SASI Spatial Analysis Methods

Introduction

The objectives of the SASI Spatial Analysis were to 1) explore the spatial structure of the asymptotic area swept ($z\infty$), 2) define clusters of high and low $z\infty$ for each gear type, 3) determine the levels of $z\infty$ in present and candidate management areas relative to the model domain, and 4) identify alternative management areas with $z\infty$ values similar to or higher than the tested areas.

These analyses were developed to answer two types of questions. First, the Local Indicators of Spatial Association (LISA) analysis shows which areas of the continental shelf are most vulnerable to fishing by particular gear types. This will help the Council to select priority areas for implementation of adverse impacts minimization measures such as gear restrictions. Second, the Equal Area Permutation (EAP) analysis will allow the Council to evaluate the extent to which current EFH closures or other management areas encompass habitats that are vulnerable to certain types of fishing gears. In cases where a particular area is relatively less vulnerable compared to other areas of similar size throughout the region, the Council may choose to eliminate that habitat closure. In other instances, maintaining an existing habitat closure area but changing its boundaries may better protect vulnerable habitats.

Note that in the methods description below, $Z\infty$ (Z infinity) refers to the terminal year adverse effect (Z) value from each 100 km^2 grid cell of the SASI uniform fishing effort simulation runs. These values were estimated for otter trawl, scallop dredge, hydraulic clam dredge, demersal longline, sink gillnet, and trap gear types. The spatial domain for each gear type varies, and was truncated to only include depths equal to or shallower than the depth at which 99.9% of the observed trips for that gear type have occurred. These maximum depths limit the analysis for each gear type to an area where fishing could possibly occur.

Determining z_∞ spatial structure and clusters

Local Indicators of Spatial Association (LISA) statistics including Moran Scatterplots and Local Moran's I were used to explore the spatial structure of z_∞ and to delimit clusters of model cells with statistically high and low z_∞ (Anselin 1995).

Global Moran's I is an index of linear association between a set of spatial observations x_i x_j, and a weighted average w_{ij} of their neighbors (Moran 1950):

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j} x_i x_j}{\sum_{i=1}^{n} x_i^2},$$

where $x_i = z_{\infty i} - \overline{Z_\infty}$, $z_{\infty i}$ is the asymptotic area swept accumulated in cell i, and $\overline{X}$ is the overall mean asymptotic area swept accumulated in the entire model domain. The neighborhood weights, $w_{i,j}$, were determined using Queen Contiguity (the 8-neighbor rule) (Fortin and Dale 2005). Moran's $I > 0$ indicates that the z_∞ values in the model domain are positively autocorrelated, while $I < 0$ indicates negative autocorrelation. When $I = 0$ the values are spatially random.

The spatial association of each survey station with its neighbors was estimated with the Local Moran's I_i (Anselin 1995):

$$I_i = \frac{x_i}{Q_i^2} \sum_{j=1, j \neq i}^{n} w_{i,j} x_i,$$

where

$$Q_i^2 = \frac{\sum_{j=1, j \neq i}^{n} w_{i,j}}{n-1} - \overline{X}^2.$$

When $I_i > 0$ there is positive local autocorrelation, i.e., the cell is in a neighborhood of cells with similar characteristics, but which deviate (positively or negatively) from the overall mean cell characteristics ($\overline{Z_\infty}$). Negative autocorrelation ($I_i < 0$) occurs when the cell is in a neighborhood with dissimilar z_∞ characteristics. When $I_i = 0$ the cell is in a neighborhood with random characteristics, or when the cell and its neighbors have characteristics equal to the overall mean (Boots 2002).

Moran scatterplots are bivariate plots of w_i as a function of x_i, and the slope of a line fit to the scatterplot gives global Moran's I (Anselin 1996). The four quadrants of the scatterplot indicate each observation's value relative to its neighbors. Cells with higher than average values ($x_i > 0$) with neighboring high values ($w_i > 0$) are in the High-High quadrant and together with those in the Low-Low ($x_i < 0$, $w_i < 0$) quadrant indicate positive local spatial autocorrelation. The High-Low and Low-High quadrants indicate negative local spatial autocorrelation.

The null hypotheses that z_∞ was globally or locally randomly distributed (I and $I_i = 0$) were tested by estimating p-values for I and I_i. The p-values were calculated using 9,999 permutations of a spatially random z_∞ reference distribution (GeoDa® software, Anselin et al. 2006). These p-

values are one-sided *pseudo*-significance values: $p = (M + 1) / (R + 1)$ where R is the number of permutations and M is the number of instances where I or I_i are greater than or equal to the observed value for positive autocorrelation, or less than or equal to the observed value for negative autocorrelation.

Global autocorrelation in the data increases the likelihood of Type I errors when testing the significance of I_i because cell values may not be independent (Ord and Getis 2001, Boots 2002). However, as not all samples in the data set are correlated to all others multiple comparison corrections (e.g. Sidak or Bonferonni) are too conservative (Boots 2002). Therefore, when the data exhibited global autocorrelation $p \leq 0.01$ was used to define "significant" clusters of z_∞.

Calculating z_∞ in present and proposed management areas

Equal Area Permutation (EAP) tests were used to determine the levels of z_∞ in present and proposed management areas relative to the model domain. The area-weighted mean z_∞ ($\overline{z_W^\infty}$) for each tested area was compared to a permutation distribution of $\overline{z_W^\infty}$ calculated using 9,999 randomly placed areas equal in size to the test area. The percentile of the tested area's $\overline{z_W^\infty}$ value and number of areas with $\overline{z_W^\infty}$ greater than or equal to the tested area were identified. These permutation-based areas were mapped along with the 100 highest $\overline{z_W^\infty}$ value areas (99th percentile of the permutations distribution) to indicate alternative management area locations. The shapes and orientations of the tested areas vary depending on their locations and original management objectives. Circles were used to construct consistent permutation distributions for the EAP tests because they are isotropic and their areas can calculated simply using radii (Area = 2π x raduis^2).