Appendix 3

Shadow Maps of Data Density & Quality for the Seafloor Habitat and Lithology Maps of Oregon & Washington

April, 2003

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Background:

It is often difficult to examine a map and visually assess the density and quality of the underlying data used to produce the map. Maps produced with Geographic Information System (GIS) often contain metadata or documentation that details the origin, extent, accuracy, scale, resolution, and creation date. Metadata provides a means to assess the utility of the spatial information for a specific purpose. However, this type of information can be difficult to translate in terms of a visual and spatial description of data density and quality. Additionally, it is not in a form that readily applies to spatial models, which require quantitative spatial inputs.

We have created supplemental maps of weighted data density to address the data quality issue for the Seafloor Habitat & Lithology Maps. The map set displays continuous density surfaces, weighted according to the unique qualities of each principle dataset and for the strict purpose of interpreting the physiographic and lithologic character of mapped habitats. The composite weighted density surface or “shadow map” serves as a visual guide among data rich and data poor regions and as a model input. Its raster data format permits the researcher or modeler to make spatial queries and receive quantitative assessment of quality within each grid cell. We specifically designed these maps for incorporation into the Essential Fish Habitat modeling exercise of the Pacific Fisheries Management Council.

In total there are five individual shadow maps of data density and quality, the first four maps are each unique to a particular data type or survey technique (bathymetric, samples, seismic reflection, and sidescan datatypes). The fifth map is an additive composite of the principle four. We also provide the data distribution maps used to create the weighted density surfaces. In this format, the deliverable product is not a dead-end product. It remains possible to view, reorder, or re-render any map according to the needs of the research question at hand.

Methods:

The quality mapping method evaluates the spatial coverage (or density) of each data type, first independently on a scale of one to ten, then in aggregate (final composite map) on a scale of one to forty. Quality ranks are determined according to the nature and shape of density distributions and to our interpretation as to their utility. That is, each data type is standardized to a qualitative assessment of their value for habitat mapping. This standard ranking procedure allows us to combine disparate data types in the final assessment of their additive "quality".

Bathymetric Density and Quality:

The number of depth soundings per unit area is highly variable over the continental margins of Oregon and Washington. Soundings are typically most abundant over the continental slope. This is especially true off Oregon where naval restrictions on seafloor mapping do not apply, and soundings are densest. The continental shelves remain less well covered and in some areas rely heavily on historic point soundings. Nearshore waters where bathymetric surveys become difficult and expensive are typically areas of lowest bathymetric sounding density.

The mapping scheme used in the Seafloor Habitat & Lithology Maps depicts local physiographic habitats and their associated lithology. An uneven distribution of soundings will undoubtedly have an effect on both our perception of what the actual bathymetric surface looks like and how to map it. This effect is what is of immediate importance when evaluating the quality of the habitat map. Logically, areas of dense soundings are of the highest quality.

The density of available depth or bathymetric soundings is determined within a 100m grid cell area by using an extension within *MB SYSTEM* (Caress, 2003), a swath bathymetric mapping tool. All available data for the survey area is input to the gridding operation. The extents of the survey area were set at -127 W, -123.5 W, 48.5 N, and 42.0 N (the final composite map also shares these same coordinates). Density of soundings per 100m grid cell (10,000m^2) ranged from 0 to 101871.

The density distribution is negatively skewed and long tailed (mean = 51.10 or 0.511 soundings per m^2, sd = 264.02). This highly skewed and long tailed density distribution was reclassified to emphasize the lower portion of the range. We create 5 bins to accent where large increases in habitat map quality are gained by seemingly small increases in data density. This assumption may or may not be valid in other types of seafloor investigations, however, is well suited to our interpretations of local physiography.

Table 1. Bathymetric Weighting Scheme

Density of soundings per 100m grid cell	Quality/Rank
0*	1
1	2
2–5	3
5–60	5
>60	10

Layers Provided:	UTM/WGS1984
(1) Unclassified sounding density grid	orwa_100m_density_num.img
(1) Classified sounding density grid	orwa_den_utmf.grd

Sidescan Survey Density and Quality:

This map describes the distribution and quality of sidescan sonar surveys available and used while making the habitat map. Several extensive high resolution surveys, which cover large areas of the continental shelf and slope of Washington and Oregon, are available from earlier geophysical investigations. The surveys were originally collected to map faults, scarps, and authigenic carbonate rock, but are used here for habitat. Additionally we include interpretations from a nearshore survey (Siletz Reef Area) collected for habitat by the Oregon Department of Fish and Wildlife. Subsequent versions of the habitat map will include sidescan data provided by ODFW (at Perpetua and Orford Reefs) and the Olympic Coast National Marine Sanctuary (for areas of the northern Washington Shelf and Slope).

High-resolution sidescan sonar systems provide detailed information within the swath that allows us to infer the hardness of the seafloor. This type of data becomes more useful when referenced to a nearby core sample or other form of ground truth, suggesting support for the final additive composite map. When mapping habitat, sidescan sonar data is extremely valuable and no quality differentiation among high-resolution survey systems is needed. However, a regional low-frequency survey (Gloria EEZ) exists and is used where other data are unavailable, within its known limitations.

The Gloria survey system differs from the other systems in that it is acquired using a surface-towed, high-energy, low-frequency technique. An unfavorable characteristic of the GLORIA system when used to map habitat is its penetration of the surface sediment, imaging extensive areas of underlying rock. This characteristic may yield an overestimation of hard substrate at the sediment water interface. GLORIA imagery also has a very large pixel size (50m) limiting its ability to resolve fine detail in the seafloor surface structures and sediments.

To create a continuous raster surface of sidescan density and quality we applied the weighting scheme below (Table 2) to the imagery used during the habitat mapping process. An additive combination of sidescan images was made using Arc Map Raster Calculator. The final raster is reclassified (or scaled) so that areas of overlapping data do not exceed the maximum quality ranking of 10. It is not an intention to suggest that overlapping sidescan imagery has an additive effect on the quality of the habitat map, but simply that areas of high-resolution sidescan correspond to high quality interpretations.

Table 2.	Sidescan Sonar Weighting Scheme	Quality/Rank
	Gloria EEZ Survey	1
	High Resolution Deep-Tow Surveys	10
	High Resolution Nearshore Surveys	10
Layers Provided:		UTM/WGS1984
(1) Unweighted high resolution sidescan		highres_ss.grd
(1) Unweighted GLORIA EEZ sidescan (geographic)		gloria.grd
(1) Weighted sidescan density grid		ss_density.grd

Substrate Sample Data:

The habitat maps provide a description of lithology within each habitat polygon, accomplished by constructing and using a comprehensive sediment samples database for the survey area. The database consists of over 4000 individual samples collected over the continental shelves and slopes of Washington and Oregon. Densest sampling occurs over the shallow shelves. Seaward of the continental shelf break sample density generally becomes localized and sparse with increasing depth.

In 1975 Dr. Laverne Kulm published a map of sediment facies of the Oregon continental shelf in a paper which summarizes over a decade of work by himself and his graduate students (Kulm, 1975). We use this map a starting point for our descriptions of lithology and make appropriate changes where additional data suggest such. We also adopt Fulm's sediment classification scheme (Kulm, 1975) An analog map, based on a similar sampling pattern, does not exist at this time for Washington. However, it remains our objective to interpret the sediments of the Washington margin in a manner consistent with the Oregon lithology descriptions.

There are two principle problems associated with mapping the quality of habitats interpreted while using the sample database. The first being that the sample data was collected over several decades during which time navigational techniques evolved significantly. Also and perhaps more importantly, mapping several decades of samples implies that sediment patterns have remained fixed, however sediment distribution, particularly on the inner shelf is most likely not fixed. The second, that it's difficult to understand or quantify how surficial sediment properties, which were sampled at irregularly spaced points (in both time and space), may vary between the points. Sidescan sonar imagery often reveals complex surficial sediment patterns not described or missed in a contoured point surface. For these reasons we adopt a rule to constrain the quality ranking to a single value of 10 within a 500m radius of the sample point.

An alternative to this method may have been to assign a decreasing level of quality away from the sample position, potentially as concentric rings. This type of assignment is less favorable due to potential positional error associated with each sample. The current method implies a certainty that the actual sample position is contained within the buffered area and a reasonable assumption is that the sample describes that area.

The density tool of the Spatial Analyst Extension in Arc Map is used to create the raster density surface of samples. The analysis layer was the map of all sediment samples. A search radius is specified at 500m and the output grid cell size set at 100m. The final processing step is to reclassify the grid such that all cells within 500m of a sample received a quality ranking of 10

Table 3.	Sediment Sample Data Weighting Scheme	Quality/Rank
	All Sediment Samples	10

Grids Provided:	UTM/WGS1984
(1) Unweighted sample density grid	samples_den.grd
(1) Weighted sample density grid	samples_final.grd

2-D Seismic Reflection Data:

Seismic reflection profiles are aids to locating rock outcrops as well as areas overlain by soft sediment deposits. They are a two-dimensional acoustical technique developed to image changes in subsurface lithology. The primary limitation of this technique applied to habitat mapping is that it does not directly image the character of the sediment water interface. Seismic reflection profiles are instructive when used to identify areas of potential rock outcropping as they are implied by noting eroded, faulted, or scarp surfaces. The technique also confirms the presence of depositional environments where hard rock outcrops are less likely to exist. Additionally, they may provide clues for locating authigenic carbonate rock formations by revealing sites of fluid venting.

Collectively, the Active Tectonics Lab personnel have extensive experience and knowledge of the specific seismic surveys used for the habitat maps and we make several distinctions in their quality for habitat mapping purposes (Table 4). These distinctions are based on knowledge of the survey techniques, their specifications and objectives. Unlike sidescan imagery, it is not appropriate to generalize that all seismic reflection data are created equal for mapping habitat. Unique systems and surveys show significantly different abilities to image habitat features.

A weighted vector layer of all seismic survey distributions is created during the first step in the quality mapping procedure. Again the density tool within the Spatial Analyst extension of Arc Map is used to create a density raster. The search radius is set at 500m and the output grid cell size specified at 100m. The final grid is reclassified by quantiles to yield 10 ranked classes (Table 5).

Table 4.	Seismic Reflection Data Weighting Scheme	Quality/Rank
	USGS, Corliss Cruise (Twichell, 1998)	10
	MCAR(McCrory, 1998)	10
	OSU (Goldfinger, 1997)	10
	*Industry Dataset 1	10
	*Industry Dataset 2	5
	*Industry Dataset 3 (unpublished)	5
	**USGS, Boomer	5
	UW (Palmer, 1998)	5
	Dgicon (Goldfinger, 1992)	5
	Sonne (Flueh, 1996)	5
	*Industry Dataset 4	1

Table 4. (cont.)**Seismic Reflection Data Weighting Scheme**	**Quality/Rank**
Silver (Silver, 1972)	1
**UW TT79	1
USGS Open File Report 87-607 (Snavely, 87-607)	1

*Reference information for the industry datasets used in these maps exists, but remains confidential by agreement.
**No reference available.

Table 5. Reclassification Scheme using Quantile Breakpoints

Weighted density score (per 100m grid cell)	Quality/Rank
0	excluded
0.00069455	1
0.001041832	2
0.003820052	3
0.005209162	4
0.005903717	5
0.006945550	6
0.010071047	7
0.012154712	8
0.015280210	9
0.088903040	10

Layers Provided:	UTM/WGS1984
(1) Unclassified density grid	seis_den.grd
(1) Weighted density grid	seis_den_fin.grd
(1) Weighted vector track lines	final_wt_seis.shp

Composite Shadow Map

The composite map or final shadow map is assembled by simply adding each of the four principle weighted rasters together in a method common to suitability modeling. This operation is performed using the raster calculator tool of the spatial analyst extension in Arc Map. Each quality map is overlain in an editable environment and the additive sum value at for each cell is calculated. The composite raster has cell values that range from 1 (lowest density and quality) to 40 (highest density or quality) and a cell size of 100m.

Layers Provided:	UTM/WGS1084
(1) Final composite quality grid	orwa_quality.grd

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