

INTRODUCTION

In a previous set of studies, shrimp were randomly purchased and analyzed for all 209 PCB congeners. While purchased from local markets, these shrimp originated from 14 countries in three continents.<sup>1,2,3</sup> The main conclusions of these studies were:

- Significant differences were not found between wild-caught and farm-raised shrimp ( $p=0.962$ )<sup>1</sup>.
- Concentrations were significantly different among shrimp from different countries ( $p<0.0001$ )<sup>1</sup>.
- The average contributions of PCBs 28, 90/101, and 153 were significantly different between wild-caught and farm-raised shrimp ( $p<0.001$  to  $p=0.021$ )<sup>1</sup>.
- No statistical differences were observed among shrimp from different continents, even after adjusting for sample type ( $p=0.161$ )<sup>2</sup>.
- Congener patterns and homologue fractions were also highly variable among the different regions<sup>3</sup>.

To get a better understanding on how the PCB congener profile in shrimp varies by sample type, and continent of origin, principal components analysis (PCA) is used. PCA is a multivariate statistical technique that reduces data set dimensions to more clearly demonstrate trends and associations and can be used to distinguish congener profiles<sup>4</sup>.

The objectives of this study are two-fold:

- To describe how PCB congener profiles in shrimp vary based on sample type and continent of origin, and
- To compare the congener profiles in shrimp to known congener profiles of Aroclor and Kanechlor PCB mixtures to help identify the potential sources of contamination in shrimp.

MATERIALS AND METHODS

The data included 84 uncooked and 3 cooked shrimp that 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<sup>1</sup>.

In general,

- Samples were analyzed by Vista Analytical Laboratory (El Dorado Hills, CA) for all 209 PCB congeners using HR GC/MS according to the EPA Method 1668.
- Multiple PCBs co-eluted resulting in a total of 168 congener/congener pairs for each sample.
- Detection limits were very low, with maximum levels ranging from 1.01 to 3.74 pg/g.

For the PCA,

- Concentrations below the LOD were assumed to have values equal to the  $LOD/\sqrt{2}$ .
- Wet-weight concentrations were used.
- Only PCB congeners that were detected in at least 50% of the uncooked and cooked shrimp were included (51 out of 168 congeners or co-eluted congener pairs).
- The percent contributions to the total of the 51 PCB congeners were used in the PCA.
- The percent contribution data for the same 51 congeners for Aroclors 1016, 1242, 1248, 1254, and 1260<sup>5</sup>; and for Kanechlors 300, 400, 500, and 600<sup>6</sup> were included. Figure 1 presents the congener profiles for these PCB mixtures.
- All factors with eigenvalues greater than one were evaluated.

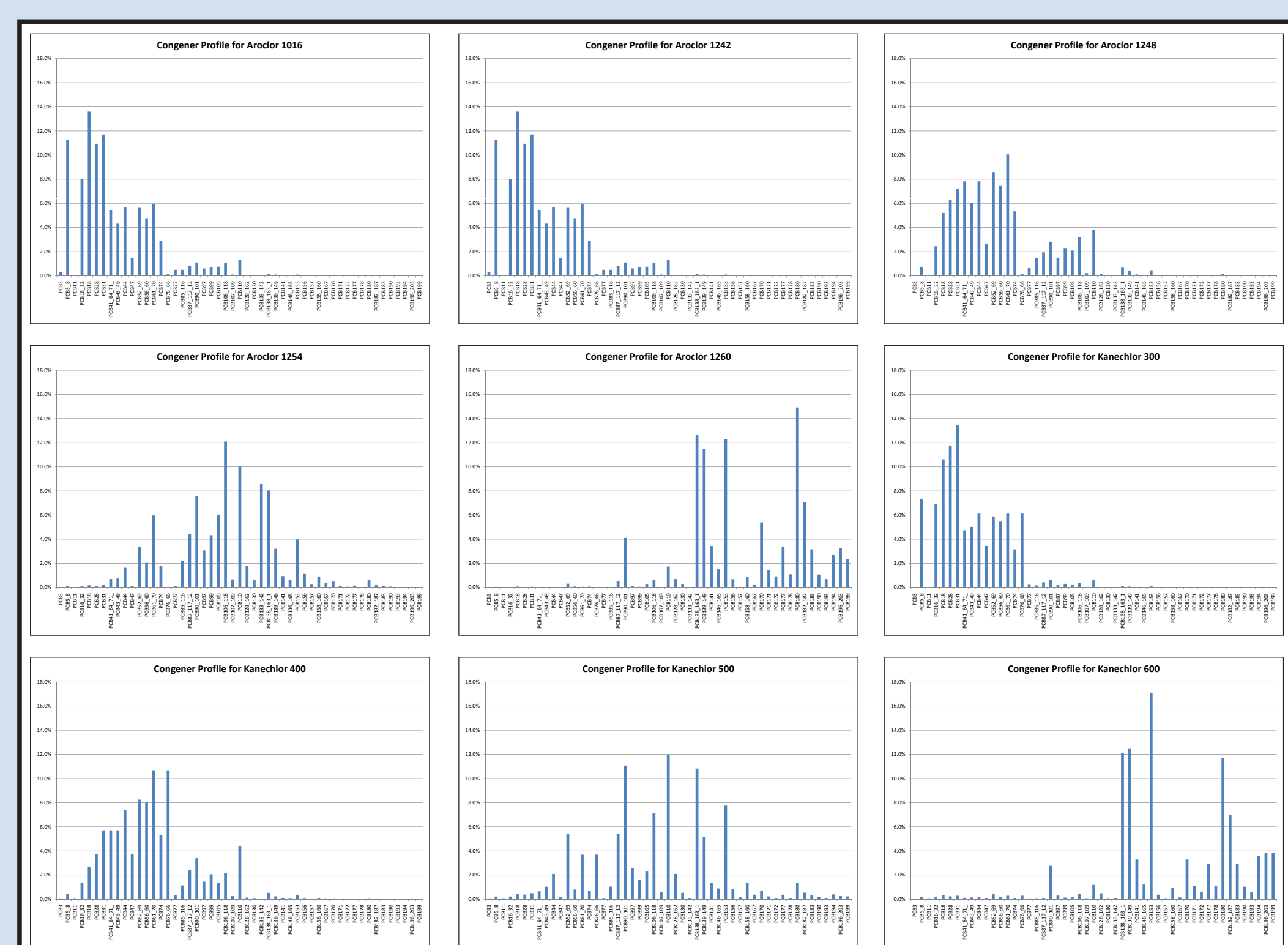


Figure 1. PCB Congener Profiles for Aroclors 1016, 1242, 1248, 1254, and 1260; and for Kanechlors 300, 400, 500, and 600.



RESULTS AND DISCUSSION

The PCA resulted in a set of 9 factors that explained a total of 84.4% of the total variance in the data set. To simplify discussion, our analysis focuses on the first four factors that explain 66.6% of the total variance and each explain at least 6% of the total variance. Figure 2 presents the factor loadings for each of these four factors.

Discussion of Factor Loadings

Factor 1:

- Represents the differences due to the contributions of low chlorinated PCB mixtures.
- The lowest scores are associated with Aroclors 1016, 1242, and 1248 and Kanechlors 300 and 400.
- Scores closer to zero are associated with Aroclor 1254 and Kanechlor 500.
- The highest scores are associated with Aroclor 1260 and Kanechlor 600.
- Indicates that the level of chlorination for the PCB congeners detected in a shrimp sample explains the largest amount of variation in these data.

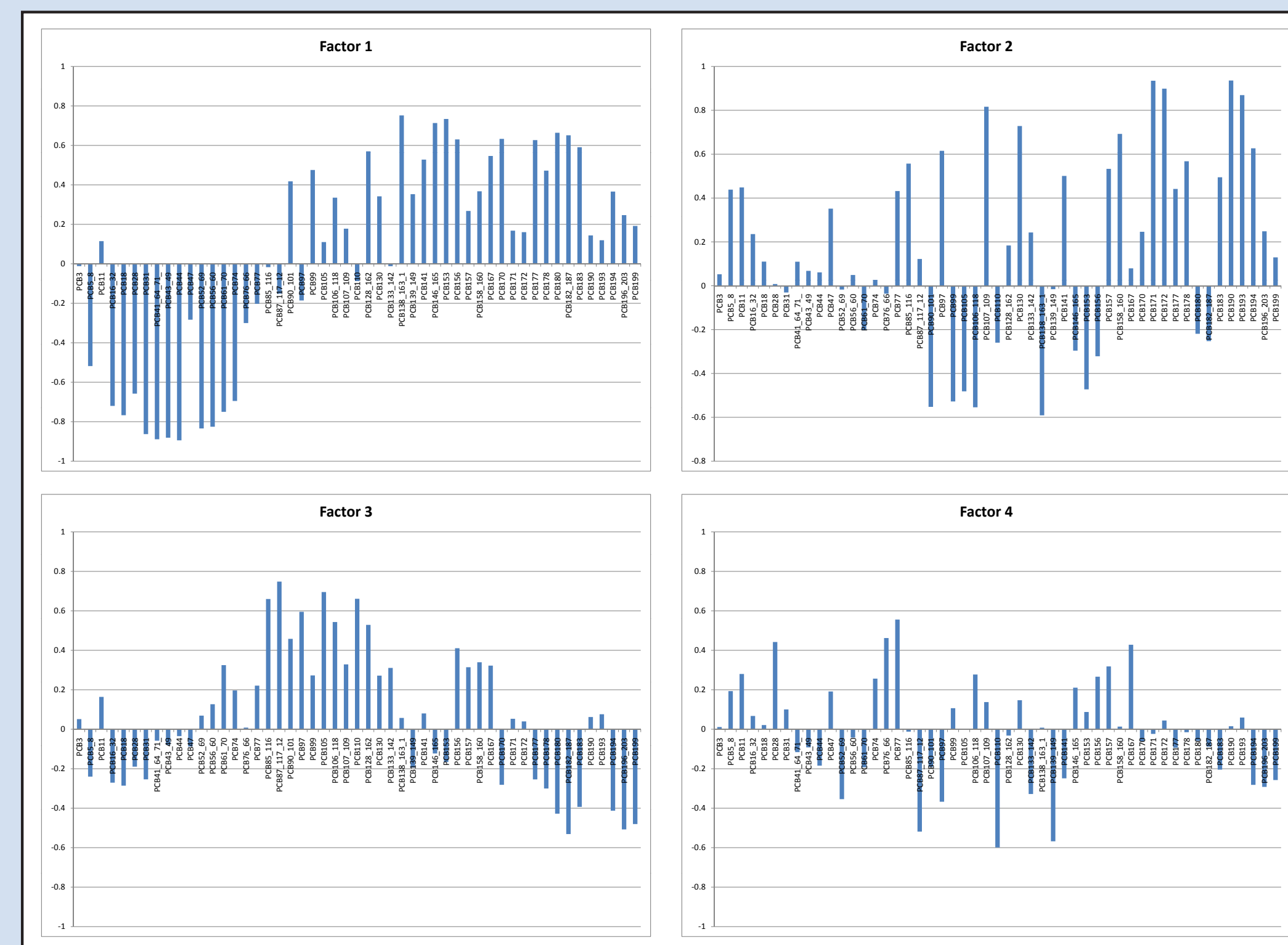


Figure 2. PCB congener distributions for the top four factors.

Factor 2:

- Appears similar to a mixture of Aroclors 1254 and 1260.
- The highest scores are associated with 5 samples from Bangladesh with 8/10 shrimp samples from Bangladesh having scores greater than 1.5.
- Has a high contribution of PCB 11 that is not present for any of the Aroclor or Kanechlor profiles.
- PCB 11 is known to be associated with commercial paint pigments.
- 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.
- High positive values indicative of higher contributions of Aroclor 1254 or Kanechlor 500 and the lower values associated with the other mixtures.

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.

Comparison of Factor Scores by Sample Type and Continent of Origin

Figures 3 and 4 present the pairwise factor score plots for Factors 1 through 4 with shrimp samples categorized by sample type and continent of origin, respectively.

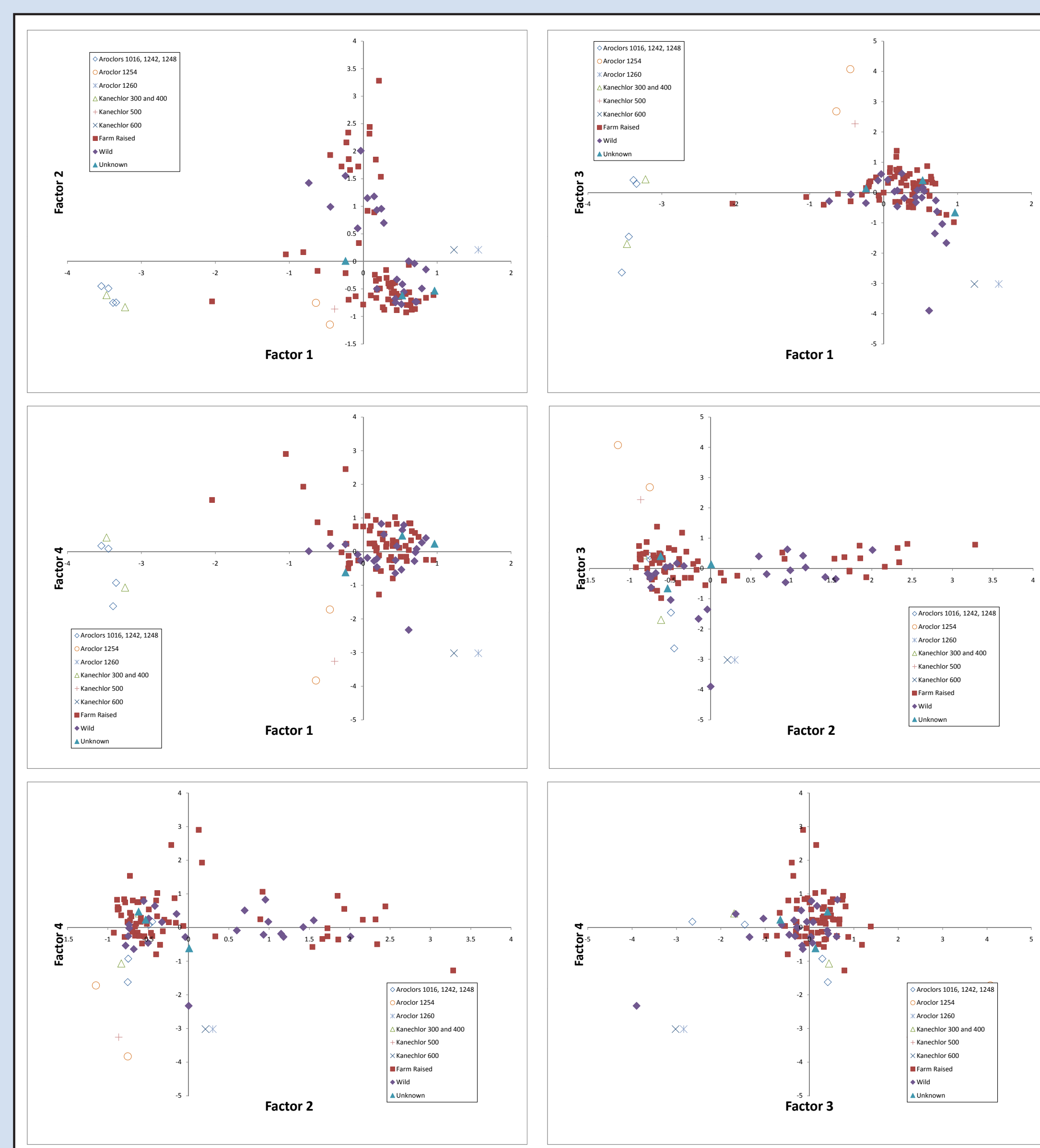


Figure 3. Factor Score Plots for Factors 1, 2, 3, and 4 by Sample Type (wild-caught versus farm-raised).

RESULTS AND DISCUSSION CONTINUED

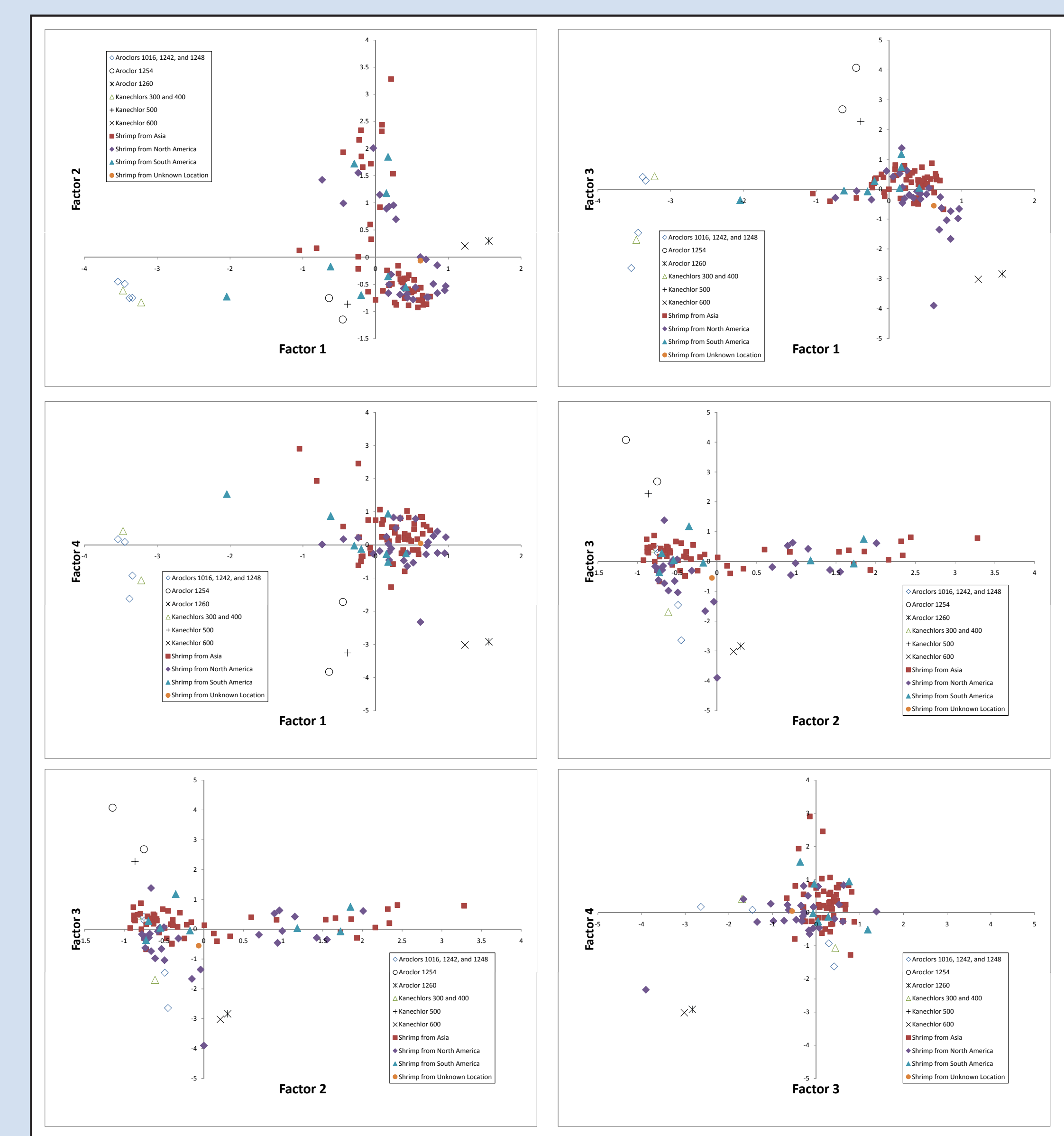


Figure 4. Factor Score Plots for Factors 1, 2, 3, and 4 by Continent of Origin.

Overall,

- There are no systematic differences in the scores for samples due to sample type or continent of origin.
- The scores are, for the most part, bounded by the factor scores for the Aroclor and Kanechlor mixtures. This is especially true for Factors 1 and 3. This indicates that the PCB congener profiles in the shrimp are due to exposure to a combination of Aroclor mixtures.
- The PCBs in the shrimp are more likely due to shrimp exposure to either Aroclors 1254 and 1260 or Kanechlors 500 and 600 rather than to either Aroclors 1016, 1242, and 1248 or Kanechlors 300 and 400.
- There is one sample that appears to have a higher contribution from the less chlorinated mixtures.
  - a farm-raised shrimp sample from Ecuador which had the lowest Factor 1 score of all shrimp samples
  - this sample was previously identified as a high-end outlier.<sup>3</sup>
- Based on Factor 2, there appears to be a contribution from a non-Aroclor or non-Kanechlor source of PCBs for select samples.

Presence of a PCB Source Not Related to Aroclor or Kanechlor Mixtures.

Although no general trends in congener profiles based on the factor scores due to sample type or continents of origin were identified, 17 shrimp samples have Factor 2 scores greater than 1. These samples include:

- 8 farm-raised samples from Bangladesh;
- 2 farm-raised samples from Vietnam;
- 2 farm-raised samples from Ecuador;
- 3 wild-caught samples from Mexico;
- 1 wild-caught sample from the United States, and;
- 1 wild-caught sample from Argentina.

Figure 5 presents the average congener profile for these samples. Based on this profile, these samples have high contributions of PCBs 8 and 11, congeners known to be associated with commercial paint pigments.<sup>7</sup> This indicates that shrimp samples with high Factor 2 scores may be impacted by PCBs from PCB sources unrelated to Aroclor or Kanechlor sources, such as commercial paint pigments.

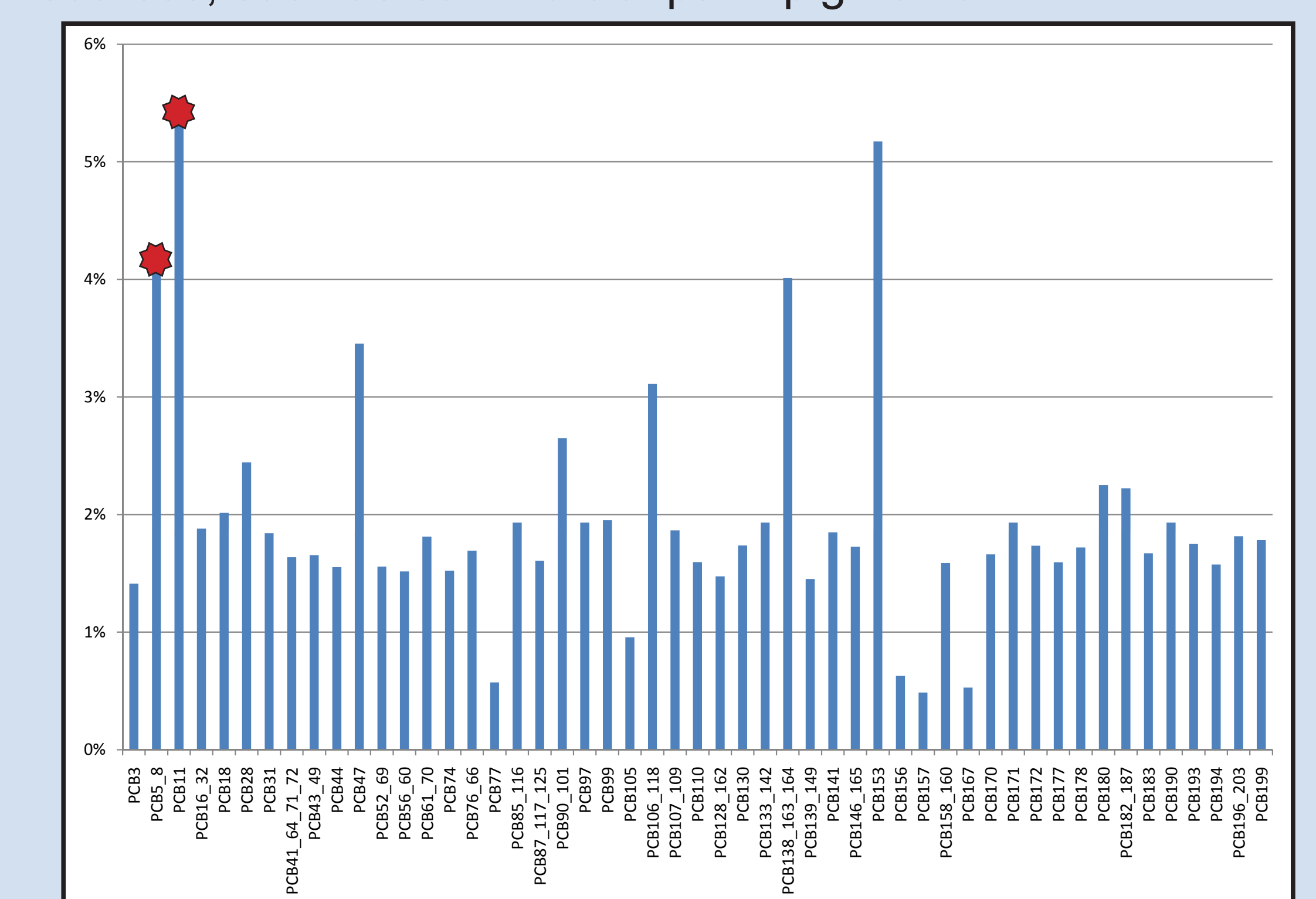


Figure 5. Average PCB Congener Profile for Samples with Factor 2 Scores Greater Than 1.0.

CONCLUSIONS

While the PCA 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. The majority of the shrimp samples are impacted by sources of Aroclors 1254 and 1260 or Kanechlors 500 and 600 rather than the other 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

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REFERENCES

Same as in abstract or available upon request.