Sonia Anorga
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Analyzing Nutrient and Mercury Pollution in the Florida Everglades

Introduction

The Florida everglades have been deeply affected by both historical and ongoing pollution, stemming from direct sources and indirect sources. Over the years, legislation has been passed to minimize these forms of pollution and protect the flora and fauna of this important ecosystem. Though these efforts have succeeded in reducing pollutant levels, it is still vital to assess the impact of the residual pollution not covered under the legislative attempts. This analysis hypothesizes that elevated levels of nutrients in surface water, such as phosphate, nitrogen, and sulfate enhance mercury and methylmercury bioavailability, which can pose risks to the Florida Everglades ecosystem as a whole.

Literature Review

The causes and sources of mercury and methylmercury production and pollution in the everglades has been studied before. Mercury's sources in the everglades include both atmospheric and local deposition (Frederick 2000). Methylation rates have regional variations and are influenced by abiotic factors like sulfur availability. This relationship between sulfur availability and mercury/methylmercury is due to sulfur-reducing bacteria, which thrive in anaerobic conditions and use sulfate ions (SO_4) to oxidize organic carbon, primarily drive methylation (Fink, Rumbold, and Rawlik). This is important for our analysis since South Florida is a high pesticide use area, and nutrient driven eutrophication can create anaerobic conditions. Furthermore, these nutrients from pesticides and fertilizers include sulfate, which enhances methylmercury formation. Methylmercury is absorbed at much higher rates (98%) by birds and mammals than inorganic mercury (7–15%), which leads to bioaccumulation and sublethal effects like behavioral changes and embryonic mortality (Frederick 2000).

Data Description

The data used for this analysis was the EPA's Everglades Regional Environmental Monitoring and Assessment Program (REMAP). This data was measured through a probability-based sampling approach to measure multiple types of data. Concentrations for various nutrients, other molecules, biomass prevalence, and other factors were measured at each site. The subset of the data that this analysis focuses on are concentrations of Nitrate, Nitrogen, Phosphorous, Mercury, Methylmercury, Sulfate, and Chlorophyll-A in units of milligrams per liter. The two most important variables as determined by their significant correlation and importance to the above stated hypothesis are Chlorophyll-A and Methylmercury.

(See Figure 1: Histograms of Chlorophyll-A and Methylmercury (mg/L))

Results A: Correlation

To assess the possible variable correlations, the Pearson and Spearman Coefficients and P-values were calculated for all pairs. The Pearson coefficient shows how strong/present the linear relationship is between variables, and the Pearson P-value measures the significance of the coefficient's measured relationship. The Spearman coefficient is similar in its values, but it measures nonlinear relationships as well. Correlation coefficients greater than 0.3 usually indicate moderate correlation and p-values below 0.05 suggest statistical significance. Thse pairs and their values are shown in Figure 2A. The variable pairs with greatest Pearson or Spearman correlation (significant) were Nitrogen (TNS) vs Sulfate (SO4), Phosphate (TPS) vs Sulfate (SO4), Phosphorous (TPS) vs Chlorophyll-A (CHLA), and Methylmercury (THG) vs Chlorophyll-A (CHLA). The correlation between nutrients (TNS, SO4, TPS) is expected as they usually come from the same sources. Correlation between TPS and CHLA is also relevant to the hypothesis and is expected, since nutrients increase productivity and chlorophyll-A is crucial for photosynthesis. The positive correlation between MEHG and CHLA is also relevant to the hypothesis. This correlation shows the relationship between eutrophication and the fixation of methylmercury in anaerobic conditions.

(See *Figure 2: Scatter plots with regression line for Phosphate vs Chlorophyll-A and Methylmercury vs Chlorophyll-A)*

Results B: PCA

PCA is a technique that transforms original variables into principal components to highlight patterns in complex data sets. When conducting Principal Component Analysis, the low correlation of the variables became clearer. This data can then be graphed on a plot with the principal components that should display the greatest variability (1 and 2) as the X and Y axis. Data points on this type of graph should cluster by similar correlations. Although there were certain variable pairs with moderate correlations, these were still relatively low. This can be seen in the PCA plot with the weak clustering of the data points. The influence of the Chlorophyll-A concentrations can be further visualized by color coding the data points. As can be seen in Figure 3B, PC1 describes the variability of Chlorophyll-A pretty well. *(See Figure 3A: Scatter plot of Principal Component 1 and Principal Component 2 and Figure 3B: Bar graph showing the weights of each variable/component in PC1)*

Conclusion

The analysis described above supports the hypothesis that elevated levels of nutrients, such as nitrogen, phosphate, and sulfate in surface water increase the bioavailability of methylmercury, which can be harmful to the Everglades' ecosystem. The correlation between these nutrients points to their common source, and the correlation between TPS and CHLA shows the effect of nutrients on productivity. Importantly, the relationship seen between MEHG and CHLA highlights the relationship between eutrophication and methylmercury fixation in anaerobic conditions. As hypothesized, there should be some positive correlation between an increase in productivity and concentration of methylmercury. Despite this, the PCA reveals that this correlation is still low, as shown by the weak clustering. Although the analysis supports the hypothesis, it only does so weakly. Further investigation is required to reach a more definite conclusion.

Limitations and Future Work

Low correlation is indication of future work needed to confirm and achieve precise results. Limitations could include lack of data over time, which could show how these chemicals interact with each other, which is crucial to understanding the sulfur-methylmercury relationship. Longer studies can also show the larger effect on the flora and fauna of the ecosystem and if bioaccumulation improves or does not. Data can also be confounded by outliers, so increasing replication can help minimize this source of error.

Supplemental Figures

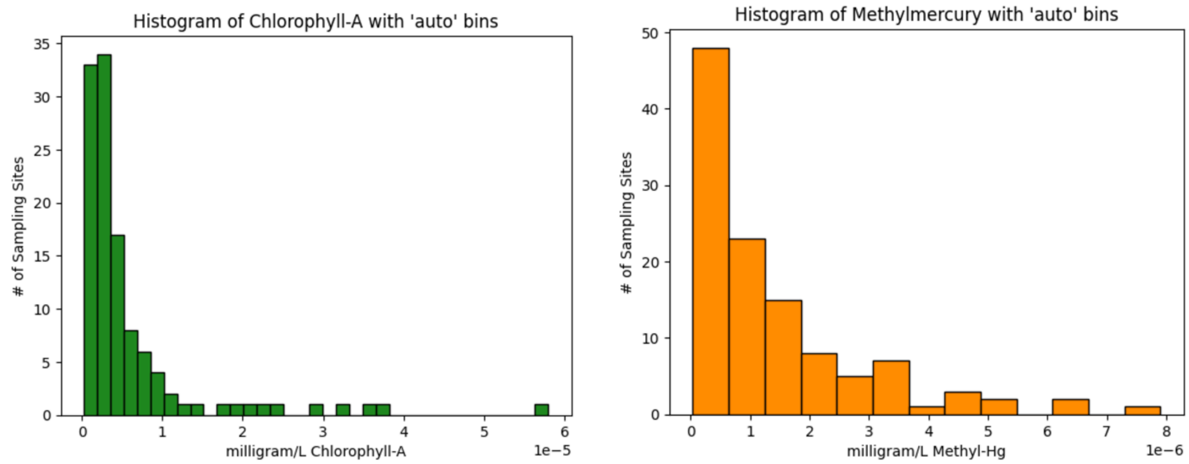

Figure 1: Histograms of Chlorophyll-A and Methylmercury (mg/L)

Significant Pearson Correlation

	X Column	Y Column	Pearson Correlation	Pearson P-Value	Spearman Correlation	Spearman P-Value
10	TNSWFB	SO4SWEA	0.525981	1.574260e-09	0.50046	1.231145e-08
16	THGSWFC	CHLASWFB	0.326558	3.682413e-04	0.37839	3.051680e-05

Significant Spearman Correlation

	X Column	Y Column	Pearson Correlation	Pearson P-Value	Spearman Correlation	Spearman P-Value
10	TNSWFB	SO4SWEA	0.525981	1.574260e-09	0.500460	1.231145e-08
11	TPSWFB	THGSWFC	0.257091	5.543061e-03	0.351868	1.151580e-04
13	TPSWFB	CHLASWFB	0.188863	4.323496e-02	0.406805	6.435764e-06
14	TPSWFB	SO4SWEA	0.133890	1.537071e-01	0.416527	3.653613e-06
16	THGSWFC	CHLASWFB	0.326558	3.682413e-04	0.378390	3.051680e-05
18	MEHGSDFC	CHLASWFB	0.107328	2.535809e-01	0.308244	8.039605e-04

Figure 2A: Variable Pairs with Moderate and Significant Pearson or Spearman correlations

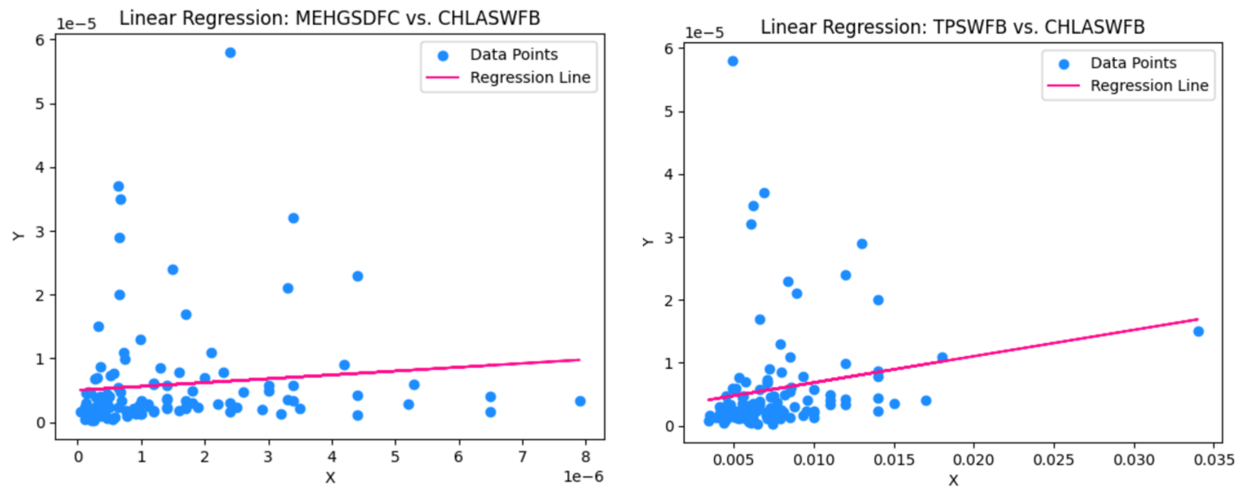

Figure 2: Scatter plots with regression line for Phosphate vs Chlorophyll-A and Methylmercury vs Chlorophyll-A

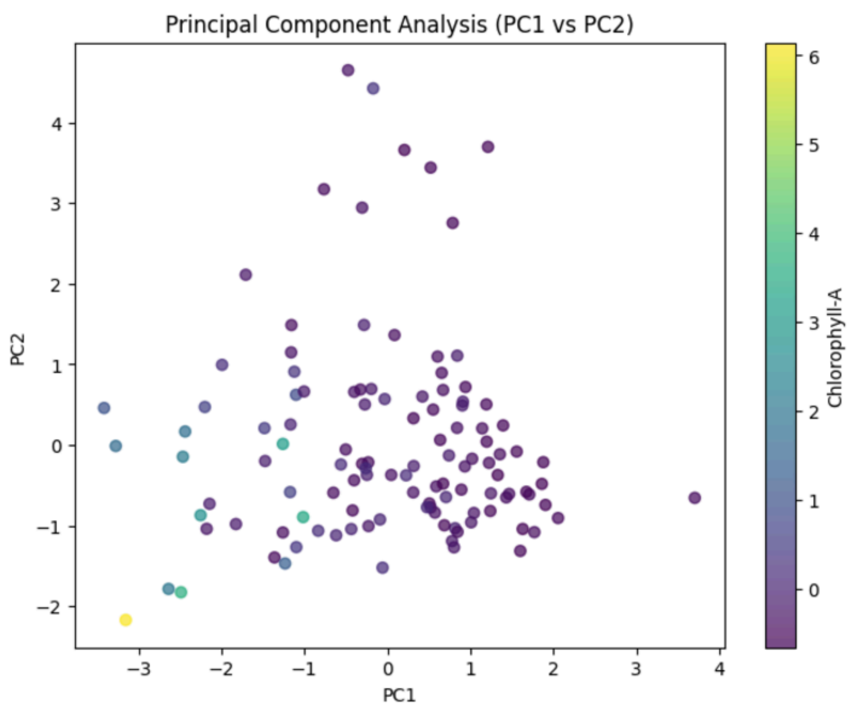

Figure 3A: Scatter plot of Principal Component 1 and Principal Component 2

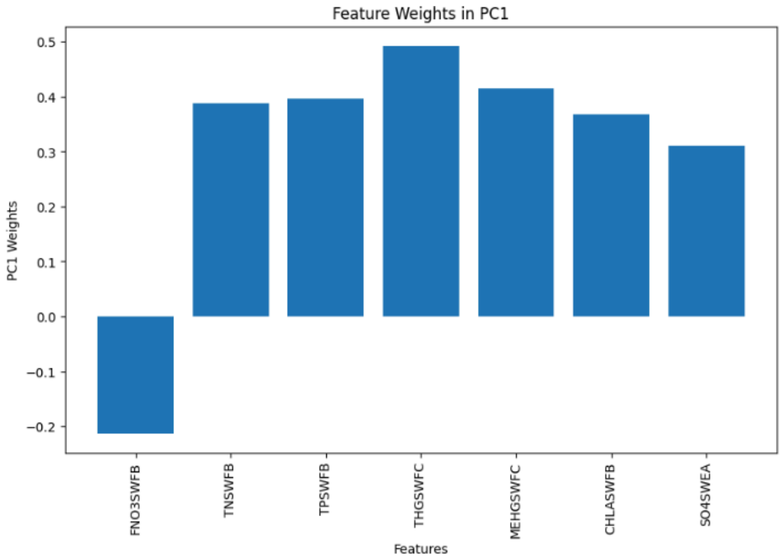

Figure 3A: Scatter plot of Principal Component 1 and Principal Component 2

Bibliography

Frederick, Peter C. *Mercury Contamination and Its Effects in the Everglades*, wec.ifas.ufl.edu/pdf/frederick/Frederick 2000 Mercury contamination and its effects Everglades.pdf. Accessed 5 Dec. 2024.

Fink, Larry, et al. *Chapter 7: The Everglades Mercury Problem*, apps.sfwmd.gov/sfwmd/SFER/1999_Everglades_Interim_Report/interimrpt_98/16_chpt7.pdf. Accessed 5 Dec. 2024.