitat Map Series (CMBHMS) was used as the basemap for the Southern and Central regions (Kvitek et al., 2001). These interpretive maps were based on the seafloor geology depicted in the California Continental Margin Geologic Map Series (CCMGMS, 1:250,000) jointly published by the California Department of Mines and Geology (CDMG) and USGS (Greene and Kennedy, 1986, 1987a,b, 1989a,b, 1990). The CMBHMS consists of probabilistic maps in the sense that they delineate areas where various geologic or substrate types likely crop out on the seafloor. Although seven adjacent regions encompassing all of offshore California were mapped in this series, contiguous geologic maps were created only for Areas 1-5, corresponding to the region from the Mexican border to Tomales Bay. Therefore, the basemap available for the Northern region, created solely from the limited geologic map of Area 7, was far less detailed and devoid of data in most regions. Each habitat type depicted in the CMBHMS was modified to one of the 46 available habitat types developed for this project (Table I). Habitat attributes were determined from seafloor geology, bathymetry, and previously interpreted habitat. These attributes characterize habitat types that range from soft, unconsolidated mud to hard granite basement rock exposures.

Construction of the CCMGMS was based primarily on seismic-reflection profile and seafloor sediment and rock sample data. These data provided a general picture of where bedrock and unconsolidated sediment are located with lithologic contacts being interpretive. Although more advanced imaging techniques are now available, no other extensive data sets exist in the offshore California margin to provide a regional outline of the various lithologic units that may crop out on the seafloor. Most all lithologic units depicted in the CCMGMS, with the exception of Quaternary sedimentary units, are either exposed on the seafloor or lie no more than three meters beneath the seafloor. This detail was taken into consideration during the interpretive process that led to the construction of both the CMBHMS and the EFH products. However, it should be noted that not all of the more than 70 habitat types defined in the CMBHMS easily converted to the more restrictive code established for this project.

After the CMBHMS was converted to EFH attributes, it was separated into Southern, Central, and Northern regions as previously described and augmented in each region with newly interpreted, higher resolution data sources. The project "Fisheries habitat characterization of the

California Continental Margin: Identification, quantification, and synthesis of existing information.", developed for the National Sea Grant College System was being completed within the duration of this project (Greene et al. 2002). Maps developed for Sea Grant were modified to fit EFH attributes in the manner described above and integrated into the CMBHMS basemap for each region. Many additional data sources were also located and interpreted specifically for this project. In addition, two digital bathymetry files of offshore California were used during interpretations and were helpful in distinguishing physiographic provinces and large-scale seafloor features. Bathymetry was also contoured and used whenever possible from region-specific multiebeam grids. A list of these and all geophysical data sources interpreted for this project is included (Table II).

How to Use these Maps

The habitat maps produced under this contract reflect the most probable locations for the various habitat types depicted. However, in many cases basement and bedrock outcrops are probably locally or extensively covered with thin (<1m) Quaternary sediment and soft sedimentary habitats may contain some rocky outcrops. This is largely a result of the scale of the map interpretations and the sampling methods. In general, the accuracy and detail of the map interpretations is directly related to the resolution of the source data.

These maps are excellent formulative tools and can be used to effectively plan for scientific investigations that require knowledge about potential seafloor conditions. They are useful for determining bottom relief, physiography, geomorphology and other parameters important for classifying EFH or as a basis for habitat affinity studies that can lead to effective conservation and management.

Results

Like all interpretive seafloor maps, this map series is in flux and will need to be periodically updated once significant new data are available. For example, new geologic and bathymetric data recently published for the Monterey Bay, Santa Barbara Channel and Southern California Borderland regions are not included in this series and should be incorporated in the near future. Extensive seafloor observations, video data, and rock samples have also recently been collected in southern California by Mary Yoklavich and others during six-weeks of manned submersible dives. Some of these data are being used to groundtruth and update interpretations a small portion of that region part of a separate project. We are also aware of several other new data sets that are becoming available and are poised to utilize these data to update and modify the EFH maps once the need is recognized and supported.

Due to the extensive distillation of complex previously interpreted habitat types to the more limited EFH habitat types, confusing, and sometimes misleading, habitat characteristics have been designated in some instances. This is often the case where habitats were previously determined to be a mixture of both hard and soft substrate. Under the EFH attribute code, no mixed category was available. This has no doubt resulted in the misdesignation of some habitats as soft when they may be either mixed or primarily hard (and vice-versa).

From simple map observations one can determine the resolution and sophistication of the data sets used in the compilation along with the confidence of the interpretations. Boundaries that delineate habitat types (polygons) can be used as the determining feature. For example, boundaries that are comprised of general sweeping curves at large scales represent poorly defined and mapped habitat. Conversely, boundaries that are more crenellated and complex represent smaller scale, higher resolution data sets and a greater degree of confidence in the interpretations. For more specific data inquiries, a table containing mapping scales, data types, and data sources are included (Table II).

Conclusions

The California Marine Benthic Habitat Map Series and the EFH maps represent the most comprehensive habitat maps of the seafloor found anywhere in the world. Although these maps are probabilistic, they represent the most advanced knowledge available with regard to the interpretation of seafloor habitat types in the offshore region of California. However, they can be considerably improved over time and with the addition of technologically advanced data sets such as digital multibeam bathymetric and backscatter images, the accuracy and resolution can be enhanced. It must be considered that the final EFH map of California was constructed over a very short time frame (less than 4 months) from a multitude of disparate bathymetric and geophysical data sets that individually required intensive interpretation. This process allowed for the production of only preliminary EFH maps, maps that are in need of groundtruthing and critical editing. Nevertheless, these maps will provide indications of: 1) where various habitat types are located, 2) what the mapping accuracy is, and 3) where data voids are located and future mapping efforts should be concentrated.

Literature Cited:

Bax, N.J. and Williams, A. 2001. Seabed habitat on the south-eastern Australian Continental shelf: context, vulnerability, and monitoring. Mar. Fresh. Res. 52(4): 491-512.

Greene, H.G. Kvitek, R., Bizzarro, J.J., Iampietro, P., and Bretz, C. 2002. "Fisheries habitat characterization of the California Continental Margin: Identification, quantification, and synthesis of existing information." National Sea Grant College System Project #R/F-181A. Vol. 1-4.

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. Vol. 22: 6. pp. 663-678.

Greene, H.G. and Kennedy, M.P. (eds.), 1986a,b, 1987a,b, 1989, 1990. Geologic Map Series of the California Continental Margin: California Division of Mines and Geology, Area 1 through 7, Maps 1A through 7D (28 maps), Scale 1:250,000.

Kvitek, R., Greene, H.G., Iampietro, P., Bretz, C., Sandoval, E., and Bizzarro, J.J. 2001. "California nearshore marine habitats: Mapping and characterization." California

Department of Fish and Game Contract #FG8293MR. Vol. 1-7.

APPENDIX I

Deep-Water Marine Benthic Habitat Classification Scheme

Key to Habitat Classification Code for Mapping and use with GIS programs

(modified after Greene et al., 1999)

<u>Interpreted from remote sensing imagery for mapping purposes</u>

Megahabitat – Use capital letters (based on depth and general physiographic boundaries; depth ranges approximate and specific to study area).

A = Aprons, continental rise, deep fans and bajadas (3000-5000 m)
B = Basin floors, Borderland types (floors at 1000-2500 m)
F = Flanks, continental slope, basin/island-atoll flanks (200-3000 m)
I = Inland seas, fiords (0-200 m)
P = Plains, abyssal (>5000 m)
R = Ridges, banks and seamounts (crests at 200-2500 m)
S = Shelf, continental and island shelves (0-200 m)

Seafloor Induration - Use lower-case letters (based on substrate hardness).

h = hard substrate, rock outcrop, relic beach rock or sediment pavement
m = mixed (hard & soft substrate)
s = soft substrate, sediment covered

<u>Sediment types</u> (for above indurations) - Use parentheses.

(b) = boulder
(c) = cobble
(g) = gravel
(h) = halimeda sediment, carbonate
(m) = mud, silt, clay
(p) = pebble
(s) = sand

Meso/Macrohabitat - Use lower-case letters (based on scale).

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

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

r = rill

s = scarp, cliff, fault or slump

t = terrace

w = sediment waves

y = delta, fan

$z_{\#}$ = zooxanthellae hosting structure, carbonate reef

- 1 = barrier reef
- 2 = fringing reef
- 3 = head, bommie
- 4 = patch reef

Modifier - Use lower-case subscript letters or underscore for GIS programs (textural and lithologic relationship).

$_a$ = anthropogenic (artificial reef/breakwall/shipwreck)

$_b$ = bimodal (conglomeratic, mixed [includes gravel, cobbles and pebbles])

$_c$ = consolidated sediment (includes claystone, mudstone, siltstone, sandstone, breccia, or conglomerate)

$_d$ = differentially eroded

$_f$ = fracture, joints-faulted

$_g$ = granite

$_h$ = hummocky, irregular relief

$_i$ = interface, lithologic contact

$_k$ = kelp

$_l$ = limestone or carbonate

$_m$ = massive sedimentary bedrock

$_o$ = outwash

$_p$ = pavement

$_r$ = ripples

$_s$ = scour (current or ice, direction noted)

$_u$ = unconsolidated sediment

$_v$ = volcanic rock

Seafloor Slope - Use category numbers. Typically calculated for survey area from x-y-z multibeam data.

1 Flat (0-1º)

2 Sloping (1-30º)

3 Steeply Sloping (30-60º)

4 Vertical (60-90º)

5 Overhang (> 90º)

Seafloor Complexity - Use category letters (in caps). Typically alculated for survey area from x-y-z multibeam slope data using neighborhood statistics and reported in standard deviation units.

A Very Low Complexity (-1 to 0)

B Low Complexity (0 to 1)

C Moderate Complexity (1 to 2)
D High Complexity (2 to 3)
E Very High Complexity (3+)

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

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

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

Determined from video, still photos, or direct observation.

Macro/Microhabitat – Preceeded by an asterik. Use parentheses for geologic attributes, brackets for biologic attributes. Based on observed small-scale seafloor features.

Geologic attributes (note percent grain sizes when possible)
(b) = boulder
(c) = cobble
(d) = deformed, faulted, or folded
(e) = exposure, bedrock (sedimentary, igneous, or metamorphic)
(f) = fans
(g) = gravel
(h) = halimeda sediment, carbonate slates or mounds
(i) = interface
(j) = joints, cracks, and crevices
(m) = mud, silt, or clay
(p) = pebble
(q) = coquina (shell hash)
(r) = rubble
(s) = sand
(t) = terrace-like seafloor including sedimentary pavements
(w) = wall, scarp, or cliff

Biologic attributes
[a] = algae
[b] = bryozoans
[c] = corals
[d] = detritus, drift algae
[g] = gorgonians
[n] = anemones

[o] = other sessile organisms
[s] = sponges
[t] = tracks, trails, or trace fossils
[u] = unusual organisms, or chemosynthetic communities
[w] = worm tubes

Seafloor Slope - Use category numbers. Estimated from video, still photos, or direct observation.

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

Seafloor Complexity - Use category numbers. Estimated from video, still photos, or direct observation. Numbers represent seafloor rugosity values calculated as the ratio of surface area to linear area along a measured transect or patch.

A Very Low Complexity (1 to 1.25)
B Low Complexity (1.25 to 1.50)
C Moderate Complexity (1.50 to 1.75)
D High Complexity (1.75 to 2.00)
E Very High Complexity (2+)

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

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

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

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

APPENDIX II

Deep-Water Marine Benthic Habitat Classification Scheme

Explanation for Habitat Classification Code

(modified after Greene et al., 1999)

Habitat Classification Code

A habitat classification code, based on the deep-water habitat characterization scheme developed by Greene et al. (1999), was created to easily distinguish marine benthic habitats and to facilitate ease of use and queries within GIS (e.g., ArcView®, TNT Mips®, and ArcGIS®) and database (e.g., Microsoft Access® or Excel®) programs. The code is derived from several categories and can be subdivided based on the spatial scale of the data. The following categories apply directly to habitat interpretations determined from remote sensing imagery collected at the scale of 10s of kilometers to 1 meter: Megahabitat, Seafloor Induration, Meso/Macrohabitat, Modifier, Seafloor Slope, Seafloor Complexity, and Geologic Unit. Additional categories of Macro/Microhabitat, Seafloor Slope, and Seafloor Complexity apply to areas at the scale of 10 meters to centimeters and are determined from video, still photos, or direct observations. These two components can be used in conjunction to define a habitat across spatial scales or separately for comparisons between large and small-scale habitat types. Categories are explained in detail below. Not all categories may be required or possible given the study objectives, data availability, or data quality. In these cases the categories used may be selected to best accommodate the needs of the user.

Explanation of Attribute Categories and their Use

Determined from Remote Sensing Imagery (for creation of large-scale habitat maps)

1) Megahabitat **–** This category is based on depth and general physiographic boundaries and is used to distinguish regions and features on a scale of 10s of kilometers to kilometers. Depth ranges listed for category attributes in the key are given as generalized examples. This category is listed first in the code and denoted with a capital letter.

2) Seafloor Induration – Seafloor induration refers to substrate hardness and is depicted by the second letter (a lower-case letter) in the code. Designations of hard, mixed, and soft substrate may be further subdivided into distinct sediment types, which are then listed immediately afterwards in parentheses either in alphabetical order or in order of relative abundance.

3) Meso/Macrohabitat – This distinction is related to the scale of the habitat and consists of seafloor features ranging from 1 kilometer to 1 meter in size. Meso/Macrohabitats are noted as the third letter (a lower-case letter) in the code. If necessary, several Meso/Macrohabitats can be included either alphabetically or in order of relative abundance and separated by a backslash.

4) Modifier **–** The fourth letter in the code, a modifier, is noted with a lower-case subscript letter or separated by an underline in some GIS programs (e.g., ArcView®). Modifiers describe the texture or lithology of the seafloor. If necessary, several modifiers can be included alphabetically or in order of relative abundance and separated by a backslash.

5) Seafloor Slope – The fifth category, represented by a number following the modifier subscript, denotes slope. Slope is typically calculated for a survey area from x-y-z multibeam data and category values can be modified based on characteristics of the study region.

6) Seafloor Complexity – Complexity is denoted by the sixth letter and listed in caps. Complexity is typically calculated from slope data using neighborhood statistics and reported in standard deviation units. As with slope, category values can be modified based on characteristics of the study region.

7) Geologic Unit – When possible, the geologic unit is determined and listed subsequent to the habitat classification code in parentheses.

Determined from video, still photos, or direct observation (for designation of small-scale habitat types)

8) Macro/Microhabitat –Macro/Microhabitats are noted by the eighth letter in the code (or first letter, if used separately) and preceded by an asterisk. This category is subdivided between geologic (surrounded by parentheses) and biologic (surrounded by brackets) attributes. Dynamic segmentation can be used to plot macroscale habitat patches on Mega/Mesoscale habitat interpretations (Nasby 2000).

9) Seafloor Slope – The ninth category (or second category, if used separately), listed by a number denotes slope. Unlike the previous slope designation (#5), the clarity of this estimate can be made at smaller scales and groundtruthed or compared with category #5. Category values can be modified based on characteristics of the study region.

10) Seafloor Complexity – The designations in this category, unlike those in category #6, are based on seafloor rugosity values calculated as the ratio of surface area to linear area along a

measured transect or patch. Category letters are listed in caps and category values can be modified based on characteristics of the study region.

Literature Cited:

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. A classification scheme for deep seafloor habitats. Oceanologica Acta. Vol 22: 6. pp. 663-678.

Nasby, N.M. 2000. Integration of submersible transect data and high-resolution sonar imagery for a habitat-based groundfish assessment of Heceta Bank, Oregon. M.S. Thesis, College of Oceanic and Atmospheric Science, Oregon State University. pp. 49.