

PRINCIPAL COMPONENTS ANALYSIS (PCA) OF PCB CONCENTRATIONS IN SHRIMP FROM THE U.S. RETAIL MARKET

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Introduction

Previously, we determined concentrations of all 209 PCB congeners in shrimp samples that originated from 14 countries in three continents. Significant differences in PCB concentrations were not found between wild-caught and farm-raised shrimp; however, PCB concentrations were significantly different among shrimp from different countries.¹ No statistical differences in PCB concentrations were observed among shrimp from different continents, even after adjusting for sample type.² Lowest and highest concentrations were observed in shrimp from Asia and North America, respectively, with North American samples having highly variable PCB concentrations and several high-end outliers relative to other shrimp.³ Congener patterns and homologue fractions were also highly variable among the different regions.

Principal Components Analysis (PCA), also called factor analysis, is a multivariate statistical technique used on environmental data sets to transform correlated variables into uncorrelated factor subsets or principal components that are linear functions of the original variables.⁴ The technique reduces data set dimensions to more clearly demonstrate trends and associations and can be used to distinguish congener profiles. In the present study, we used PCA to further describe the variation in PCB levels in shrimp based on sample type (wild-caught and farm-raised) and origin of collection. Furthermore, we aimed to compare congener profiles observed in shrimp samples to known congener profiles of commercial Aroclor and Kanechlor PCB mixtures to help elucidate potential sources of contamination in shrimp.

Materials and Methods

Eighty-four uncooked shrimp samples and three cooked shrimp samples were randomly purchased from local markets in the Northern California area between February and April 2009. Detailed sampling information, including collection methods, has been previously described.¹ Samples were analyzed by Vista Analytical Laboratory (El Dorado Hills, CA) for all 209 PCB congeners using high-resolution gas chromatography-mass spectrometry according to the EPA Method 1668; however, multiple PCBs co-eluted resulting in a total of 168 congener/congeners pairs for each sample. Detection limits were very low, with maximum levels ranging from 1.01 to 3.74 pg/g. Non-detect concentrations were assumed to have values equal to the LOD divided by the square root of two. **Wet-weight concentrations were used in the PCA models.**

For the PCA, we included the percent contribution to total PCB concentrations for 51 congeners that were detected in at least 50% of uncooked and cooked shrimp samples. To evaluate PCB sources potentially contributing to differences in observed congener patterns in the shrimp, we also included the congener patterns for Aroclors 1016, 1242, 1248, 1254, and 1260⁵; and for Kanechlors 300, 400, 500, and 600⁶ in our analysis. All factors with eigenvalues greater than one were evaluated as part of the PCA.

Results and Discussion

The PCA resulted in a set of nine factors that explained a total of 84.4% of the total variance in the data set. In order to simplify discussion, our analysis focuses on the first four factors that explain approximately 67% of the total data variance.

Figure 1 presents the factor loadings for each of the four factors. Factor 1 represents the differences due to the contributions of low chlorinated PCB mixtures (Aroclors 1016, 1242, and 1248; Kanechlors 300 and 400) and highly chlorinated PCB mixtures (Aroclor 1260 and Kanechlor 600). The lowest Factor 1 scores are associated with PCB mixtures that contain less chlorinated congeners while the highest Factor 1 scores are associated with the mixtures with the more highly chlorinated congeners.

The Factor 2 profile appears similar to a mixture of Aroclors 1254 and 1260 and the highest Factor 2 scores are associated with five samples from Bangladesh. In addition, eight out of ten shrimp samples from Bangladesh have Factor 2 scores greater than 1.5. This suggests that Factor 2 may represent a specific source of PCBs located in Bangladesh.

Factor 3 represents contribution of Aroclor 1254 and Kanechlor 500 to the PCBs measured in the shrimp, with high values indicative of higher contributions of Aroclor 1254 or Kanechlor 500 and the lowest values associated with the other Aroclor and Kanechlor mixtures. Finally, Factor 4 appears to be associated with contributions of Aroclor 1254 and 1260 and Kanechlors 500 and 600, with the lowest values for this factor being associated with those PCB mixtures.

Figure 1: PCB congener distributions for the top four factors

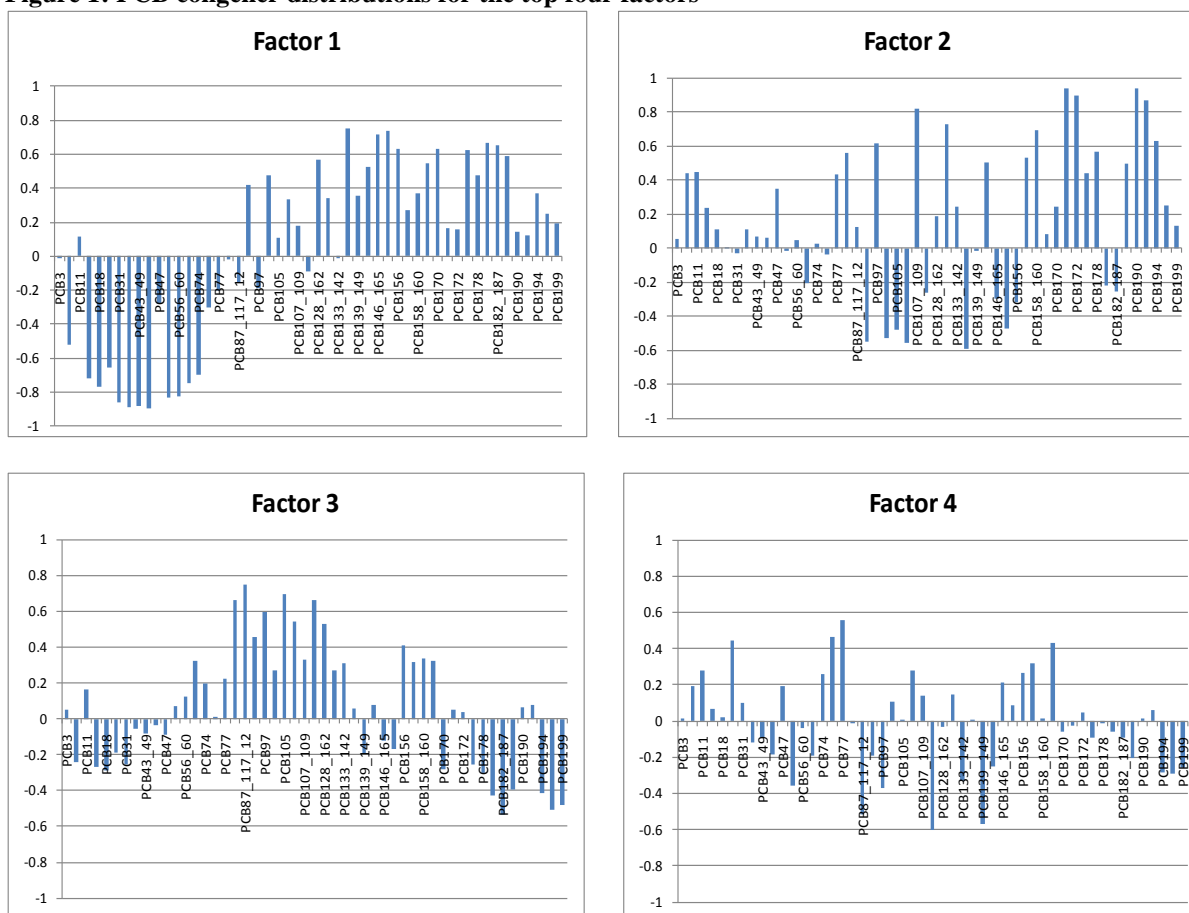
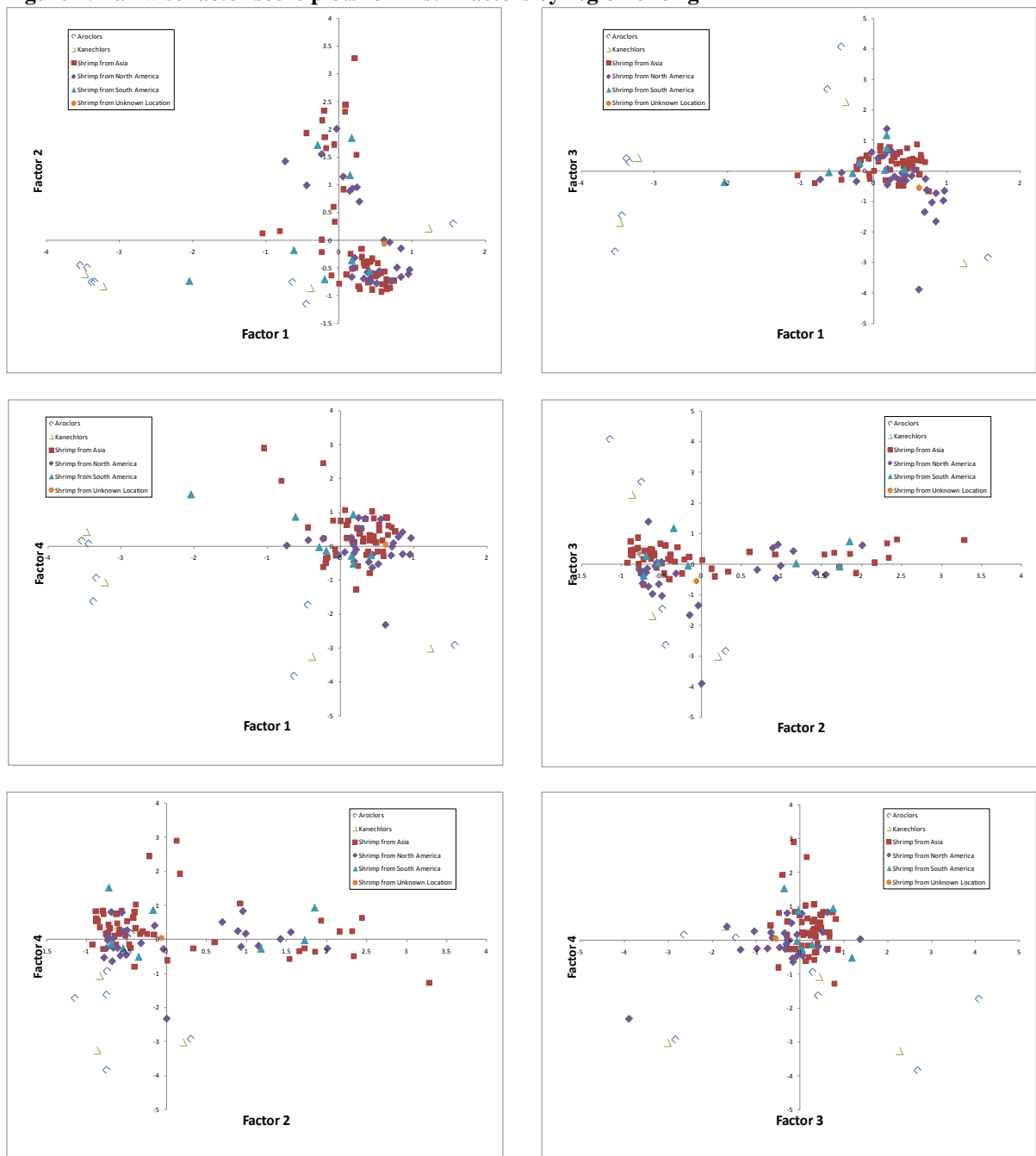


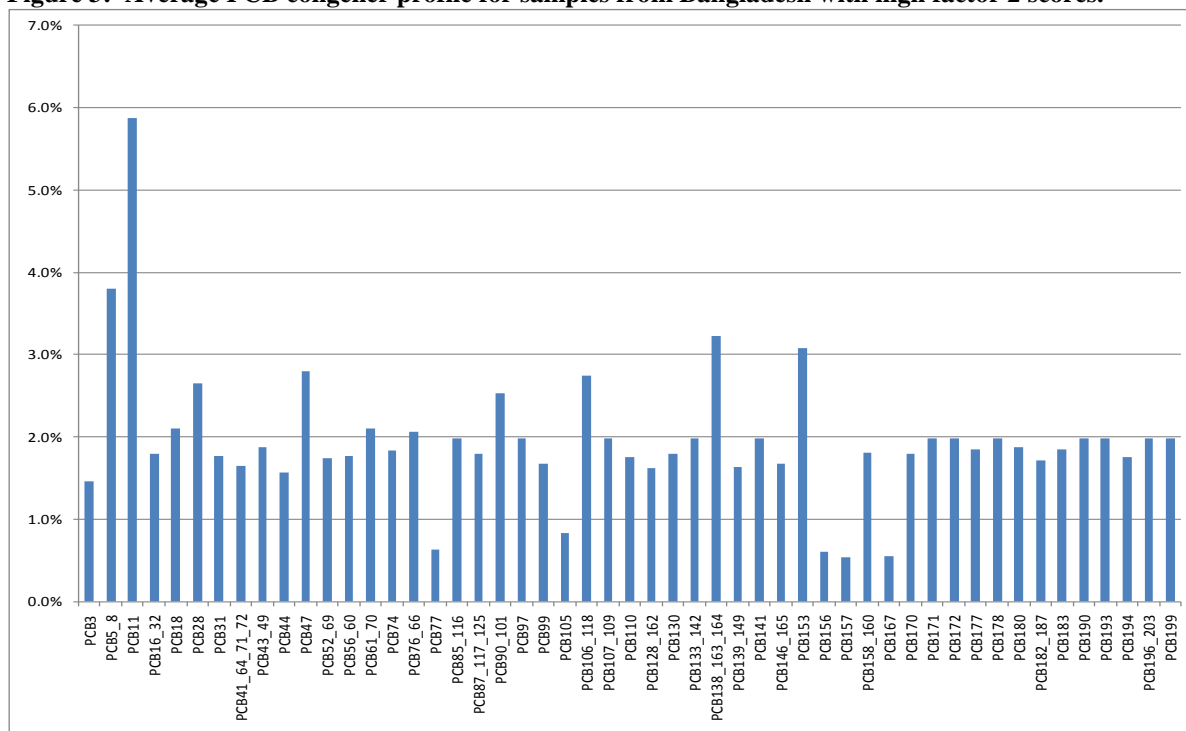
Figure 2 presents the pairwise factor score plots for Factors 1 through 4 with shrimp samples categorized by continent of origin. Based on a comparison of Factor 1 and 3 that differentiate the different Aroclor mixtures from each other, the majority of samples appear to be different mixtures of Aroclor 1254 and 1260 or Kanechlors 500 and 600 rather than mixtures of the less chlorinated PCB mixtures. The primary exception to these findings is a farm-raised shrimp sample from Ecuador which had the lowest Factor 1 score of all shrimp samples. Interestingly, this sample was previously identified as a high-end outlier.³ Four of the wild samples from North America (two from the U.S. and two from Panama) had factor scores consistent with the congener patterns associated with Aroclor 1260 and Kanechlor 600.

Figure 2: Pairwise factor score plots for first 4 factors by region of origin



Although no general trends in congener profiles based on the factor scores due to sample type (wild-caught and farm-raised) or regions of origin were identified, we noted that the majority of shrimp samples from Bangladesh presented high Factor 2 scores. Figure 3 illustrates the congener profile for eight samples from Bangladesh. Based on this profile, these samples demonstrate high contributions of PCBs 8 and 11, congeners known to be associated with commercial paint pigments.⁷ This indicates that shrimp samples with high Factor 2 scores may be impacted by PCBs from non-Aroclor or Kanechlor sources, such as commercial paint pigments.

Figure 3: Average PCB congener profile for samples from Bangladesh with high factor 2 scores.



While the PCA of this data set did not identify any general trends in congener profiles by sample type or region of origin, it did reveal that the primary sources of PCBs for the majority of shrimp samples were due to Aroclor or Kanechlor mixtures. Based on Factors 1 and 2 scores, the majority of the shrimp samples are impacted by sources of Aroclors 1254 and 1260 or Kanechlors 500 and 600 rather than any of the less chlorinated Aroclor or Kanechlor mixtures. In addition, some of the samples also show impacts from PCBs 8 and 11 that are associated with commercial paint pigment sources, rather than Aroclor or Kanechlor mixtures.

Acknowledgements

Funding for the sample collection, laboratory analysis, and subsequent data analysis described in this paper was provided by ChemRisk, LLC and Vista Analytical Laboratory.

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