Exploring Spatial Associations of Environmental Mercury and Acid Rainfall Deposition

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Introduction

Researchers have recently begun using spatial datasets to explore the distribution of environmental mercury and its relationship to atmospheric deposition and ecosystem processes. While spatial analysis presents numerous problems when comparing varying types of data, diverse approaches have been employed. Recent efforts have involved mapping large amounts of tissue data from both fish and soils (Ebers and Clair, 2005; Kamman et al., 2005; Driscol et al., 2007). In this meso-scale approach, tissue data were aggregated into raster cells of 5km and hot spots were identified. One recent macro-scale approach by Hammerschmidt and Fitzgerald (2006) fish tissue data, mercury deposition records, acid rainfall records, and climate data were aggregated by state political boundaries. While somewhat linear relationships were discovered to exist from state to state, some variables have only one sample within a state. Drewnick (2007) demonstrated a significant correlation between reductions in sulfate deposition and reductions in methylmercury concentrations in lake across island Royale NP.

This study began by addressing the underlying question inherent in all spatial analysis techniques: What is the appropriate scale? Statistical distance or inverse-distance weighted techniques depend upon an exponent to determine how much weight nearby points receive over others. In spatial aggregation, whether it is to grids, a lattice, or another physical or political units, there lies a concern that aggregating will result in the loss of variance. We decided to explore relationships that have previously been revealed concerning acid rain and mercury bioaccumulation, not to discover if a relationship exists, but to see how these relationships change at varying scales. It was expected that the strength of association would increase with decreasing scale until some point that too few samples are within range.

Study Area

We decided to use the State of Ohio as our study area primarily due to the variation in sulfate deposition across the state, ample NADP data, and an extensive fish tissue dataset. Consistently, the highest deposition of sulfate and hydrogen ions of any NTN site in North America is sampled in southeast Ohio at OH4H. There are six NTN sites active in Ohio that exhibits a similar spatial pattern to fish tissue collection locations. Fish tissue data were provided by the OEPAs from streams and lakes across Ohio. Fish sampled between the years 1999 and 2006, inclusive, and the average annual deposition for each pollutant collected at the Ohio NTN sites during the same time period were used in this study. All fish tissue records were included that had valid lab records and were not sampled in Lake Erie, home of the top piscivores and the most significant industrial influence.

Methodology

In order to view the effect of increasing radius on the association between fish tissue and NTN records the following set of steps was followed by utilizing a python script and ERDAS IMAGINE 9.3. The steps were performed on increasing radii at an interval of 5km until an upper bound of 140 km was reached.

1. A random selection of fish records was made consisting of half the samples, or three fourths of the sample pool.
2. A buffer was drawn around each NTN site with the current radius.
3. The selected fish tissue records were spatially joined to the buffer polygons and aggregated by taking a mean value.
4. This process was repeated 100 times and a final average for each polygon was computed and recorded.
5. The process was repeated again at the next radius interval.

Following the procedure, the fish tissue concentrations were compared with NTN annual deposition averages. This was done by calculating Pearson’s R for each variable at each tested radius. The results were then graphed for a visual comparison to each other. The procedure was performed using several different subsets of fish tissue concentrations.

Conclusions

- This approach clearly demonstrates a correlation between wet deposition of $SO_2^-$, $H^+$, and $Cl^-$ when compared to methylmercury concentrations found in Ohio sport fish.
- When comparing Ohio NTN and fish MeHg data, the association remains fairly strong to about 60km and then diminishes rapidly for all datasets examined, except the random sample which showed none to begin with.
- This could be a good approach, or guide to estimating fish concentrations at the meso-scale elsewhere.
- These relationships should likely be enhanced by normalizing output to Landusx/Landcover and/or watershed dynamics.

References