Goldschmidt 2024 Abstract
https://doi.org/10.46427/gold2024.24703

Combatting seafood fraud: Application of machine learning to develop chemometric differentiation tools using metal isotope ratios and chemical contaminants in eastern oysters

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Seafood fraud is a pervasive global issue, resulting in billions of dollars of lost revenue each year from the global food industry. In the U.S., an example of seafood fraud involves trafficking of eastern oysters. These oysters are distributed along the eastern and gulf coasts of the U.S., and despite being of the same species, eastern oysters have several locally named varieties with distinct flavors, shell shapes, and textures depending on environmental factors such as salinity and temperature. Thus, the monetary value of eastern oysters is largely based on their geographic origin, and mislabeling lower-value oysters as a higher-value variety interferes with consumers' decisions, threatens the integrity of the seafood supply chain, and undermines environmental management measures. In this study, we aim to develop a chemometric model that links eastern oyster samples to their geographic origin, which would aid law enforcement in identifying and combatting seafood fraud. We have developed a preliminary model using previous metal and organic contaminant concentration analyses of historically collected oysters from the NOAA NS&T Mussel Watch Program (1986–2021). Using a community detection algorithm, oyster tissue samples were grouped into "communities" based on similarities in their contaminant concentration profiles, which when plotted on a map of the U.S., revealed regional differences along the coasts (Figure 1). This was coupled with a random forest model, which accurately predicted the community to which an oyster sample belonged approximately 83% of the time. Our next step is to incorporate Sr, Pb, Cu, and Zn isotope ratio measurements of a subset of newly collected (2023) and archived (1986–2008) oyster tissue samples into this model. These metal isotope ratios are expected to be good geographic tracers, reflecting local anthropogenic contamination and variable bedrock weathering. Metal isotope ratios in oyster tissue may also be less susceptible to changes over time compared to contaminant concentrations, which may fluctuate due to regulation and remediation efforts or the emergence of new pollution sources. We hypothesize that incorporating these metal isotopic analyses alongside previous metal and organic contaminant concentration analyses will improve the accuracy of our chemometric model in predicting the geographic origin of eastern oysters.

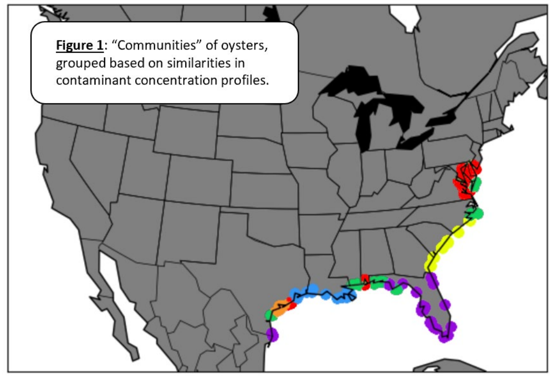

Figure 1: "Communities" of oysters, grouped based on similarities in contaminant concentration profiles.