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# Speciation of Mercury in Eelgrass (*Zostera marina* L.): a Seasonal Study in the Great Bay Estuary, New Hampshire

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**The first detailed determination of mercury(II) [Hg(II)] and monomethylmercury cation ($MeHg^+$) concentrations in eelgrass (*Zostera marina* L.) is described. The rapid and simple method includes digestion by the new reagent tetrabutylammonium bromide/potassium hydroxide, derivatization by sodium borohydride and detection by hydride generation–cold vapor atomic fluorescence spectrometry. Mercury in leaves/stems and roots/rhizomes of eelgrass samples collected near Adams Point of the Great Bay Estuary, NH, from May to November of the 1997 growing season was speciated. The seasonal ranges of concentrations in leaves and stems of eelgrass are: Hg(II), 14.9–40.4 ng Hg $g^{-1}$ dry weight; $MeHg^+$, 1.06–3.89 ng Hg $g^{-1}$ dry weight. $MeHg^+$ content averaged 6.9% of total mercury. Analogous values for roots and rhizomes are: Hg(II) 15.4–57.7 ng Hg $g^{-1}$ dry weight; $MeHg^+$ 0.91–2.41 ng Hg $g^{-1}$ dry weight; $MeHg^+$ averaged 6.4% of total mercury. The non-parametric Kendall test showed that Hg(II) and $MeHg^+$ concentrations in leaves and stems increased from May to July, then decreased. For roots and rhizomes the Kendall test showed that Hg(II) concentrations were unchanged from May to August, then decreased, and that $MeHg^+$ concentrations decreased throughout the growing season. The non-parametric Wilcoxon Signed-Ranks method showed no systematic difference in Hg(II) or $MeHg^+$ concentrations between leaves/stems and roots/rhizomes.** 

**Keywords: speciation; mercury; methylmercury; hydride derivatization; eelgrass; *Zostera marina* L.; estuary; atomic fluorescence spectrometry**

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## 1 INTRODUCTION

Seagrasses rank with mangroves and coral reefs as some of the most productive coastal habitats in the world.[1] The seagrass *Zostera marina* L. (eelgrass) grows under water along the coasts of the USA, Japan and Europe.[2] In a comparison of three nursery habitats in a Cape Cod estuary, Heck *et al*.[3] found that eelgrass supported the greatest number of species and had the greatest estimated production of macroinvertebrates. It covers 46% of the our study area of the Great Bay Estuary, NH, USA, provides habitat for juvenile finfish and invertebrates, and is an important primary producer in the detrital food chain in coastal waters.[4] Clearly eelgrass is significant in the coastal and estuary ecosystem and undoubtedly has a major role in heavy-metal cycling there.

Despite the importance of seagrasses, very little research exists on forms of mercury in eelgrass and its role in cycling of mercury in coastal waters. In a preliminary study, Puk and Weber[5] found mercury (II) [Hg(II)], $MeHg^+$ and $Me_2Hg$ in eelgrass using a detection method of lower sensitivity than that of the current paper. Morrison and Weber,[6] while developing a digestion technique for speciation of mercury in eelgrass, found average Hg(II) concentrations of 40 ng Hg $g^{-1}$ dry weight and average $MeHg^+$ concentrations of 2.8 ng Hg $g^{-1}$ dry weight. A Review[7] noted a concentration of 10 ng (g $Hg_{tot}$)$^{-1}$ concentration in eelgrass.

In contrast to a paucity of mercury studies on *Zostera marina* L., several studies exist for cadmium, lead and zinc.[7] As cited in that Review,[7] concentrations in above- and below-ground parts of eelgrass were about 1 $\mu$g $g^{-1}$ for cadmium, 1–40 $\mu$g $g^{-1}$ for lead and 30–130 $\mu$g $g^{-1}$ for zinc. $Hg_{tot}$ concentrations of *ca* 0.02 $\mu$g $g^{-1}$ in this study

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are much lower than those of the above metals. The Brix and Lyngby group[8–11] have emphasized cadmium, copper, lead and zinc in detailed studies of eelgrass near the coast of Denmark. Their studies include determination of concentrations of metals in above- and below-ground parts of eelgrass from 40 sites,[9] translocation of zinc added to each of separate compartments of leaves/stems and roots/rhizomes growing in the laboratory,[8] variations in metal concentrations as plants decay[10] and a seasonal study of metals.[11] Many of these studies are not directly applicable to the current mercury results, but some important lessons are present. First, eelgrass probably sequesters significant amounts of metals for long periods of time, thus providing an important pool of them in coastal environments.[10] Second, because of the ability of eelgrass to reflect metal concentrations in its surroundings, it would make an excellent biomonitor to assess pollution.[7] Considering the importance of eelgrass to the estuarine and coastal environment and concerns with the toxicity of mercury, it is surprising that only a few studies have investigated mercury in these plants.

This paper describes a quick and simple method of determining Hg(II) and $MeHg^+$ in eelgrass by digestion in the recently developed reagent tetrabutylammonium bromide/potassium hydroxide ($Bu_4NBr/KOH$),[6] derivatization by $NaBH_4$, and detection by cold vapor atomic fluorescence spectrometry (CV-AFS). The major research goal was to determine how Hg(II) and $MeHg^+$ concentrations varied during the May–November growing season in leaves/stems and roots/rhizomes of eelgrass from the Great Bay, NH. During the growing season Hg(II) and $MeHg^+$ concentrations in the eelgrass leaves and stems changed significantly. Concentrations of Hg(II) (and $MeHg^+$) in leaves and stems were statistically equal to those in the roots and rhizomes. The most significant result of the present study is the differences in seasonal patterns between this study and an eelgrass study of other metals.[11]

# 2 EXPERIMENTAL

## 2.1 Cleaning of glassware, plasticware and Teflon items

All glassware and Teflon items used in the HG–CV-AFS system were cleaned once by a known procedure prior to use.[12,13] For general cleaning, all glassware and plasticware was soaked in 10% $HNO_3$ overnight, rinsed with $H_2O$ and heated in 1% HCl overnight. Then the items were cooled, rinsed with $H_2O$ and dried in an oven at 70 °C.

## 2.2 Reagents and calibration standards

Water purified by reverse osmosis followed by deionization and distillation (Corning Mega-pure still) was used in all experiments unless noted otherwise. HCl was trace metal grade (Fisher Scientific), and other reagents were ACS reagent grade.

Aqueous 6% $NaBH_4$ (w/v) was prepared from 99% $NaBH_4$ (Aldrich) as described previously[5] and purged with helium purified by a gold column for 3 h to remove any traces of mercury(0).

The extracting solution of 0.25 M tetrabutylammonium bromide (Acros, 98%) in 4 M potassium hydroxide ($Bu_4NBr/KOH$) was prepared by diluting 8.06 g of solid $Bu_4NBr$ to 100 ml with 4 M KOH.

Stock solutions and calibration standards of Hg(II) and $MeHg^+$ were prepared as previously described.[13] Calibration standards were prepared every three days.

## 2.3 Eelgrass collection and processing

Samples of eelgrass (*Zostera marina* L.) were collected near Adams Point, Great Bay Estuary, NH, during the 1997 growing season. Eelgrass was collected 300 m off Adams Point from a boat on 8 and 28 May and 11 June. All other samples were collected 1–3 m off Adams Point at low tide from the same 3 m of shoreline. The plants were flowering during July and August. Whole plants were pulled, rinsed briefly in the estuary water, and placed in Ziploc™ bags for transport.

In the laboratory before processing, roots and rhizomes were separated from the leaves and stems, and rinsed with $H_2O$ purified only by reverse osmosis until the rinse was clear. The leaves and stems were then cut into roughly 1 cm pieces, mixed and frozen in Ziploc™ bags until use. Roots and rhizomes were cleaned similarly until all debris was removed from between the roots. Roots and rhizomes were then cut into small pieces (less than 1 cm), mixed, and frozen in Ziploc™ bags.

Before digestion, eelgrass (*ca* 15 g wet) was rinsed with 1 liter of $H_2O$, frozen in liquid nitrogen, and ground to a fine powder with a mortar and

 

pestle. Aliquots for digestion and wet/dry ratio determination were placed in pre-weighed vials. Samples not digested immediately were frozen in the sealed digestion containers until use.

### 2.4 Digestion procedure for determination of Hg(II) and $MeHg^+$ in eelgrass

About 2 g of wet leaves and stems or 1 g of wet roots and rhizomes were ground in liquid nitrogen and placed in a pre-weighed 30-ml FEP centrifuge tube (Nalgene, Oak Ridge, TN). The $Bu_4NBr$/KOH digestion reagent (5 ml) was vortexed for 10 s to homogenize it immediately before its addition to the eelgrass. The tubes were capped, then the samples were vortexed (VWR Vortex II) for 1 min and allowed to sit at room temperature for 7 h. Samples were then sonicated (Branson 2200 L) at 60 °C for 1 h and allowed to cool. Water (5 ml) was added to ensure good separation of the plant material from the solution before centrifugation at 6000 rpm (International Clinical Centrifuge, Model CL) for 8 min.

### 2.5 Procedural spike recoveries for roots and rhizomes

Morrison and Weber[6] previously reported spike recovery of 83–105% from digestion reagents and reagents plus eelgrass leaves and stems, and these experiments were not repeated. Only roots and rhizomes were tested to determine if the extraction procedure was suitable for them. After addition of 10.0 ng each of Hg(II) and MeHgCl to *ca* 1 g of eelgrass in centrifuge tubes, samples were vortexed for 1 min, and allowed to equilibrate at room temperature for 30 min before addition of digestion reagents.

### 2.6 Operating procedure for HG–CV-AFS

The overall apparatus and derivatization conditions were described previously,[6,13] with one exception. An important difference is that after $NaBH_4$ was injected into the hydride generation flask, the contents of the flask were allowed to react with stirring for 5 min before being purged onto the cryotrap.

Samples were normally run within 24 h of digestion. Typically 500 µl aliquots were used for HG–CV-AFS determination. Typical retention times were 1.00 min for Hg(II) as mercury(0) and 1.70 min for $MeHg^+$ as MeHgH.

The method of standard additions was used for eelgrass extracts because of matrix interferences that alter sensitivity. One sample for each set of replicate extracts was used to construct the standard addition curve, which was used for quantification of the entire set.

## 3 RESULTS

### 3.1 Calibration data and detection limits

We recorded calibration curves for Hg(II) and $MeHg^+$ in the NaCl medium with and without aliquots of both digestion solutions, and used standard additions to quantify Hg(II) and $MeHg^+$ in the presence of digests of eelgrass. Standard addition data for one replicate in a sample were used for quantification of all three samples in the set. Slopes of Hg(II) and $MeHg^+$ calibration curves generally range between 14 and 18 (area units $\times 10^6$ $ng^{-1}$ Hg) in NaCl and aliquots of digestion solutions in it, but slopes for $MeHg^+$ in the presence of eelgrass extracts can be outside the 14–18 range. Correlation coefficients ($r^2$) for the calibration curve slopes in all media were generally greater than 0.99.

Limits of detection (LOD) for Hg(II) in the method were calculated based on $3\sigma$ of blanks in the various reagents.[6] The Hg(II) blank ($3\sigma$) was about 30 pg in $Bu_4NBr$/KOH. Use of approximately 0.2-g samples (dry weight) and 500-µl aliquots resulted in an LOD of 3.0 $ng^{-1}g$ for Hg(II) in $Bu_4NBr$/KOH. Because $MeHg^+$ does not contaminate reagents, its LOD was *ca* 0.02 ng $g^{-1}$.

### 3.2 Spike recoveries

Morrison and Weber[6] showed that spike recoveries of Hg(II) and $MeHg^+$ from the $Bu_4NBr$/KOH reagent and from eelgrass stems and leaves varied from 83 to 105%. In this study recoveries of Hg(II) and $MeHg^+$ from $Bu_4NBr$/KOH containing about 1 g (fresh weight) of eelgrass roots and rhizomes were 97.7% (± 7.6% RSD) and 77.6% (± 4.3% RSD). Recoveries from roots and rhizomes are comparable with those from leaves and stems, demonstrating that the use of the same extraction procedure is possible.

**Table 1** Concentrations of Hg(II), $MeHg^+$ and total mercury ($Hg_{tot}$) (ng Hg $g^{-1}$ dry wt), and percentage of $MeHg^+$, in leaves/stems of eelgrass from the Great Bay Estuary during the 1997 growing season[a]

| Date | No of replicates | Hg(II) (± RSD (%)) | $MeHg^+$ (± RSD (%)) | $Hg_{tot}$ (± RSD (%)) | $MeHg^+$ (%) |
|---|---|---|---|---|---|
| 8 May | 3 | 40.4 (±7.41) | 2.84 (± 8.85) | 43.3 (± 7.47) | 6.56 |
| 28 May | 3 | 17.3 (± 18.45) | 1.30 (± 4.31) | 18.6 (± 17.39) | 7.00 |
| 11 Jun | 6 | 24.7 (± 20.14) | 1.53 (± 13.0) | 26.2 (± 20.0) | 5.28 |
| 30 Jun | 5 | 25.7 (± 17.10) | 1.43 (± 23.4) | 27.1 (± 17.16) | 5.28 |
| 7 Jul | 3 | 29.1 (± 2.94) | 1.57 (± 9.99) | 30.7 (± 3.26) | 5.12 |
| 15 Jul | 2 | 36.1 (± 4.82) | 3.89 (± 1.28) | 40.0 (± 4.47) | 9.72 |
| 28 Jul | 2 | 34.7 (± 2.09) | 2.05 (± 5.60) | 36.8 (± 1.67) | 5.57 |
| 6 Aug | 3 | 31.1 (± 4.20) | 2.43 (± 10.8) | 33.5 (± 4.25) | 7.26 |
| 14 Aug | 3 | 25.2 (± 11.89) | 2.08 (± 8.39) | 27.3 (± 11.2) | 7.61 |
| 21 Aug | 2 | 30.7 (± 0.57) | 2.28 (± 16.2) | 33.1 (± 2.00) | 6.89 |
| 4 Sep | 3 | 21.9 (± 1.47) | 1.71 (± 5.18) | 23.6 (± 1.27) | 7.24 |
| 19 Sep | 3 | 16.0 (± 8.23) | 1.06 (± 8.89) | 17.0 (± 8.26) | 6.23 |
| 3 Oct | 3 | 14.9 (± 9.42) | 1.13 (± 19.7) | 16.0 (± 9.63) | 7.04 |
| 6 Nov | 3 | 18.2 (± 8.43) | 1.64 (± 15.8) | 19.8 (± 8.66) | 8.27 |
| 21 Nov | 3 | 19.4 (± 9.46) | 1.92 (± 13.0) | 21.4 (± 9.51) | 9.00 |

[a] Samples from 8 May, 28 May and 11 June were collected *ca* 300 m off Adams Point. The remaining samples were collected there *ca* 1–3 m from shore at low tide.

## 3.3 Hg(II) and $MeHg^+$ concentrations and seasonal trends

### 3.3.1 Eelgrass leaves and stems

All concentrations of mercury in eelgrass samples collected during 1997 between 8 May and 21 November from the Great Bay Estuary, NH (Table 1 and Fig. 1), are defined as ng Hg $g^{-1}$ dry weight. Hg(II) concentrations in leaves and stems ranged from 14.9 ng $g^{-1}$ (3 October) to 40.4 ng $g^{-1}$ (8 May), $MeHg^+$ concentrations ranged from 1.06 ng $g^{-1}$ (19 September) to 3.89 ng $g^{-1}$ (15 July), and $Hg_{tot}$ concentrations varied from 16.0 ng $g^{-1}$ (3 October) to 43.3 ng $g^{-1}$ (8 May). The percentage of $MeHg^+$ of $Hg_{tot}$ in eelgrass leaves and stems varied little during 1997 (Table 1, Fig. 2). The average percentage of $MeHg^+$ (6.9 ± 1.2%), was similar that (6.5%) found by Morrison and Weber[6] in eelgrass leaves and stems collected from October 1996 to January, 1997.

We studied the significance of seasonal trends by the non-parametric Kendall method.[14] The Kendall method (Stata statistics program, Stata Corp., College Station, TX, USA) is a rank correlation test that examines the extent of correlation between two data sets. The outputs are the rank correlation coefficient ($\tau$) and the probability *(P)* of the null hypothesis, i.e. absence of trend, being correct.

We omitted plants from 8 May, 28 May and 11 June collection dates from our statistical analyses of seasonal trends in mercury concentration in leaves/stems and roots/rhizomes because their collection site was different from that of the rest of the plants. Application of the Kendall test to data from the dates 30 June to 15 July (Table 1, Fig. 1) resulted in evidence for a significant positive correlation between these collection dates and Hg(II) concentrations in leaves and stems ($\tau = 0.6158$, $P = 0.0132$). The test also indicated that from 15 July to the last sampling date in November a significant negative correlation exists between collection date and Hg(II) concentration ($\tau = -0.5033$, $P = 0.0000$).

$MeHg^+$ concentrations (Table 1, Fig. 1) show the same trends as Hg(II) concentrations. Concentrations from 30 June to 15 July show that a significant positive correlation is observed ($\tau = 0.6577$, $P = 0.0049$), and after 15 July a significant negative correlation occurs ($\tau = -0.4698$, $P = 0.0005$).

### 3.3.2 Eelgrass roots and rhizomes

Mercury concentrations in roots and rhizomes (Table 2, Fig. 3) ranged from 15.4 ng $g^{-1}$ (19 September) to 57.7 ng $g^{-1}$ (8 May) for Hg(II), and from 0.91 ng $g^{-1}$ (4 September) to 2.41 ng $g^{-1}$ (8 May) for $MeHg^+$. The average concentration of $MeHg^+$ was 6.4% (Table 2, Fig. 2), which was similar to the 6.9% $MeHg^+$ found in leaves and stems.

The Kendall test agrees with the null hypothesis up to 6 August ($\tau = 0.1234$, $P = 0.5212$) for Hg(II) concentrations (Table 2, Fig. 3). After 6 August,

 

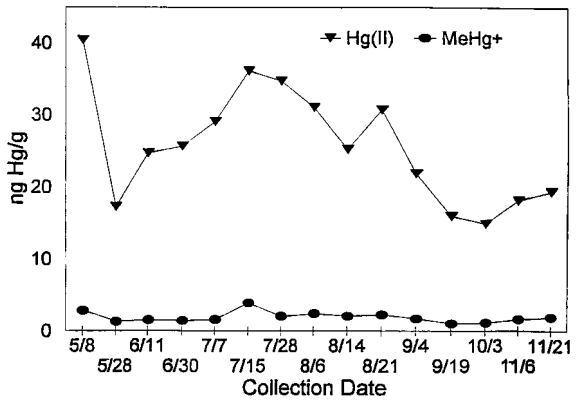


**Figure 1** Concentrations of Hg(II) and $MeHg^+$ versus sampling date in leaves and stems of eelgrass from Adams Point during the 1997 growing season.

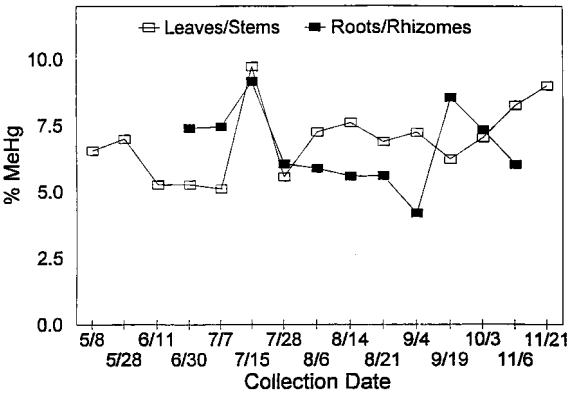


**Figure 2** $MeHg^+$ (% $Hg_{tot}$) versus sampling date in leaves/stems and roots/rhizomes of eelgrass from Adams Point during the 1997 growing season.

however, the test shows that the Hg(II) concentration decrease is significant ($\tau = -0.4668$, $P = 0.0031$). The Kendall test also agrees with a decreasing trend in $MeHg^+$ concentrations during the entire 1997 growing season ($\tau = -0.5390$, $P = 0.0000$).

We used the Wilcoxon Signed-Ranks method,[15] a non-parametric alternative to paired *t*-tests, to evaluate whether or not paired samples were equal. Specifically we used the calculation (Stata) to indicate whether or not concentrations of Hg(II) (or $MeHg^+$) in the leaves/stems differed significantly from those in the roots/rhizomes. The results for the entire sampling period show that concentrations of neither Hg(II) ($P = 0.4236$) nor $MeHg^+$ ($P = 0.2477$) vary between the leaves/stems and the roots/rhizomes.

# 4 DISCUSSION

## 4.1 Solution to problems with integration of $MeHg^+$ peaks

Initially, chromatograms from eelgrass extracts

**Table 2** Concentrations of Hg(II), $MeHg^+$ and total mercury ($Hg_{tot}$) (ng Hg $g^{-1}$ dry wt), and percentage of $MeHg^+$, in roots/rhizomes of eelgrass from the Great Bay Estuary during the 1997 growing season[a]

| Date | Hg(II) (± RSD (%))[b] | $MeHg^+$ (± RSD (%))[b] | $Hg_{tot}$ (± RSD (%))[b] | $MeHg^+$ (%) |
|---|---|---|---|---|
| 8 May | 57.7 (±5.6) | 2.41 (±12.4) | 60.2 (±5.80) | 4.01 |
| 30 Jun | 28.5 (±5.90) | 2.28 (±19.9) | 30.8 (±6.93) | 7.41 |
| 7 Jul | 26.3 (±10.0) | 2.12 (±4.51) | 28.4 (±9.47) | 7.46 |
| 15 Jul | 20.9 (±2.9) | 2.11 (±9.71) | 23.0 (±11.8) | 9.15 |
| 28 Jul | 25.1 (±2.28) | 1.62 (±2.93) | 26.7 (±2.13) | 6.06 |
| 6 Aug | 34.1 (±2.64) | 2.13 (±8.13) | 36.2 (±2.84) | 5.88 |
| 14 Aug | 22.8 (±2.58) | 1.35 (±3.05) | 24.2 (±2.34) | 5.58 |
| 21 Aug | 23.6 (±1.41) | 1.40 (±6.12) | 25.0 (±1.45) | 5.60 |
| 4 Sep | 20.9 (±3.11) | 0.91 (±9.08) | 21.8 (±3.17) | 4.18 |
| 19 Sep | 15.4 (±1.44) | 1.44 (±6.27) | 16.8 (±2.45) | 8.55 |
| 3 Oct | 16.0 (±4.35) | 1.27 (±5.14) | 17.3 (±4.08) | 7.34 |
| 6 Nov | 22.8 (±0.46) | 1.47 (±4.26) | 24.3 (±0.17) | 6.04 |

[a] Samples from 8 May were collected *ca* 300 m off Adams Point. The remaining samples were collected there *ca* 1–3 m from shore at low tide.
[b] Three replicates.

 

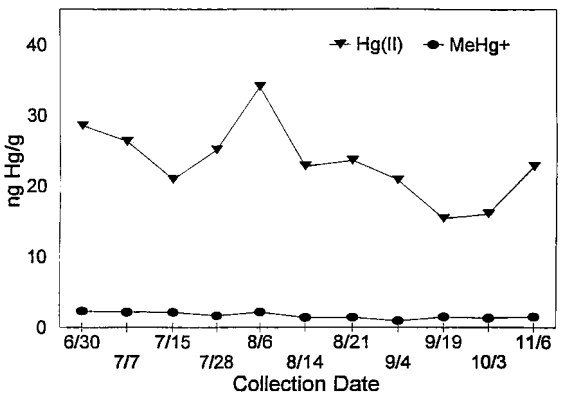


**Figure 3** Concentrations of Hg(II) and $MeHg^+$ versus sampling date in roots and rhizomes of eelgrass from Adams Point during the 1997 growing season.

often exhibited a second (and sometimes a third) peak for Hg(II). Increasing the amount of Hg(II) standard added confirmed that the additional peaks result from Hg(II). Adding areas of peaks associated with Hg(II) caused no problem in its determination, but sometimes made integration of the following smaller $MeHg^+$ peak difficult because of peak overlap. Attempts to improve separation of the two peaks by adjusting the flow rate, column temperature and pH of hydride reduction of Hg(II) to mercury(0) were unsuccessful.

We next tested the hypothesis that an increased reaction time of the eelgrass extract with $NaBH_4$, and keeping the resulting products in a closed vial before purging volatile products onto the column, would lessen the problem. We tested the procedure using several different times between addition of $NaBH_4$ and purging, and measured the of the second Hg(II) peak as a percentage of the total Hg(II) area. The reaction times (% area of second peak) were: 10 min (0%), 5 min (0.8%), 2.5 min (22%) and 1 min (44%). Reaction times of 2.5 and 1 min did not decrease the second peak sufficiently and a 10-min reaction time increased the analysis time too much and also decreased the $MeHg^+$ sensitivity. A reaction time of 5 min resulted in an acceptable compromise; the small second Hg(II) peak did not overlap with the $MeHg^+$ peak, and $MeHg^+$ had its usual sensitivity.

We hypothesize that the second peak from eelgrass digests resulted from formation of unstable $HgH_2$ due to compounds, possibly ligands, in the extract. $HgH_2$ in a continually purged vial moves rapidly to the column at liquid-nitrogen temperature (−196 °C) and stops there. Two mercury(0) peaks occur because, as the column warms, unstable $HgH_2$ moves more slowly than mercury(0) for a short time before decomposing into mercury(0). Further research is necessary to prove the presence of $HgH_2$.

## 4.2 Mercury in eelgrass

To date, the only published research on mercury speciation in eelgrass is on samples of leaves and stems from the Great Bay Estuary. Puk and Weber[5] reported eelgrass concentrations (fresh weight) of 13.7 ng $g^{-1}$ for Hg(II), 7.9 ng $g^{-1}$ for $MeHg^+$ and 9.7 ng $g^{-1}$ for $Me_2Hg$. Recently, Morrison and Weber,[6] with eelgrass samples from October 1996 and January 1997, found Hg(II) concentrations of 38.1 and 41.3 ng $g^{-1}$ and $MeHg^+$ concentrations of 2.67–2.88 ng $g^{-1}$. It is difficult to compare the Hg(II) and $MeHg^+$ concentrations of this study with those from Puk and Weber[5] because of lack of data on fresh weight/dry weight ratios in the latter study. However, concentration ranges of 14.9–40.4 ng $g^{-1}$ for Hg(II) and 1.06–3.89 ng $g^{-1}$ for $MeHg^+$ agree with those reported above by Morrison and Weber.[6]

It is difficult to explain the observed seasonal trend in Hg(II) and $MeHg^+$ concentration in eelgrass leaves/stems and roots/rhizomes. Eelgrass typically reaches a maximum biomass in July or August,[4] and it is reasonable to expect a decrease in mercury concentration due to growth dilution. Instead our results show that concentrations of Hg(II) and $MeHg^+$ increase with increasing biomass. This result is contrary to the findings of Lyngby and Brix,[11] who found maximum metal concentrations after growth ceased, followed by decreasing concentrations as biomass increased. Changes in biological and chemical activity in the plant and its rhizosphere probably contribute to increased mercury concentrations. Weber *et al.*[16] discussed these processes for *Spartina alterniflora* in a salt marsh of the Great Bay Estuary and we will not discuss them here. Other factors that might influence mercury uptake during the summer include warmer temperatures and increased photosynthetic radiation. Changes in pH of the water column are probably of little consequence, because the average pH in the Great Bay Estuary averages 7.8 with very little seasonal variation.[4] The steady decrease in $MeHg^+$ concentrations in roots and rhizomes during the growing season (Table 2, Fig. 3) is also difficult to rationalize.

Similarity in mercury concentrations in above-

 

and below-ground parts of eelgrass contrasts with differences in concentrations of certain other metals. Brix *et al*.[9] found that cadmium, copper and zinc concentrations in eelgrass were higher in leaves/stems than in roots/rhizomes. Metal uptake and distribution in plants vary with the species and metal as well as the bioavailability of the metal in the water column and sediment.[7] Clearly Hg(II) and $MeHg^+$ concentrations in estuarine sediments[7,13] are greater than those in overlying water. Therefore, we might expect higher concentrations of mercury compounds in roots/rhizomes relative to those in leaves/stems. There are at least two explanations for similar concentrations. First, translocation of mercury from below- to above-ground would result in similar concentrations in both plant parts. This possibility is not borne out by other research on eelgrass. Laboratory studies showed little translocation of zinc from leaves/stems to roots/rhizomes or the opposite;[8] cadmium, however, does migrate from above- to below-ground parts of eelgrass.[17] Second, despite higher concentrations of mercury compounds in sediments than in water, only a low percentage of mercury compounds in sediments might be bioavailable, e.g. due to formation of mercury(II) sulfide.[16]

## 5 CONCLUSION

The presence of $MeHg^+$ at approximately 6.8% of $Hg_{tot}$ in eelgrass suggests that aquatic vegetation may be an important source of $MeHg^+$ bioaccumulation in the food chain throughout the year. Eelgrass is a good candidate for a biomonitor to assess pollution of metals.[9] However, any conclusion about its usefulness for mercury requires a detailed speciation study of mercury in eelgrass, the water column, pore water and the rhizosphere. Many important research topics remain unexplored for Hg(II) and $MeHg^+$ in eelgrass that have been investigated for other metals.[8,10] These include differences in concentrations and speciation with age in various parts of the plant, decomposition studies of leaves in estuarine water to determine the ultimate fate of mercury compounds and the importance of detritus in the bioaccumulation of $MeHg^+$, and translocation studies for below- and above-ground parts of the plant.

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