Quantitative Seafloor Habitat Classification Using GIS Terrain Analysis: Effects of Data Density, Resolution, and Scale

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Introduction

Resource management efforts can benefit greatly from habitat information and maps regarding the species of interest. For benthic and demersal species, these maps are dependent upon accurate bathymetric data, which historically has been of very low resolution in all but a few select areas. Traditionally, seafloor habitat maps have been produced by visual interpretation of bathymetric and other acoustic (backscatter, sub-bottom/seismic) and non-acoustic (sediment grabs, cores, *in situ* observation) data types. Visual interpretation is often time-consuming and requires a a skilled expert to perform; thus it is by its very nature subjective and of varying repeatability. It is also subject to human limitations regarding compromises between the scale and the amount of detail possible.

As more high-resolution digital elevation model (DEM) data becomes available for the seafloor, quantitative, computer-aided terrain analysis techniques become an increasingly viable tool for creating data layers that can complement those created by expert visual interpretation. Algorithmic terrain analysis is non-subjective, repeatable, makes use of relatively inexpensive computer processing power, and is limited only by the scale and resolution of the DEM data available.

Abstract

There is a great need for accurate, comprehensive maps of seafloor habitat for use in fish stock assessment, marine protected area design, and other resource management pursuits. Recent advances in acoustic remote sensing technology have made it possible to obtain high-resolution (meter to sub-meter) digital elevation models (DEMs) of seafloor bathymetry that can rival or surpass those available for the terrestrial environment. This study attempts to use an algorithmic terrain analysis approach to efficiently, non-subjectively classify seafloor habitats according to quantifiable parameters such as slope, rugosity, and topographic position index (TPI). In addition, we explore the effects of original x,y,z and gridded data density on the results of these analyses, in order to provide insight into how inherent depth-dependent decreases in data density may affect this approach, and to assess the appropriateness of using historical, lower density bathymetric data. Finally, issues of scale with regard to rugosity and TPI are explored and their potential biological relevance are discussed.

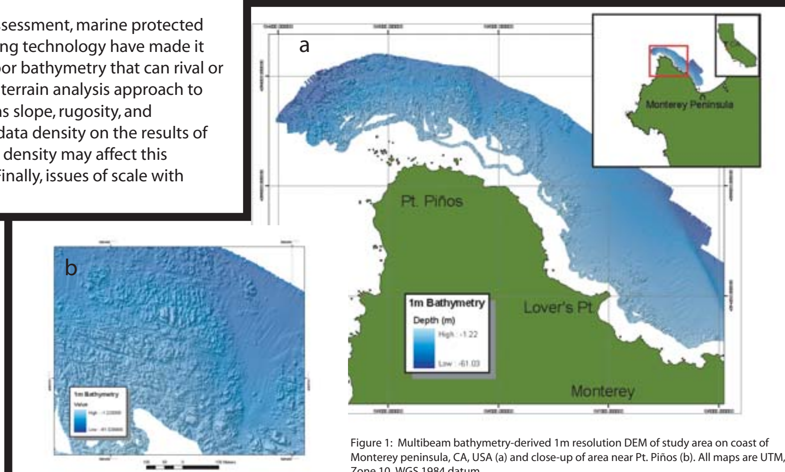

Figure 1: Multibeam bathymetry-derived 1m resolution DEM of study area on coast of Monterey peninsula, CA, USA (a) and close-up of area near Pt. Piños (b). All maps are UTM, Zone 10, WGS 1984 datum.

Study Area

This study used high-resolution bathymetric data recently collected by the CSU, Monterey Bay Seafloor Mapping Lab (SFML) using a Reson 8101 multibeam echosounder system aboard the R/V *MacGinitie*. Among other sites, the SFML has created one-meter (in some areas half-meter) resolution DEMs for the nearshore environment of the entire Monterey peninsula, in central California, USA. The Monterey peninsula bathymetric DEM dataset contains near-continuous coverage from as shallow as 4 or 5m out to a minimum of 50m, and extends from the Del Monte beach area to Point Lobos Marine Reserve. This study primarily makes use of DEM data in the Cannery Row to Point Piños area of the Monterey peninsula nearshore (Fig. 1).

Rugosity Analysis

The ratio of surface area to planar area is a measure of *rugosity* or roughness. Rugosity analysis calculates the surface area ratio for each cell in an elevation grid using the elevation of the cell and its 8 neighbors (Fig 2). Flat, smooth locations will result in surface area ratios near 1, while bumpy, high-relief locations will exhibit higher rugosity values.

The rugosity analysis shown here is accomplished using an ArcView 3.x extension entitled *Surface Areas and Ratios from Elevation Grids* (surfgrids.avx, Jeff Jenness, Jenness Enterprises http://www.jennessent.com); the diagrams below are borrowed from the user's manual for the extension.

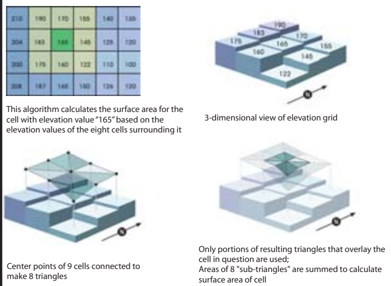

Figure 2: Diagrammatic representation of surface area ratio (rugosity) algorithm methodology.

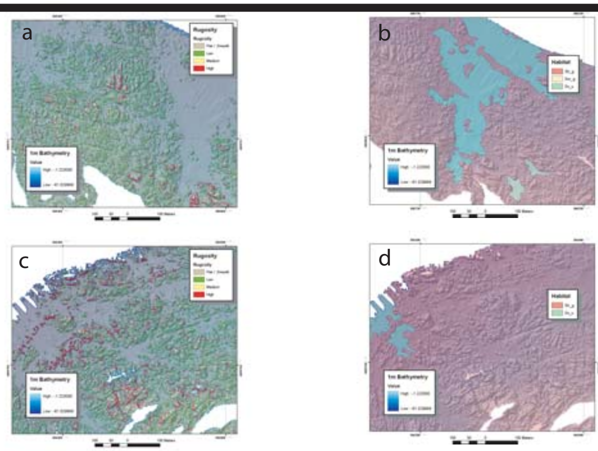

Figure 3: Comparison of rugosity analysis (a & c) and visual interpretation (b & d) results for 2 areas near Point Piños, CA.

Topographic Position Index (TPI)

Topographic Position Index (TPI) is a measure of where a location is in the overall landscape. That is, in relative terms, the topographic position of a place may be a hilltop, or a valley bottom, or a slope, or an exposed ridge, or a flat plain, or other feature. TPI can be calculated for each cell in a grid by comparing the elevation of the cell to the mean elevation of the surrounding cells in an annulus, or ring, around the cell (Fig. 4). Locations that are higher than their surroundings (at the scale specified) will have positive TPI values, while those that are lower will have negative values. Flat areas, as well as areas of constant slope, result in zero or near-zero TPI values. These two cases can then be distinuished based on slope. TPI is entirely scale- dependent; by adjusting the inner and outer radius of the annulus of cells, features of different scales can be delineated. Thus, TPI can be used to find fine-scale features in a DEM such as crevices and pinnacle tops (Fig 5a), or on a broader scale to find slope breaks, canyon axes and walls, etc. (Fig. 5b).

The TPI algorithm used in this study is adapted from Weiss, 2001 (poster presented at ESRI User Conference), from which Figure 4 is borrowed to illustrate the concept of TPI.

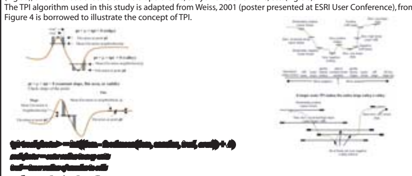

Figure 4: Diagrammatic representation of TPI algorithm methodology.

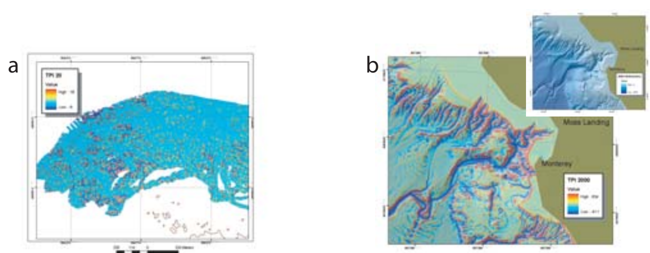

Figure 5: Fine-scale (20m annulus radius; a) and broad-scale (2000m annulus radius; b) TPI results for an area near Point Piños, and for Monterey Bay, CA, respectively. Fine-scale TPI delineates micro- and macrohabitat features such as crevices and pinnacle tops, while broad-scale TPI classifies meso- and megahabitat features such as canyon axes and shelf breaks.

Data Density & Resolution Considerations

The application of terrain analysis algorithms to lower density, especially historic, bathymetric datasets was explored using a DEM created from a subset of the x,y,z dataset used to create the 1m Cannery Row to Point Piños DEM used elsewhere in this study. To simulate the nature of extant bathymetric datasets that have been largely collected for use in creation of navigational charts, a shoal-biased x,y,z dataset was created with lowered (100m) bin size (Fig. 6a). The 100m x,y,z was then used to create a 100m DEM (Fig. 6b), which was subjected to rugosity analysis (Fig. 6c).

The 100m resolution chosen, while still much higher than that of most existing chart data, brought to light an important but unexpected consideration regarding the use of shoal-biased original data. Rather than simply yielding a reduced-resolution version of the rugosity results from the high-resolution DEM (Fig. 6d), the lower-resolution DEM rugosity results classified areas that were highly rugose as flat and smooth. This result was due to the shoal-biasing that was performed on the original x,y,z data, and should be kept in mind when applying rugosity or other algorithmic terrain analysis methods to similar datasets.

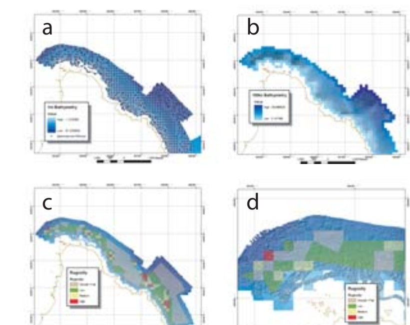

Figure 6: Rugosity analysis using lower-density (100m) shoal-biased x,y,z data to simulate use of historic bathymetry. Thinned x,y,z soundings (a), gridded DEM (b), and rugosty results (c & d) are shown.