Total mercury (THg), total selenium (TSe), and monomethyl mercury (MeHg+) in Steller sea lion liver: use of TSe:MeHg+ molar ratios

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Introduction

- Mercury (THg) global environmental contaminant of particular significance to piscivorous predators such as Steller sea lions (SSL)
- Monomethyl mercury (MeHg+) neurotoxin easily absorbed by the gastrointestinal tract and readily crosses the placenta and the blood-brain barrier
- Selenium (TSe) essential nutrient in marine diets, likely ameliorates the adverse effects of MeHg+ via antioxidant activities and demethylation
- We previously reported regional differences in whole blood concentrations of total mercury (THg) and total selenium (TSe) in SSLs. Several western Alaska Islands (WAI) SSLs had whole blood (and hair) [THg] above thresholds of concern. We have also reported age class differences in [TSe] in SSL blood and hair (Castellini et al. 2012, Rea et al. 2013)
- Pup body burdens (Correa et al. 2014) indicated tissue [THg] was high enough in some tissues from a WAI pup (Agattu Bay) that [TSe] may have been inadequate (based on molar ratios of TSe:THg ≤ 1)

We update those studies, reporting [THg], [MeHg+], [TSe], % MeHg+, and the TSe:THg and TSe:MeHg+ molar ratios in liver of Alaskan SSLs (adult to fetal carcasses from 2003–2013), to provide context to observations of high tissue [TSe] in SSLs.

Methods

Samples: Archived liver samples (n = 39) that had been collected from Alaska SSL carcasses (National Marine Mammal Laboratory, NMFS/NOAA and Alaska Department of Fish and Game) from 2003 – 2013, and 1 juvenile and 4 adult SSLs provided from subsistence harvests by The Alaska Sea Otter and Steller Sea Lion Commission (TASLC) from 2003 – 2013, and 1 juvenile and 4 adult SSLs provided from subsistence harvests by The Alaska Sea Otter and Steller Sea Lion Commission (TASLC). A total of 47 livers were collected.

Samples represent a variety of age classes: fetus, pup, young of the year (YoY), juvenile, sub-adult, and adult. Most individuals were collected from Southeast Alaska and the Gulf of Alaska. Sample distribution did not allow for regional analysis but represents regions with previously reported low to moderate [THg] in SSL blood and hair (Castellini et al. 2012, Rea et al. 2013)

Statistical Analyses:
- Age class differences for elements in liver: Kruskal Wallis One-Way ANOVA on Ranks; YoY excluded from analyses (p = 2 or ≤ 2)
- Significantly different at p < 0.05

Note: Small sample sizes within groups limit statistical comparisons and interpretation

Acknowledgements

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Table 1: Selenium (TSe), Total Mercury (THg) and Monomethylmercury (MeHg+) concentrations in Steller sea lion Liver by Age Class

<table>
<thead>
<tr>
<th>Age Class</th>
<th>TSe (μg/g)</th>
<th>THg (μg/g)</th>
<th>MeHg+ (μg/g)</th>
<th>TSe:MeHg+ Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>12.1 ± 2.6</td>
<td>6.12 ± 0.8</td>
<td>0.32 ± 0.01</td>
<td>38.4 ± 7.1</td>
</tr>
<tr>
<td>Pup</td>
<td>1.80 ± 0.4</td>
<td>20.82 ± 0.4</td>
<td>0.13 ± 0.01</td>
<td>14.3 ± 2.1</td>
</tr>
<tr>
<td>Fetus</td>
<td>0.21 ± 0.01</td>
<td>10.23 ± 0.2</td>
<td>0.07 ± 0.01</td>
<td>29.6 ± 5.0</td>
</tr>
<tr>
<td>Median</td>
<td>4.16 ± 2.1</td>
<td>12.76 ± 1.7</td>
<td>0.08 ± 0.01</td>
<td>15.1 ± 1.5</td>
</tr>
<tr>
<td>Median</td>
<td>1.17 ± 0.30</td>
<td>10.25 ± 1.2</td>
<td>0.08 ± 0.01</td>
<td>12.9 ± 1.2</td>
</tr>
<tr>
<td>Median</td>
<td>1.17 ± 0.30</td>
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</table>

Figure 2: Molar TSe:MeHg+ in relation to [THg] (A) and TSe:MeHg+ in relation to [MeHg+] (B) in SSL liver by Age Class

Figure 3: Molar concentrations and relationships between TSe, THg and MeHg+ in SSL liver by Age Class

Statistical differences between age classes (p < 0.05) are indicated by different lower case letters in each panel (a > b > c). YoY (n = 2 or 3) were excluded from statistical comparisons.

Older (adult, subadult and juvenile) and younger (pup and fetus) SSLs displayed markedly different relationships between liver [THg], [TSe] and MeHg+; largely as a result of bioaccumulation of inert Hg-Se complexes in the older age classes.

While molar TSe:THg is commonly measured to infer adequacy of Se stores, the key relationship is the molar relationship between functional Se (not sequestered in Hg-Se complexes) and MeHg+. The TSe:MeHg+ may not be sufficient to assess adequacy of Se stores as there is an obvious age specific increase in non-MeHg+/Se-Hg complexes of Hg (compare 1B and 1D), while there is no major increase in [MeHg+] across cohorts (Fig 1D).

The higher proportion of MeHg+ (Fig 1E) in pup and fetal liver, combined with lower [TSe], resulted in significantly lower TSe:MeHg+ in pups compared to adults. Where [MeHg+] was elevated in pups and fetuses, the TSe:MeHg+ approached 1, suggesting potentially insufficient stores of Se in those cases.

The TSe:MeHg+ is more easily interpreted in pups and fetuses where bioaccumulation of MeHg+ is likely not a significant confounding factor, making pups particularly useful for monitoring the effects of Hg status.

Conclusions

Optimal tissue-specific TSe:THg or TSe:MeHg+ may be 1. Adequacy of TSe stores will depend on [MeHg+] and amounts of free Se and functional selenoenzymes vs sequestered Se. These relationships will vary by tissue type – see the attached handout for [TSe], [THg] and [MeHg+] in matched SSL tissues.

Pups are an important cohort for monitoring THg, TSe and MeHg+ status (TSe:THg and TSe:MeHg+) in SSLs.