Factors Affecting Fish Mercury Concentration in Inland Lakes

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Introduction

- Mercury (Hg) is a local, regional and global problem.
- It has adverse effects when organisms including humans are exposed to methyl-mercury (MeHg).
- Michigan Upper Peninsula (UP) has higher Fish Hg than Lower Peninsula (LP), despite the fact that the LP receives more atmospheric Hg than the UP.

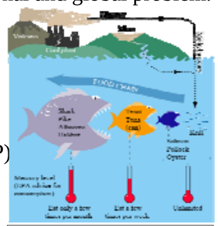


Figure 1: The figure shows the sources of mercury and how methyl mercury bioaccumulates and biomagnifies in the food chain. Source:https://en.wikipedia.org/wiki/Mercury_in_fish

Goal

Ultimate Goal: To predict the lakes that are safest for fish consumption.

Immediate Goal: To find the factors that are most strongly affecting fish mercury concentration.

Methods

- Backward Multiple Linear Regression and Principal component analysis (PCA) were performed in SPSS.
- The regression equation for the analysis is as follows:

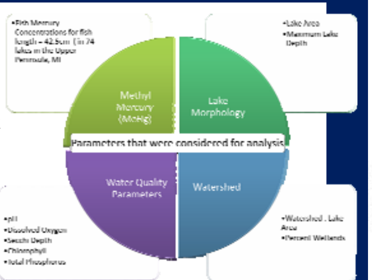
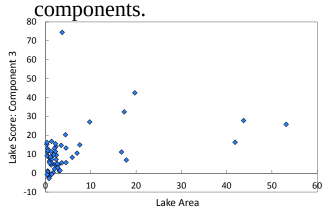


Figure 2: Parameters that were considered for the statistical analysis

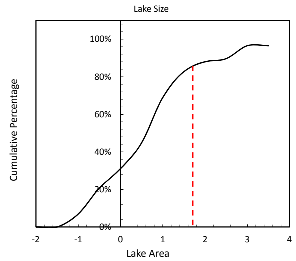
$$Fish\ Mercury = 2.99 - 1.95 * pH - 0.13 * Maximum\ lake\ depth + 0.15 * Watershed: Lake\ Area$$ (Model Adjusted $R^2 = 0.355$)

- PCA explained a total variance of 68.56% with 3 components.



Graph 1: The graph shows a relation between PCA component 3 scores and lake area. It depicts a clear separation in lakes based on lake size. Hence, for further analysis lakes were grouped in 2 groups, i.e., large lakes and small lakes

Grouping of Lakes



Graph 2: The graph shows a cumulative percentage curve of natural log normally distributed data. By observation of Graph 1 and Graph 2, the line drawing a difference between the two groups was marked at 1.5 ~ 3.0 sq. km.

- To separate the small and large lakes, a cumulative percentage curve was made.
- The separation between the 2 categories was considered at 3 sq km.
- This gave us 2 data sets i.e. large lakes (16 lakes) and small lakes (43 lakes)
- Multiple Linear Regression and Principal Component Analysis were performed separately.

Results

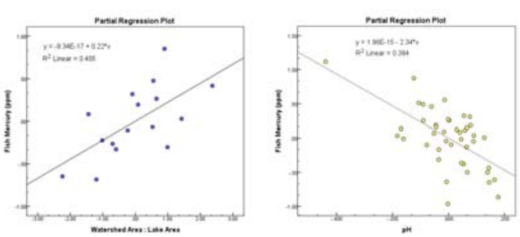
- Results for Multiple Regression Analysis are as follows:

Large Lakes

- Fish Mercury = -2.09 + 0.22* Watershed:Lake Area + 0.59*Secchi Depth (Adjusted R^2 = 0.262)

Small Lakes

- Fish Mercury = 5.17 – 2.34*pH – 0.12*Lake Area – 0.12*Maximum Lake Depth + 0.22*Total Phosphorus + 0.11*Wetland Percent (Adjusted R^2 = 0.514)



Graph 3 and Graph 4: These graphs represent partial regression plots for Watershed Area : Lake Area (most significant parameter for determining the fish mercury concentration in large lakes) and pH (most significant parameter for determining the fish mercury concentration in small lakes). A partial regression plot shows the effect of adding another variable to a model already having one or more independent variables.

- Results for Principal Component Analysis are as follows:

Large Lakes

- 71.85% variance was explained by 3 components.
- Component 1 explains the "Trophic State".
- Component 2 explains "pH"

Small Lakes

- 76.26% variance was explained by 4 components.
- Component 1 explains "DOC or Wetland parameters".
- Component 3 explains "pH".

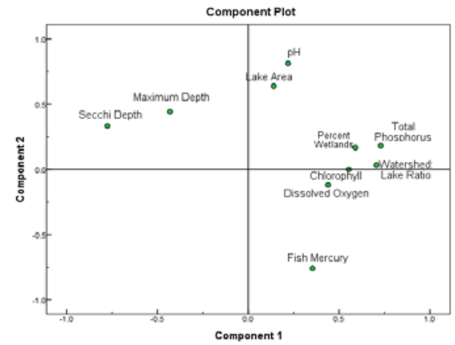


Figure 3: The figure shows a two component plot for variables for small lakes. As discussed earlier, it can be seen that component 1 is representing trophic state. It can also be seen that there is a cluster of points that could be related . These points are total phosphorus, percent wetlands, chlorophyll, watershed: lake area. A correlation analysis is done for further understanding.

The Dissolved Organic Carbon (DOC) Connection

- In previously reported literature it was seen that DOC is an important parameter in relation to fish mercury concentration. When included in the multiple regression analysis, DOC did not appear in the model. So, to study its effects a correlation analysis was performed. The results are as follows:

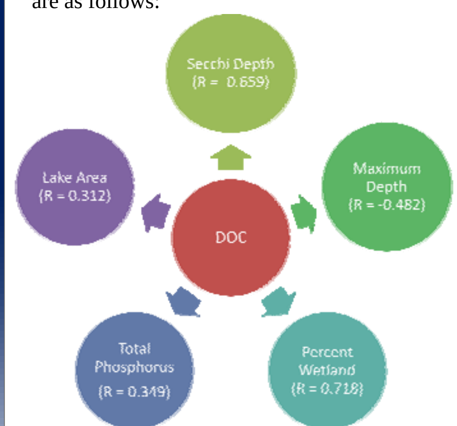
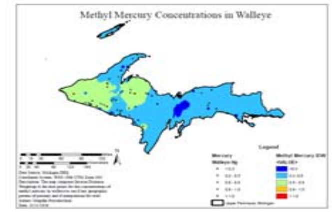


Figure 4: The figure represents correlations of DOC with other parameters. From the information obtained from figure 3 and figure 4, it can be concluded that the effect of trophic state on component 1 is the input of DOC from watershed and wetlands.

Spatial Analysis

- To determine if there are any spatial trends ArcGIS was used for spatial interpolation.



Conclusions

- **Statistical Analysis:**
  - The difference between the factors affecting big lakes and small lakes has not been reported previously in the literature.
  - Fish in large, eutrophic lakes with a small watershed area are safest for fish consumption.
  - In small lakes pH is the most significant parameter; lakes with high pH are safest for fish consumption.
- **Spatial Analysis:**
  - The spatial interpolation of MeHg in fishes shows that there are no gradients in UP .
  - Rather, isolated lakes have elevated fish Hg as a result of lake and watershed conditions as shown by MLR and PCA.
  - It also shows that there are very few lakes that are sampled in the east of UP.

References

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[6] Kidd, K.A., D.C.G. Muir, M.S. Evans, X.Wang, M.Whittle, H.K. Swanson, T. Johnston, and S. Guildford. "Biomagnification of mercury through lake trout (Salvelinus namaycush) food webs of lakes with different physical, chemical and biological characteristics."Science of the Total Environment 438 (2012): 135-143.