❖STANDARD 7: SELECT TERRESTRIAL, FRESHWATER AND MARINE CONSERVATION TARGETS/BIODIVERSITY ELEMENTS/FEATURES ACROSS MULTIPLE BIOLOGICAL AND SPATIAL SCALES.

Case Study: Pacific Northwest Coast (PNWC) Ecoregion Offshore Classification Methodology

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Purpose and Region of Analysis

This document describes an innovative method for classifying and mapping offshore benthic habitats. We utilized a topographic model and existing classifications that characterize depth and benthic substrate to model and generate offshore benthic conservation targets. Use of the benthic habitat model assumes that benthic habitat types can serve as a surrogate or coarse filter for the conservation of the majority of bottom-dwelling species in an ecoregion. The ideal data for mapping marine ecosystems is biological data on the distribution and abundance of species in the water and on the sea bottom. Unfortunately, these data are scarce offshore.

Lacking regionally comprehensive biological data along the Pacific Northwest Coast (PNWC), the Conservancy has focused on the use of geophysical data. We predict that many geophysical variables (e.g., temperature, depth and sediment type) can be correlated with the occurrence of different types of species. Geophysical information that is most useful includes sea surface temperature, bottom temperature, depth, bottom sediment type, phytoplankton density (chlorophyll a), currents and bathymetry (underwater topography). Our current model presented here uses bathymetry and marine geology to depict depth, geomorphology, and substrate type.

It is our hope that the benthic model will be predictive of ecosystem targets. Output of the model, however, needs to be tested against higher resolution data (i.e., multibeam) and underwater surveys to determine the accuracy of identifying landforms on the seafloor. In addition, these data need to be correlated with biotic assemblages in determining community or ecosystem types. A recent study used local population density estimates of juvenile demersal finfish from trawl survey data as a meaningful indicator of habitat value (Cook and Auster 2005). We believe associating species data with modeled data on benthic habitats will ultimately give us a more accurate spatial assessment of species-habitat utilization. Lastly, it should be noted that this model cannot be used to predict surface or water column patterns in diversity. Other models are required in examining the pelagic environment.

Criteria/Methods

In order to generate a continuous surface depicting the seafloor, we used a mosaic of regional bathymetric data sets to examine interpolation techniques of sounding point data. Digital Elevation Models (DEMs) of the seafloor are distinct from terrestrial models in that the survey efforts required to produce a continuous surface of depth across a region are often inconsistent temporally, spatially and methodologically. Therefore, careful examination of interpolation methods was conducted before an appropriate surface was used to model benthic habitats.

After generating a continuous surface depicting the seafloor, we examined several models that 1) classify the benthic environment into distinct landforms on the seafloor, or bedforms, and 2) identify areas of high bottom complexity, or roughness. These modeling efforts were based on bathymetry data from the National Oceanic and Atmospheric Administration (NOAA), Washington Department of Fish & Wildlife (WDFW), and the Ministry of Sustainable Resource Management (MSRM) in British Columbia, Canada. These models have been used for marine ecoregional planning throughout the continental U.S., including the Southern and Northern California ecoregions, the Floridian and Carolinian on the east coast, as well as in the Northwest Atlantic Coastal and Marine region. This document is part one of a two part series, and focuses on the development of bedforms for the Pacific Northwest Coast ecoregion (Figure 1).

Using a variety of bathymetry data sets (NOAA, WDFW, MSRM) we examined several methods for creating a continuous seafloor surface. The particular method for generating a bathymetric surface is a critical step in that all subsequent analyses are based on its interpolation. Describing our analysis for this step is beyond the scope of this marine case study, but will be included in a future iteration. Here we describe our modeling efforts that generate offshore benthic conservation targets: classifying the benthic environment into distinct bedforms.

Classification of the Benthic Environment

The results of the model described below produce benthic habitats used as offshore conservation targets. This approach to modeling coarse scale habitats provides promise in areas of the world where comprehensive thematic mapping of the seafloor has not occurred. The benthic model combines three parameters:

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TOPOGRAPHIC (BATHYMETRIC) LANDFORM + DEPTH + SUBSTRATE

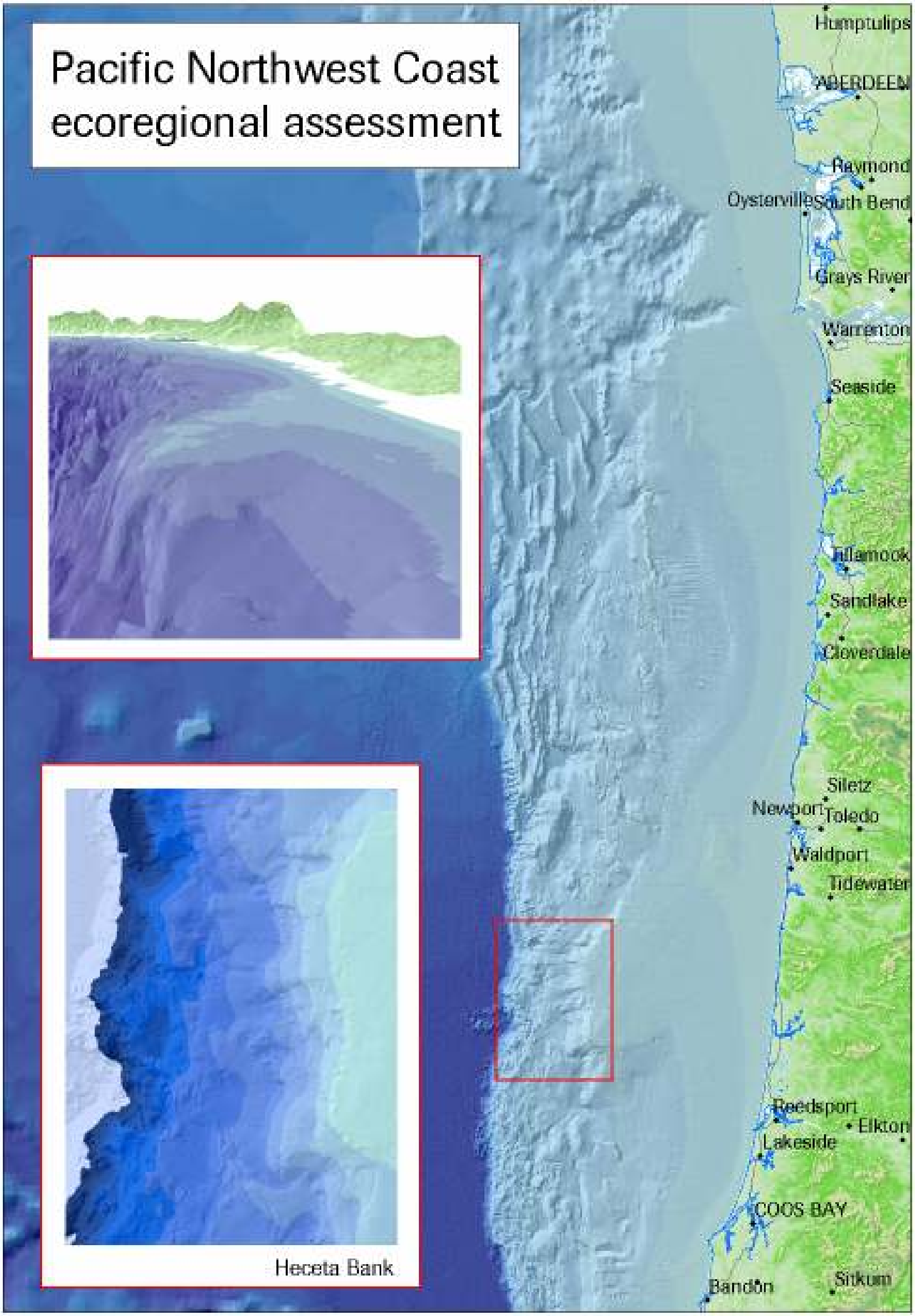


Figure 1: Pacific Northwest Coast ecoregional assessment

We applied a landscape position model described in Fel & Zobel (1995), and later described in detail by Weiss (2001). Since landscape classifications are not based on morphology alone but also on the position of the land surface in relation to its surroundings, Fel (1994) developed a quantitative index of landscape position. Also called Topographic Position Index, or TPI, the basic algorithm compares the elevation of a given cell in a Digital Elevation Model (DEM) to the mean elevation of a specified neighborhood around that cell. Positive TPI values represent locations that are higher than the average of their surroundings, while negative TPI values represent locations that are lower than their surroundings. TPI values near zero are flat areas. This model was created to describe landforms in the terrestrial environment, but is easily adaptable to marine data.

Topographic position is an inherently scale-dependent phenomenon. Scale of the source data and the landscape context are two important factors to consider when deciding the search radius of a specified neighborhood (see Zeiler 1999 for a good explanation of geospatial terminology).

a) Scale of the source data determines the level of detail that the model can depict. For instance, if the search radius is small then features within a small geography will be explicitly depicted, given detailed source data; on the contrary, if the search radius is large, then features may be missed or dissolved into larger categories. This scenario can also be true if the search radius is smaller than the source data can support. In other words, if the search radius is relatively small for coarse scale data then errors in interpolation may be mistaken for distinct features. To avoid these potential miscalculations it is important to evaluate the scales of the source data and examine different search radii to determine appropriate output models.

b) Landscape context determines the position of a distinct feature in relation to its surroundings. For example, a point in a valley may be coded as flat when the search radius is small; with a large search radius that same point may be considered at the bottom of a canyon if the surrounding area contains steep slopes that rise dramatically. Therefore, the nature of the broader land or seascape needs to be considered when setting the search radius in order to accurately represent variation in habitat.

As a general rule, the continuum of TPI values sort out along a topographic gradient from depressions and canyon or valley bottoms through lower slopes, mid slopes, upper slopes, up to ridge and hilltops. By determining thresholds for the continuous values they can be classified into distinct slope position categories (Figure 2).

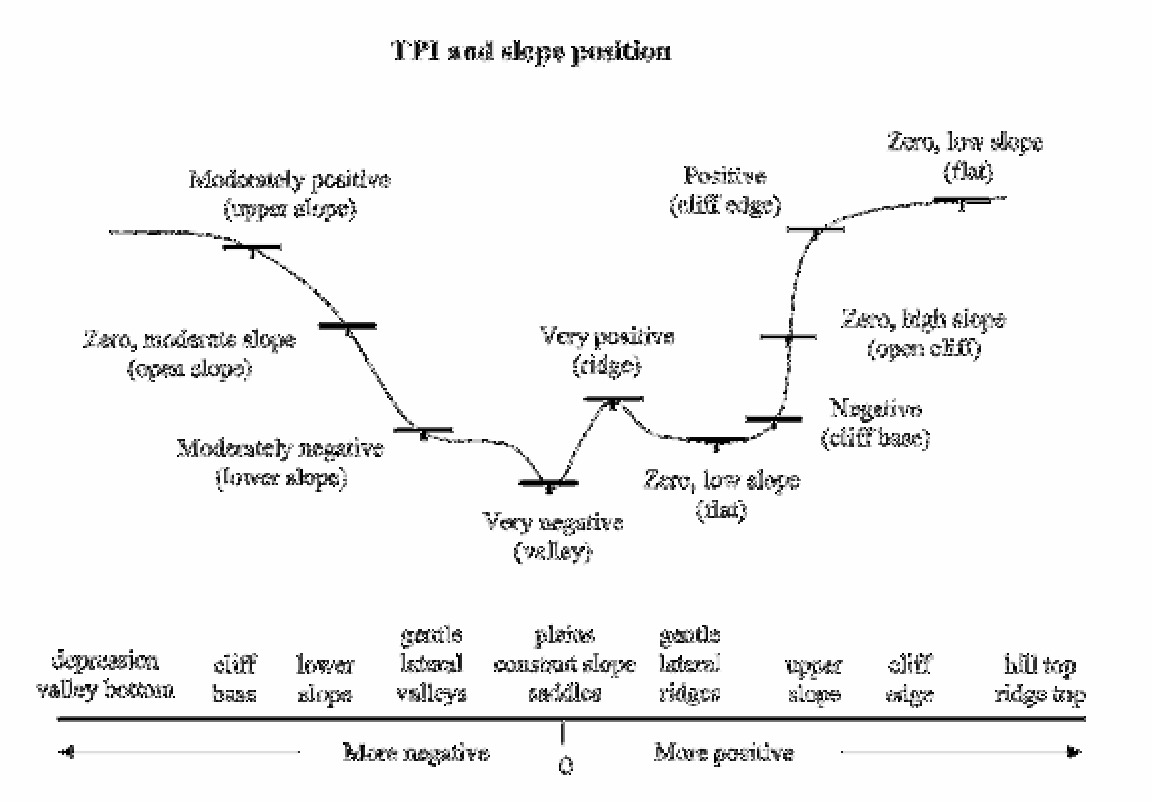


Figure 2: TPI is scale-dependent both in terms of a specified neighborhood surrounding a particular point on the landscape, and the level of detail supported by the source data. Both these factors directly determine the accuracy of modeling specific benthic features along a gradient of continuous values.

Many physical and biological processes acting at a given location are highly correlated with the topographic position: a hilltop, valley bottom, exposed ridge, flat plain, upper slope, etc. These processes (i.e., soil deposition, hydrologic balance and response, wind or wave exposure) are often important predictors of vegetation and other biota. Physical processes are difficult to model directly across large areas, but an index of topographic position can be used within a statistical predictive modeling framework as a surrogate variable to represent the spatial variation of these processes.

For this exercise we modeled benthic landforms, or bedforms, using the same principles and tools developed in terrestrial models (Figure 3). In both environments a cell-based DEM is required, with cell values either representing elevation (positive) or depth (negative).

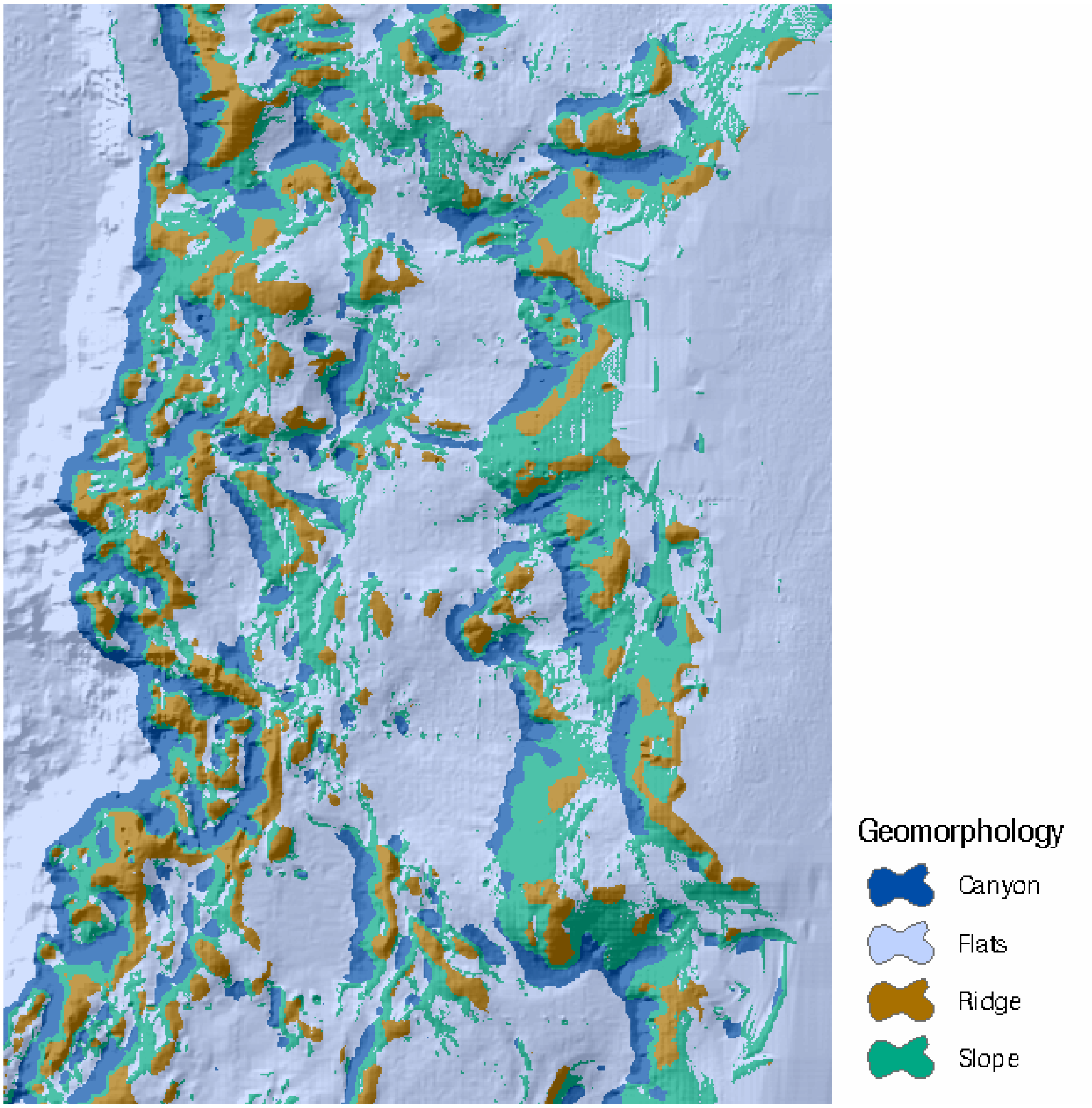


Figure 3: Classified landforms on the seafloor, or bedforms, for Heceta Bank off the Oregon Coast.

Recently, marine practitioners have adopted this method for deriving landforms, calling this the Bathymetric Position Index, or BPI (Rinehart et al. 2004). Although the BPI model derives landforms on the seafloor, we have added two factors that further delineate distinct marine formations: depth classes and substrate types. We used existing benthic landform classifications (Greene 1999, Allen and Smith 1988) to guide our depth class breaks and incorporate substrate type to explicitly target seafloor characteristics. Depth ranges were as follows (Figure 4):

Class	Definition
Inner shelf	0-40m
Mid shelf	40-200m
Mesobenthal	200-700m
Bathybenthal	700-5000m

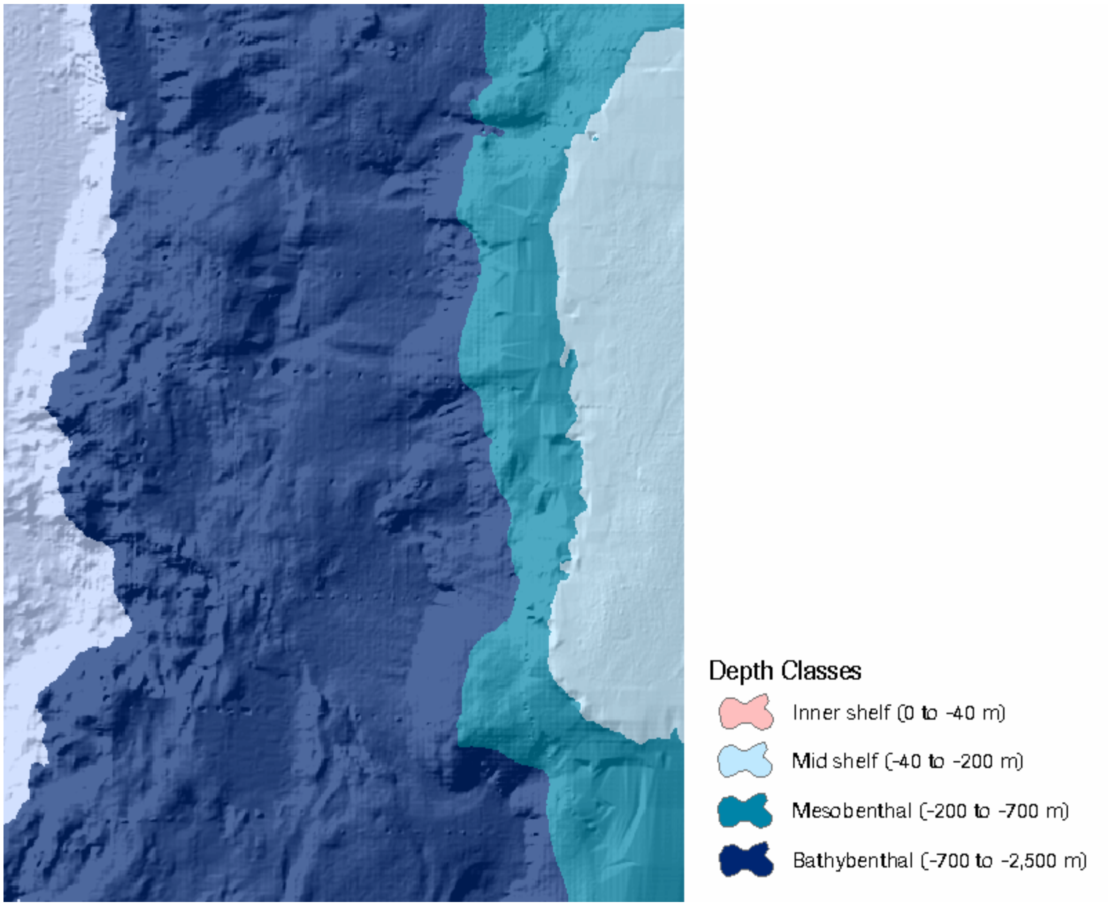


Figure 4: Depth class breaks for Heceta Bank off the Oregon Coast.

Table 1 illustrates the bathymetric position method used to derive the specific bedform, and the depth class that stratifies them.

ID	Description	Method
1	inner shelf ridge	> mean + 1 STDV, depth >= -40 meters
2	mid shelf ridge	> mean + 1 STDV, depth < -40 meters, depth >= -200 meters
3	mesobenthal ridge	> mean + 1 STDV, depth < -200 meters, depth >= -700 meters
4	bathybenthal ridge	> mean + 1 STDV, depth < -700 meters, depth >= -5000 meters
5	inner shelf upper slope	> 0.5 STDV, <= 1 STDV, depth >= -40 meters
6	mid shelf upper slope	> 0.5 STDV, <= 1 STDV, depth < -40 meters, depth >= -200 meters
7	mesobenthal upper slope	> 0.5 STDV, <= 1 STDV, depth < -200 meters, depth >= -700 meters
8	bathybenthal upper slope	> 0.5 STDV, <= 1 STDV, depth < -700 meters, depth >= -5000 meters

9	inner shelf middle slope	> -0.5 STDV, < 0.5 STDV, slope > 5 deg, depth >= -40 meters
10	mid shelf middle slope	> -0.5 STDV, < 0.5 STDV, slope > 5 deg, depth < -40 meters, depth >= -200 meters
11	mesobenthal middle slope	> -0.5 STDV, < 0.5 STDV, slope > 5 deg, depth < -200 meters, depth >= -700 meters
12	bathybental middle slope	> -0.5 STDV, < 0.5 STDV, slope > 5 deg, depth < -700 meters, depth >= -5000 meters
13	inner shelf flats	>= -0.5 STDV, <= 0.5 STDV , slope <= 5 deg, depth >= -40 meters
14	mid shelf flats	>= -0.5 STDV, <= 0.5 STDV , slope <= 5 deg, depth < -40 meters, depth >= -200 meters
15	mesobenthal flats	>= -0.5 STDV, <= 0.5 STDV , slope <= 5 deg, depth < -200 meters, depth >= -700 meters
16	bathybenthal flats	>= -0.5 STDV, <= 0.5 STDV , slope <= 5 deg, depth < -700 meters, depth >= -5000 meters
17	inner shelf lower slope	>= -1.0 STDV, < 0.5 STDV, depth >= -40 meters
18	mid shelf lower slope	>= -1.0 STDV, < 0.5 STDV, depth < -40 meters, depth >= -200 meters
19	mesobenthal lower slope	>= -1.0 STDV, < 0.5 STDV, depth < -200 meters, depth >= -700 meters
20	bathybenthal lower slope	>= -1.0 STDV, < 0.5 STDV, depth < -700 meters, depth >= -5000 meters
21	inner shelf canyon	< -1.0 STDV, depth >= -40 meters
22	mid shelf canyon	< -1.0 STDV, depth < -40 meters, depth >= -200 meters
23	mesobenthal canyon	< -1.0 STDV, depth < -200 meters, depth >= -700 meters
24	bathybenthal canyon	< -1.0 STDV, depth < -700 meters, depth >= -5000 meters

Table 1: Twenty four potential benthic habitats determined by benthic landform and depth.

After examination we determined that the upper, mid, and lower slope positions could be combined into one slope category per depth class. This produced 16 categories and was determined to be more suitable given the scale of the source data. Table 2 represents the final list of bedforms and depth classes used for the Pacific Northwest Coast ecoregion.

id	description	Method
1	inner shelf ridge	> mean + 1 STDV, depth >= -40 meters
2	mid shelf ridge	> mean + 1 STDV, depth < -40 meters, depth >= -200 meters
3	mesobenthal ridge	> mean + 1 STDV, depth < -200 meters, depth >= -700 meters

4	bathybenthal ridge	> mean + 1 STDV, depth < -700 meters, depth >= -5000 meters
5	inner shelf slope	>= -1.0 STDV, <= 1 STDV, slope > 5 deg, depth >= -40 meters
6	mid shelf slope	>= -1.0 STDV, <= 1 STDV, slope > 5 deg, depth < -40 meters, depth >= -200 meters
7	mesobenthal slope	>= -1.0 STDV, <= 1 STDV, slope > 5 deg, depth < -200 meters, depth >= -700 meters
8	bathybental slope	>= -1.0 STDV, <= 1 STDV, slope > 5 deg, depth < -700 meters, depth >= -5000 meters
9	inner shelf flats	>= -0.5 STDV, <= 0.5 STDV , slope <= 5 deg, depth >= -40 meters
10	mid shelf flats	>= -0.5 STDV, <= 0.5 STDV , slope <= 5 deg, depth < -40 meters, depth >= -200 meters
11	mesobenthal flats	>= -0.5 STDV, <= 0.5 STDV , slope <= 5 deg, depth < -200 meters, depth >= -700 meters
12	bathybenthal flats	>= -0.5 STDV, <= 0.5 STDV , slope <= 5 deg, depth < -700 meters, depth >= -5000 meters
13	inner shelf canyon	< -1.0 STDV, depth >= -40 meters
14	mid shelf canyon	< -1.0 STDV, depth < -40 meters, depth >= -200 meters
15	mesobenthal canyon	< -1.0 STDV, depth < -200 meters, depth >= -700 meters
16	bathybenthal canyon	< -1.0 STDV, depth < -700 meters, depth >= -3500 meters

Table 2: Sixteen potential benthic habitats determined by benthic landform and depth after combining slope classes.

The final parameter to constructing benthic habitats is substrate. The Oregon and Washington continental shelf geologic data set compiled and mapped by Oregon State University (Goldfinger et al. 2001) and others (Greene et al. 1999), as updated for the Groundfish EFH-EIS process, incorporates available information on seafloor substrate types for the region. In addition, geologic data was available for British Columbia (MSRM 2001). The combined data set for the Pacific Northwest Coast ecoregion comprised discrete boundaries of seafloor types depicted as polygon themes. For the purposes of developing the benthic habitat model we identified the most common descriptions of bottom induration types: hard, soft, or unclassified (Figure 5).

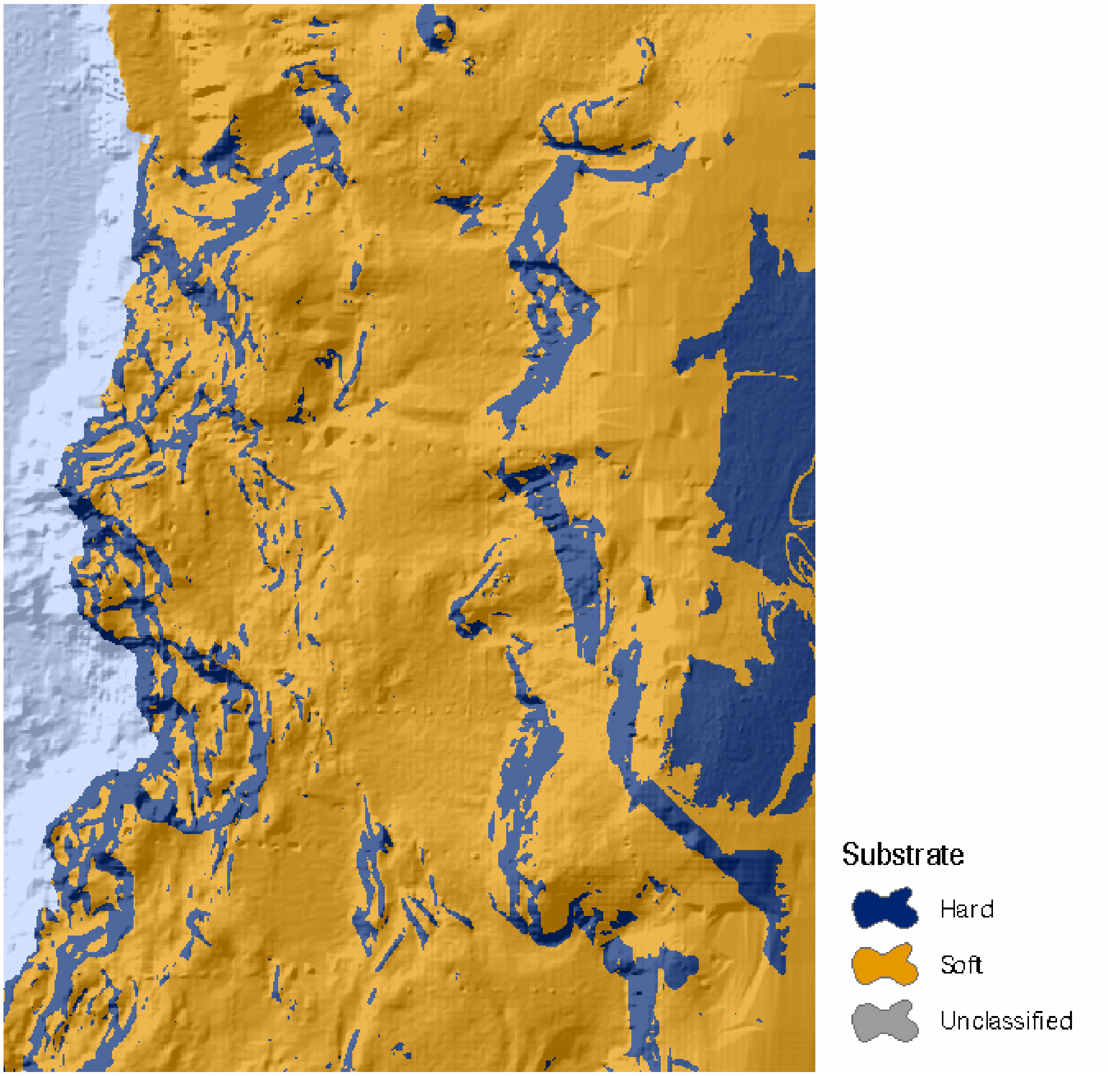
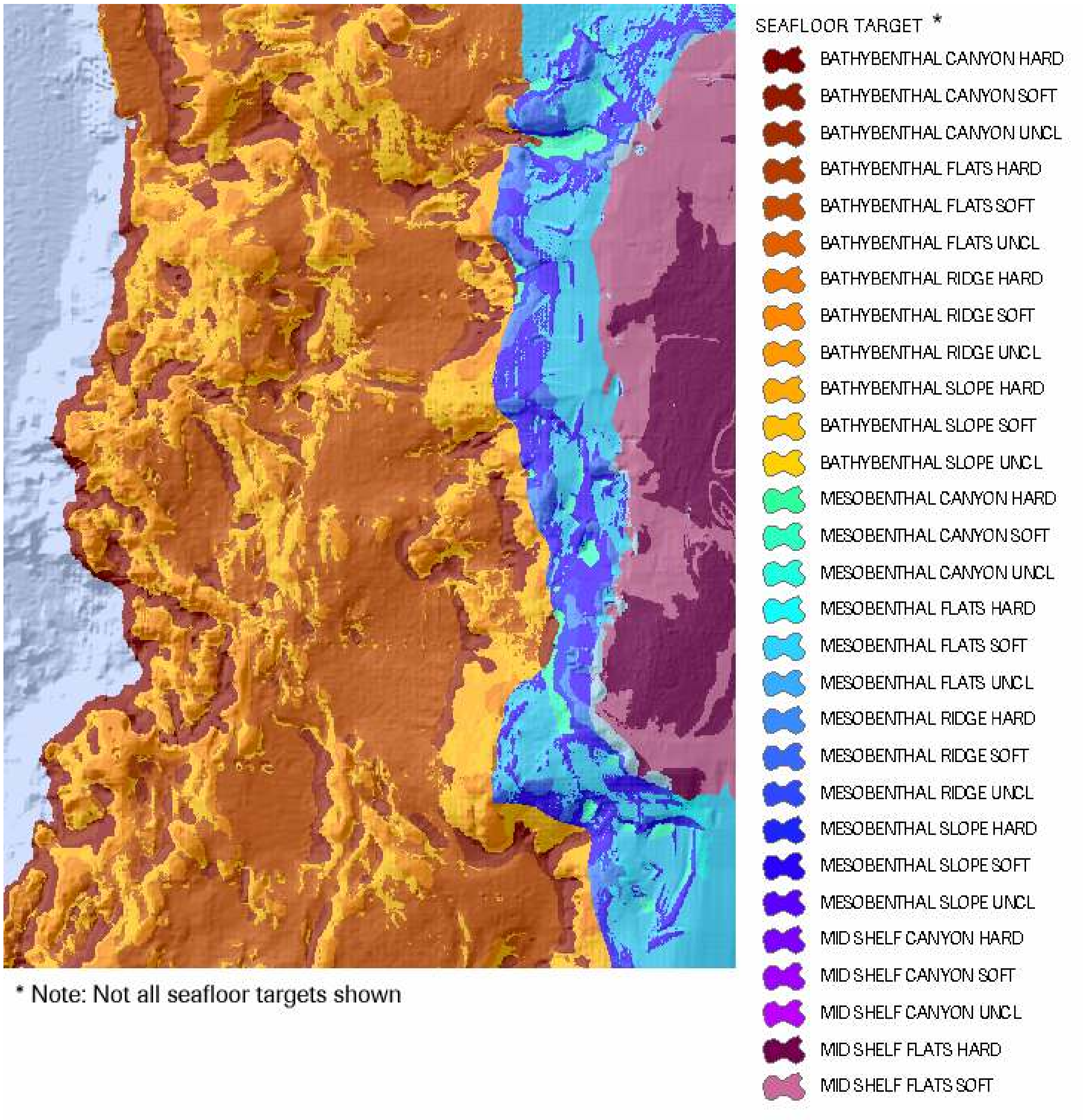


Figure 5: Dominant substrate types for Heceta Bank off the Oregon Coast.

The resultant grid after combining landform and depth with substrate types tracked all potential combinations of inputs resulting in 48 (4 landforms x 4 depth classes x 3 substrate types) unique benthic habitat types (Figure 6). A final check was conducted to determine whether all 48 modeled benthic habitat types were present in the ecoregion; a few types were present but at <100 total hectares (inner shelf canyon unclassified (1.2 hectares), inner shelf slop unclassified (53.6 hectares), and mid shelf canyon unclassified (82.2 hectares)). The largest category was bathybenthal flats unclassified (3,725,682.2 hectares); the total area cover was 14,716,641.8 hectares from mean high water to approximately 2,500 meters depth.

It should be noted that these categories were also used in the Northern California Coast ecoregion and therefore could be combined to illustrate Pacific west coast-wide coverage (TNC 2005).



* Note: Not all seafloor targets shown

Figure 6: Final benthic habitat types for Heceta Bank off the Oregon Coast.

The full text for the Willamette Valley Puget Sound Georgian Bay ecoregional assessment is now available online at http://www.ecotrust.org/placematters and on conserve online at http://conserveonline.org/2004/06/g/WPG_Ecoregional_Assessment. This report details how one assessment team used this approach to select marine targets.

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