

MERCURY CONCENTRATIONS IN DEER MOUSE
(*PEROMYSCUS MANICULATUS*) TISSUES FROM ISLE ROYALE
NATIONAL PARK

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Jack Oelfke

*Natural Resource Manager
Isle Royale National Park Headquarters
Houghton, MI 49931*

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Submitted by:

Leah M. Vucetich
John A. Vucetich

*School of Forestry and Wood Products
Michigan Technological University
Houghton, MI 49931, USA*

ABSTRACT

We used the deer mouse (*Peromyscus maniculatus*), an omnivore with small home range, to investigate variation in fine scale mercury exposure across the terrestrial ecosystem of Isle Royale National Park. This study was prompted by the discovery of elevated mercury concentrations in northern pike (*Esox lucius*), moose (*Alces alces*), and common loons (*Gavia immer*) from Isle Royale. Previous work suggested that mercury levels may be higher inside than outside the watershed of Sargent Lake, near the east end of Isle Royale. We collected deer mice from five locations inside and outside the Sargent Lake watershed. Mercury levels were significantly higher in kidneys than in livers. Mercury levels in livers were significantly higher outside (100.13 ng Hg/g dry tissue) than inside (35.50 ng Hg/g dry tissue) the Sargent Lake watershed. Mercury levels in kidneys did not differ significantly outside (443.23 ng Hg/g dry tissue) and inside (360.62 ng Hg/g dry tissue) the Sargent Lake watershed. Although these levels are not alarmingly high, concern is warranted because any exposure in the deer mouse, a mid-trophic level species, represents a path for biomagnification of mercury in the terrestrial ecosystem.

INTRODUCTION

Awareness of elevated levels of mercury in biotic and abiotic components of the ecosystem has increased over the past decade. For example, sediment cores from Michigan and Wisconsin suggest that mercury levels in the Lake Superior region are currently 3-4 times greater than they were in 1850 (Swain et al. 1992). The U.S. and Canada have also posted fish consumption advisories because of elevated mercury (USGS 1996). Mercury is one of nine environmental toxins of concern addressed by the U. S. - Canadian *Binational Program to Restore and Protect the Lake Superior Basin*. Furthermore, the 1996 USEPA *Conference on Mercury in the Midwest* called for monitoring the biota to identify affected areas.

This increased awareness and concern over environmental mercury motivated an investigation of mercury levels on Isle Royale National Park, a wilderness island in Lake Superior (Fig. 1A). Being a remote wilderness, Isle Royale might be expected to serve as a baseline ecosystem which has been only minimally affected by human sources of pollution. However, preliminary investigations from inland lakes of Isle Royale revealed that mercury concentrations in northern pike (*Esox lucius*) exceed the Michigan consumption advisory of 0.50 ppm (Kallemeyn, in prep., MiDNR 1977). Also, mercury concentrations in the teeth of moose (*Alces alces*) from Isle Royale increased from the 1940s to the 1970s (Eide and Peterson 1997). In addition, mercury concentrations in a common loon (*Gavia immer*) chick from the inland waters of Isle Royale was six times higher than that found in loons from Lake Superior waters surrounding Isle Royale (Evers *et al.*, in press). These findings justify further investigation of mercury in the Isle Royale ecosystem.

Because most mercury research focuses on aquatic systems, less is known about mercury in terrestrial systems. However, small mammals are known to accumulate heavy metals (Jeffries and French 1976, Anthony and Kozlowski 1982, Smith and Rongstad 1982, Talmage and Walton 1990). Deer mice (*Peromyscus maniculatus*) are important bio-indicators of heavy metal pollution in the terrestrial ecosystems of Isle Royale for several reasons. Because deer mice are predators of insects and other invertebrates, they are likely to bioaccumulate environmental toxins more rapidly than terrestrial herbivores. Because deer mice have relatively small home ranges (typically 0.2 - 2.5 ha), they provide a fine-scale resolution of the distribution of heavy metals in terrestrial environments. Finally, because deer mice are the only small mammal (i.e., <150 grams) inhabiting Isle Royale, they are a primary prey item for foxes, owls, and weasels. Thus, deer mice on Isle Royale should be an important link in the transport of heavy metals through the terrestrial food chain. Here, we report the mercury concentrations in tissues of adult deer mice (*P. maniculatus*) from Isle Royale National Park.

MATERIALS AND METHODS

Sample collection

Based on preliminary data from fish studies, the Sargent Lake watershed was suspected to contain high mercury concentrations (relative to other portions of Isle Royale) and identified by the National Park Service as a focal point for further investigations on the distribution of mercury within Isle Royale (Fig. 1B). To address the hypothesis that the Sargent Lake watershed contains high mercury concentrations (relative to other portions of Isle Royale), we live-trapped (in

accordance with methods approved by the Michigan Technological University Institutional Animal Care and Use Committee) three adult deer mice from each of five locations inside the Sargent Lake watershed and five locations outside the watershed (Fig. 1B and 1C). Mice were sacrificed by cervical dislocation and frozen for storage.

In the lab, mice were thawed for processing. All lab equipment (glass, Teflon, or stainless steel) was washed with 10% nitric acid and triple rinsed with distilled, deionized water. Prior to analyzing the Isle Royale study specimens, we analyzed the livers, kidneys, and carcasses of four trial mice (two from Sargent Lake and two from Chassell, MI) to determine which tissues accumulate mercury. We recorded the sex, full body weight, liver weight and kidney weight of each specimen. Each tissue type was homogenized and refrozen for storage in separate Teflon vials. Because the carcasses of the trial mice had very low mercury levels, we retained only the livers and kidneys from the Isle Royale study specimens. Tissues from the three specimens from each location were pooled and analyzed as a single composite sample from that location. Livers and kidneys were analyzed separately.

Mercury analysis

Mercury analysis was done at the Department of Water Chemistry, University of Wisconsin, Madison, WI under the direction of L. B. Cleckner and P. R. Gorski.

Statistical analysis

We used nanograms of mercury per gram dry tissue for all statistical analyses to minimize possible differences in moisture content of the tissues. However, we also report nanograms of mercury per gram wet tissue to facilitate comparison to other studies. We compared the average

mercury concentrations in deer mice from inside and outside the Sargent Lake watershed using the two-sample z -test. We also compared average mercury concentrations in kidneys and livers using the two-sample z -test. In the event that variation in mercury accumulation may be influenced by sex, we calculated the proportion of males collected from each location and performed a chi-squared test to determine if sex was associated with sample composition. In the event that variation in mercury accumulation may be influenced by weight, we calculated the mean body weight of specimens comprising each sample and compared them using a two-sample t -test. In addition, we looked for correlations between body weight and mercury concentrations in livers or kidneys. We also calculated the correlation between mercury concentrations in livers and kidneys.

RESULTS

In the trial samples, mercury concentration was greatest in the kidneys, intermediate in the livers, and least in the carcasses (Table 1). In Isle Royale study specimens, kidneys also had significantly higher mercury concentrations than livers both inside the Sargent Lake watershed ($z=3.78$, $p<0.001$) and outside the watershed ($z=2.97$, $p<0.01$; Tables 2 and 3, Fig. 2). Sites outside the Sargent Lake watershed had significantly higher liver mercury concentrations than sites inside the Sargent Lake watershed ($z=1.90$, $p=0.03$; Tables 2 and 3, Fig. 2). However, sites inside and outside the Sargent Lake watershed did not differ significantly for mercury concentrations of kidneys ($z=0.59$, $p=0.14$; Tables 2 and 3, Fig. 2).

The proportion of males in the samples from inside (6/15) and outside (7/15) the Sargent Lake watershed were not significantly different ($\chi^2=0.54$, $p>0.25$). Thus, variations in mercury

concentrations between samples is unlikely biased by an uneven sex ratio. The mean weight of specimens from inside (17.03 g) and outside (18.01 g) the Sargent Lake watershed were not significantly different ($t = -1.3, p=0.20$). However, because $p=0.20$ is not a convincing failure to reject the null hypothesis, we investigated correlations between body weight and mercury concentrations. Although some variation in weight exists, weight was not significantly associated with mercury concentrations in livers ($r=0.014, p=0.97$) or kidneys ($r=0.18, p=0.62$).

The correlation between liver and kidney mercury inside the Sargent Lake watershed was weaker ($r=0.79, p=0.12$) than between liver and kidney mercury outside the Sargent Lake watershed ($r=0.998, p<0.001$; Fig. 3). Pooled samples from both sites resulted in an intermediate correlation between liver and kidney mercury ($r=0.82, p<0.01$). Variation in the mercury levels of kidneys inside (coefficient of variation, $CV=0.53$) and outside ($CV=0.56$) the Sargent Lake watershed was similar. However, variation in the mercury levels of livers inside the Sargent Lake watershed ($CV=0.44$) was about 50% less than variation in the mercury levels of livers outside the Sargent Lake watershed ($CV=0.74$).

DISCUSSION

In contrast to expectations, mercury concentration in livers was higher outside than inside the Sargent Lake watershed and mercury concentration in the kidneys was not significantly different between the two sites. Consistent with the results of previous studies (Jeffries and French 1976, Bull *et al.* 1977, Talmage and Walton 1990), mercury levels throughout Isle Royale were higher in kidney than in liver tissue. Average dry weight mercury concentrations of Isle Royale kidneys (0.361 ppm inside and 0.443 ppm outside the Sargent Lake watershed) were

higher than that reported for laboratory raised control *Peromyscus* mice (0.20 ppm; Talmage and Walton 1990). However, mercury concentrations of all deer mouse tissues studied on Isle Royale are also below the Michigan fish consumption advisory of 0.50 ppm.

New world mice of the genus *Peromyscus* are regarded as ecological equivalents to old world mice of the genus *Apodemus* (Montgomery 1989). The mean wet weight mercury concentrations in livers of *Apodemus* found near a polluted chlor-alkali site (0.23 ppm) and at an associated control site (0.04 ppm) were higher than mercury concentrations in Isle Royale *Peromyscus* livers inside (0.011 ppm) and outside (0.030 ppm) the Sargent Lake watershed (Bull *et al.* 1977). The mean wet weight mercury concentration in kidneys of *Apodemus* found near the same polluted chlor-alkali site (0.52 ppm) was higher than the mean wet weight mercury concentration in Isle Royale *Peromyscus* kidneys inside (0.103 ppm) and outside (0.126 ppm) the Sargent Lake watershed (Bull *et al.* 1977). However, the mean wet weight mercury concentration in Isle Royale *Peromyscus* kidneys is similar to that of *Apodemus* kidneys from the associated control site (0.12 ppm; Bull *et al.* 1977). All mean wet weight mercury concentrations of Isle Royale tissues are well below livers (2.66 ppm) and kidneys (3.95 ppm) of *Apodemus* trapped in a wheat field two months after it was planted with wheat seeds coated in mercury-containing compounds (Jeffries and French 1976).

Evidence suggests that total mercury concentrations and the proportion of methylated mercury tend to be greater for organisms positioned at higher trophic levels. For example, near a polluted smelter in northern Sweden, mercury concentrations in Tengmalm's owl (*Aegolius funereus*) nestlings (0.043 - 0.048 ppm) equalled or exceeded that of their primary prey, the bank

vole (*Clethrionomys glareolus*) (0.01 - 0.043 ppm; Hornfeldt and Nyholm 1996). In another example of mercury bioaccumulation, total mercury concentrations were high (0.27 - 1.7 ppm) and methyl mercury concentrations were relatively low (<0.001 ppm; Gardner *et al.* 1978) for samples from the top 5 cm of sediments in a polluted salt marsh near a chlor-alkalai plant (Brunswick, Georgia). Mercury concentrations of primary producers in this marsh were greater than in the sediments, and higher trophic levels had higher total mercury concentrations with increasing proportions in the methylated form (Gardner *et al.* 1978). For example, herbivorous cotton rats (*Sigmodon hispidus*) had dry weight concentrations of total liver mercury of only 3.8 ppm (19% in methylated form), while those of the omnivorous Norway rat (*Rattus norvegicus*), opossum (*Didelphis marsupialis*), and raccoon (*Procyon lotor*) were 15, 13, and 8.0 ppm (88, 42, and 26 % in methylated form), respectively.

In addition to mercury contamination being substantially lower than in these highly polluted ecosystems, the Isle Royale ecosystem may also exhibit a different pattern of mercury concentration across its trophic levels. For example, total mercury concentrations were 0.133 ppm for soil samples from the A-horizon near Sargent Lake and 0.071 ppm for soil samples from near the Minong Mine (located a few mile southwest of Sargent Lake where native copper and silver were mined nearly 100 years ago) (W. Cannon, pers. comm.). For additional context, total mercury concentrations in the Chequamegon forest (located in northern Wisconsin about 150 miles southwest of Isle Royale) was 0.054 ppm (W. Cannon, pers. comm.). In contrast to other studies, the omnivorous deer mice from the Sargent Lake water shed had dry weight concentrations of total mercury in livers of 0.035 ppm — lower than the soil concentrations.

However, the same Sargent Lake deer mice had dry weight concentrations of total mercury in kidneys of 0.361 ppm — higher than the soil concentrations. Future studies of mercury concentration in terrestrial predators of Isle Royale could reveal a relatively complex pattern of mercury concentration across the ecosystems of Isle Royale.

Preliminary investigations into the concentrations of mercury in tissues of Isle Royale deer mice suggests that levels are not alarmingly high. Perhaps, a more comprehensive study with larger sample sizes may provide more conclusive information. Also, sampling at additional sites across the island would give more detailed information about the fine scale distribution of mercury in Isle Royale deer mice. Continued research could reveal which compartments of the Isle Royale ecosystem have high or low concentrations of mercury, whether differences are due mainly to bioaccumulation, and if any other processes are involved. Continued monitoring will also provide strong baseline information on mercury in the ecosystem and alert researchers to any significant changes that may occur.

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FIGURE LEGENDS

Fig. 1. Locations of deer mouse collection sites. Panel B shows the locations of Sargent Lake on Isle Royale and 5 sample sites outside the Sargent Lake watershed: W=Windigo, Mb=Moskey Basin, B=Bangsund, T=Three Mile, and Mt=Mott Island. Panel C shows the locations of 5 sample sites inside the Sargent Lake watershed.

Fig. 2. Mercury concentrations in livers and kidneys collected inside (In) and outside (Out) the Sargent Lake watershed.

Fig. 3. Correlations between mercury concentrations in liver and kidney tissue for samples inside (filled symbols) and outside (open symbols) the Sargent Lake watershed.

Fig. 1

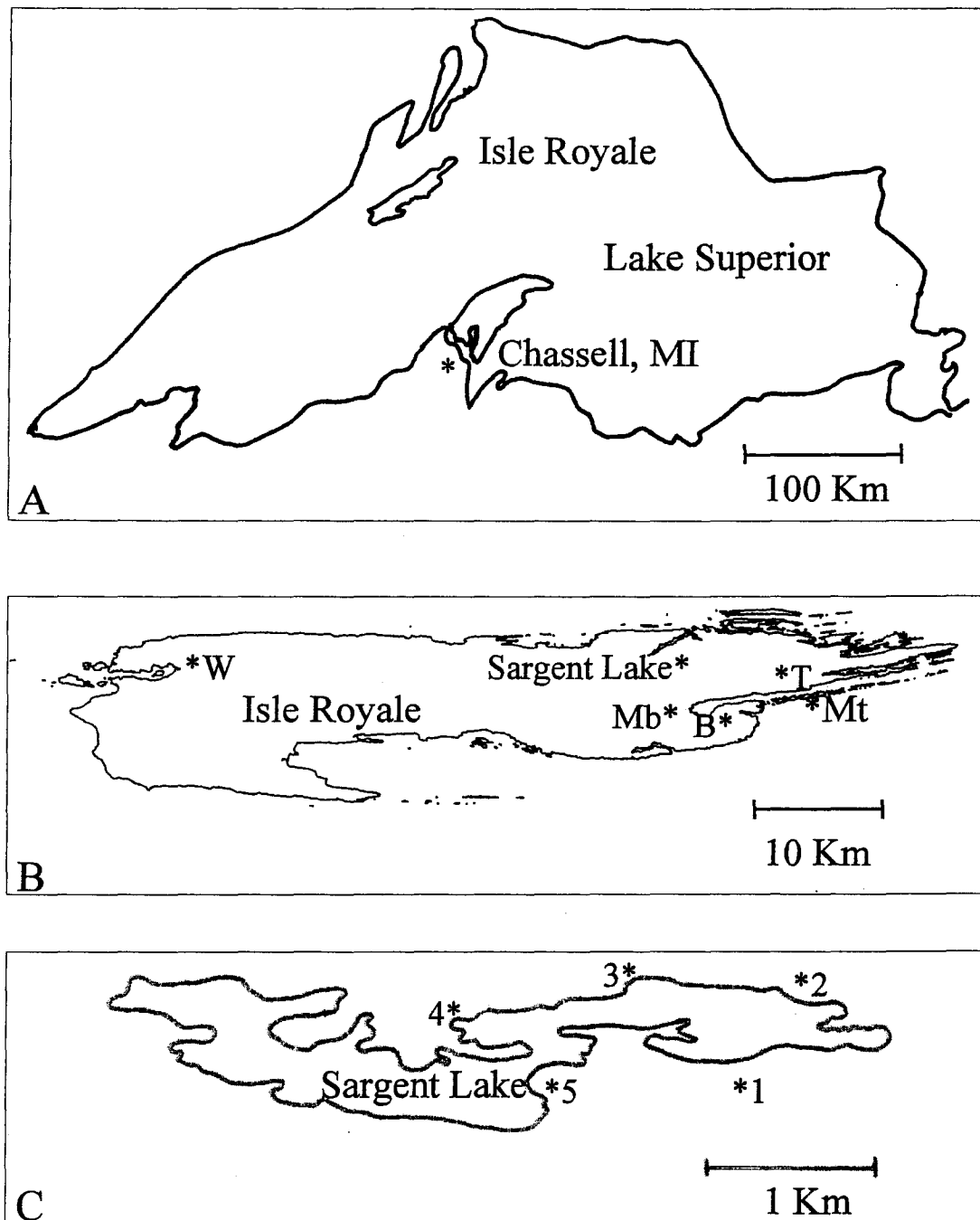


Fig. 2

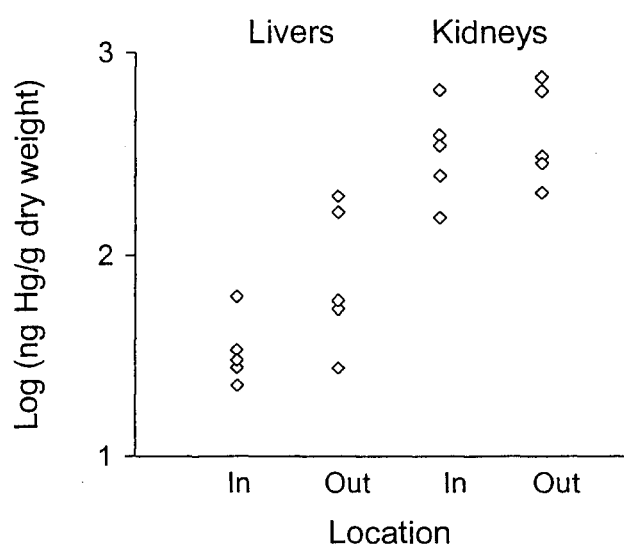


Fig. 3

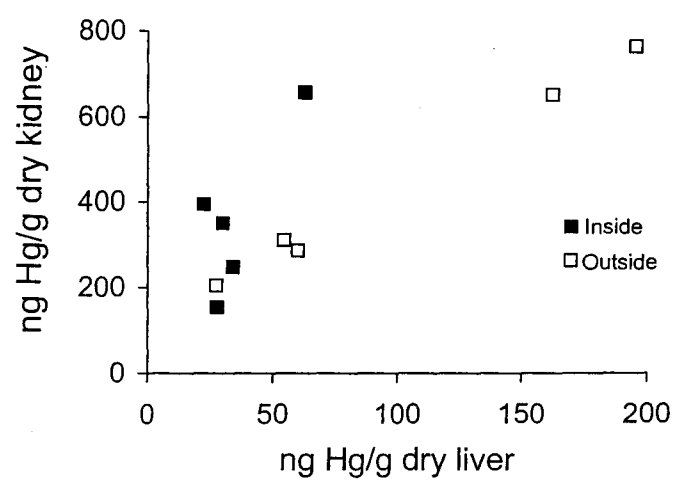


TABLE 1

MERCURY CONCENTRATIONS IN TISSUES OF TRIAL SAMPLES (IN NG Hg/G
TISSUE). SEE FIG. 1 FOR MAP OF COLLECTION SITES.

<i>Collection Site</i>	<i>Wet Liver</i>	<i>Wet Kidney</i>	<i>Wet Carcass</i>	<i>Dry Liver</i>	<i>Dry Kidney</i>	<i>Dry Carcass</i>
Sargent Lake*	16.22	107.12	12.4	52.94	372.41	39.23
Chassell, MI	21.41	155.13	<del> </del>	58.83	294.75	<del> </del>

TABLE 2

MERCURY CONCENTRATIONS IN TISSUES OF ISLE ROYALE STUDY SPECIMENS (IN NG Hg/G TISSUE). "INSIDE" AND "OUTSIDE" INDICATE SAMPLE LOCATION IN REFERENCE TO THE SARGENT LAKE (SL) WATERSHED. SEE FIG. 1 FOR MAP OF COLLECTION SITES.

<i>Watershed Reference</i>	<i>Collection Site</i>	<i>Wet Liver</i>	<i>Wet Kidney</i>	<i>Dry Liver</i>	<i>Dry Kidney</i>
<i>Inside</i>	SL#1	10.37	65.77	34.12	248.18
	SL#2	6.87	106.56	22.58	394.67
	SL#3	8.04	46.31	27.8	153.34
	SL#4	20.12	195.78	62.69	656.99
	SL#5	9.56	98.33	30.33	349.94
<i>Outside</i>	3-Mile	17.73	84.35	54.38	310.11
	Moskey	46.39	181.71	162.78	651.30
	Mott	17.55	84.70	59.89	286.14
	Bangsund	8.48	58.54	27.62	204.68
	Windigo	59.77	218.48	195.98	763.93

TABLE 3

COMPARISONS OF MERCURY CONCENTRATIONS (NG Hg/G DRY TISSUE) IN LIVERS
AND KIDNEYS INSIDE AND OUTSIDE THE SARGENT LAKE WATERSHED USING THE
TWO-SAMPLE Z-TEST.

<i>Comparison</i>	<i>z</i>	<i>p</i>
kidney inside > liver inside	3.78	<0.001*
kidney outside > liver outside	2.97	0.002*
liver outside > liver inside	1.90	0.029*
kidney outside > kidney inside	0.59	0.28
kidney outside = kidney inside	0.59	0.14