MERCURY AND PCBS IN MASSACHUSETTS RIVER OTTERS

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ABSTRACT: Mercury and polychlorinated biphenyl (PCB) residues in livers of trapper harvested river otters (*Lontra canadensis*) from Massachusetts were evaluated. We collected 210 river otters during 1986 and 1987 and composited them into 103 samples based on location. Comparisons among 20 watersheds were made using 96 samples. Mercury residues were detected in all samples and ranged from 0.45 to 4.82 ppm wet weight with an arithmetic mean of 1.93 ppm. PCB residues were detected in all but 2 samples and ranged from none-detected to 22.00 ppm with a geometric mean of 1.03 ppm wet weight. Differences were detected among watersheds for mercury ($P = 0.007$) and PCBs ($P = 0.03$). Juvenile otters had lower mercury ($P = 0.007$) and PCB ($P = 0.02$) residues than older otters. River otters can provide an indication of general watershed background mercury and PCB contamination levels for prioritizing more intensive monitoring efforts. River otter populations in Massachusetts do not appear to be limited by either mercury or PCB contamination. Population monitoring should evaluate potential additive or synergistic effects of mercury in combination with PCBs in certain watersheds.

KEY WORDS: contaminants, *Lontra canadensis*, Massachusetts, mercury, PCBs, river otter, watershed.

Studies of contaminants in river otters (*Lontra canadensis*) from the United States and Canada suggest a predictable relationship between environmental contaminant levels and those found in otters (Wren et al. 1986, Foley et al. 1988, Wren 1991, Elliott et al. 1999). This relationship, combined with the otter's wide distribution in some states and provinces, enhances its potential use as a bio-indicator of waters with elevated contaminant levels. Jenkins (1980) suggested liver tissue from carnivorous and piscivorous mammals might be an excellent biological monitor of environmental mercury levels.

Mercury and polychlorinated biphenyls (PCBs) may adversely affect the reproductive biology of otters. There seems to be an association between impaired reproduction of mink (*Mustela vison*) (Wren et al. 1987*b*) and otter (Halbrook et al. 1981) and elevated environmental contaminant levels. Reproductive failure and mortality were documented in mink from consumption of food containing levels of PCBs currently found in some environments (Platanow and Karstad 1973, Hornshaw et al. 1983, Wren et al. 1987*a*, 1987*b*). Declines in otter (*Lutra lutra*) in parts of Sweden were circumstantially linked to elevated PCB levels (Sandegren et al. 1980). Kruuk and Conroy (1991) suggested that mercury and PCBs contributed to otter mortality in Shetland, U.K.

We collected river otter carcasses in cooperation with the Massachusetts Division of Fisheries and Wildlife (MDFW) at legal pelt tagging stations during 1986 and 1987 to evaluate the use of river otters as indicators of watershed contamination levels. We were also interested in determining if otter mortality or reproductive impairment was correlated with mercury and PCB contamination.

METHODS

River otter carcasses were collected by the MDFW from licensed fur trappers at legal pelt tagging stations during November and December in 1986 and 1987. These were immediately frozen and subsequently dissected. Approximately 150 g of liver tissue was removed from each carcass for mercury and PCB analyses using stainless steel instruments rinsed in acetone. Liver tissue was placed in wide-mouth glass jars with teflon®-lined lids (1986 samples) or in polyethylene whirl-pak® bags (1987 samples). For PCB analyses, liver tissue was placed in wide-mouth glass jars or wrapped in aluminum foil and placed in polyethylene bags. Female reproductive tracts were removed and each ovary was sectioned for corpora lutea counts after preparation in 10% formalin solution. A lower canine tooth was removed from each skull for age determination using radiograph analysis (Kuen and Berg 1983).

Mercury analysis was conducted by the Environmental Trace Substances Research Center in Columbia, Missouri, USA, using cold-vapor atomic absorption spectroscopy (Hatch and Ott 1968). The detection limit was 0.008 ppm dry weight. Analysis showed recovery to be 102%. The variation in replicate analyses was 0.5 to 6.3%. Mercury residues were converted to wet weight ppm for analysis based on percent moisture of each sample. Mercury residues followed a nearly normal distribution; therefore, those data were not transformed.

PCB analysis was conducted by the Mississippi State University Chemical Laboratory. Determinations of PCBs in otter liver were completed by electron capture gas chromatography following sulfate/hexane soxhlet extraction as described by Ford and Hill (1990). The method detection limit for PCBs was 0.05 ppm. The variation in replicate analyses was 0 to 40%.

Because PCB data were not normally distributed, logarithm ($\log_{10}$) transformations were applied prior to statistical analyses. Geometric means of wet weight PCBs were used in all data analyses, following procedures of Schmitt (1981) and Foley et al. (1988).

Some samples were composited because only a limited number of samples could be submitted for analysis. Of 68 river otter livers from 1986, 4 were composited into 1 sample, 27 were composited into 9 samples of 3 livers each, 24 were composited into 12 samples of 2 livers each and 10 were individually analyzed. Of 143 river otter livers from 1987, 16 were composited into 4 samples of 4 livers each, 60 were composited into 20 samples of 3 each, 42 were composited into 21 samples of 2 each and 22 were individually analyzed. Composite samples were composed of liver tissue from otters trapped within the same watershed. In some cases, composites were further refined, consisting of samples from otters caught from the same vicinity within the watershed. Trappers were interviewed to determine capture locations. Watershed designations (Figure 1) were made according to Halliwell et al. (1982).

Mercury and PCB levels were compared among 20 watersheds (n = 96). Average sample size/watershed was 4.8 (range 2 to 12). Least squares analysis of variance (ANOVA) was used to compare means among watersheds and between years. The interaction between sampling year and watershed was evaluated for 14 watersheds that had otter samples from both 1986 and 1987. Tukey's HSD test was conducted when ANOVA showed differences among means ($P < 0.05$).

A sample of 13 adult females that were not composited for residue analysis, but analyzed as single samples, were evaluated for relationship of mercury and total PCBs to fecundity based on corpora lutea counts using ANOVA.

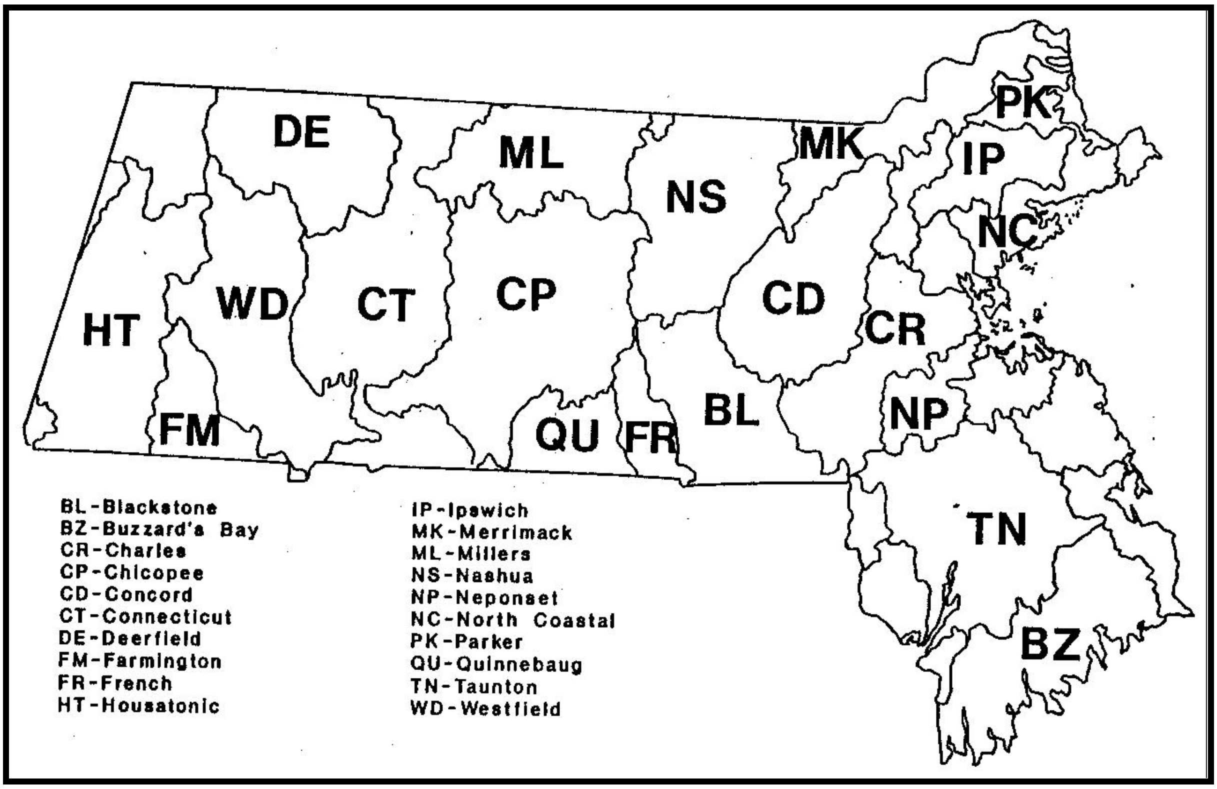

Figure 1. Massachusetts watersheds sampled for contaminants in river otters, 1986 -1987.

RESULTS

Mercury

Mercury was detected in all samples ($\bar{x}$ = 1.19 ppm, SE = 0.42), range 0.45 to 4.8). Otter mercury residues differed among the 20 watersheds (19 df, *P* = 0.007), but not between years (1 df, *P* = 0.46). Average mercury residues/watershed ranged from 0.75 (North Coastal) to 3.1 ppm (Charles) wet weight. Average residue concentrations were higher in the Charles, Blackstone, and Parker River watersheds than in the Westfield, Quinnebaug, Deerfield, Connecticut, Buzzard's Bay, and North Coastal watersheds (*P* = 0.01, Table 1). No year-by-watershed interaction was detected (13 df, *P* = 0.18).

Mercury concentrations in juvenile otters ($\bar{x}$ = 1.4 ppm, SE = 0.63, *n* = 12) were less than in yearlings and adults ($\bar{x}$ = 1.9 ppm, SE = 0.56, *n* = 35, 1 df, *P* = 0.007). No differences in age distributions of sample otters among watersheds were detected (19 df, *P* = 0.12). Mercury concentrations did not differ between adult males and adult females (1 df, *P* = 0.46).

PCBs

PCBs were detected in all but 2 samples (geometric mean = 1.0 ppm, SE = 0.568, range 0.0 to 22.0). PCB concentrations differed among watersheds (19 df, *P* = 0.028), but not between years (1 df, *P* = 0.43). Average concentrations/watershed ranged from 0.28 to 3.0 ppm (Table 2). Average PCB concentrations were higher in the Housatonic, Buzzard's Bay, Merrimack, Concord, and Charles watersheds than in 13 other watersheds (*P* = 0.05, Table 2). A year-by-watershed interaction was detected (13 df, *P* = 0.06).

PCB concentrations in juvenile otters (geometric mean = 0.46 ppm, SE = 3.9, *n* = 11) was lower than in adults (geometric mean = 1.3 ppm, SE = 3.6, *n* = 34, 1 df, *P* = 0.02). PCB concentration in males (geometric mean = 2.8 ppm, SE = 3.8, *n* = 10) were slightly higher than in females (geometric mean = 1.0 ppm, SE = 3.4, *n* = 15, 1 df, *P* = 0.06).

Table 1. Mercury (ppm, wet weight) in river otters from watersheds in Massachusetts, 1986-1987.

Watershed	$\bar{x}$	*n*	SE
Charles (A)[a]	3.1	3	0.18
Blackstone (AB)	3.1	2	1.75
Parker (ABC)	3.0	3	0.71
Neponset (ABCD)	2.9	2	1.14
Concord (ABCDE)	2.5	4	0.83
Nashua (ABCDE)	2.2	7	0.19
Merrimack (ABCDE)	2.1	6	0.21
Farmington (ABCDE)	2.1	3	0.54
Taunton (ABCDE)	2.0	3	0.22
Chicopee (ABCDEF)	1.9	12	0.18
Ipswich (ABCDEF)	1.9	6	0.22
Millers (BCDEF)	1.8	8	0.17
French (CDEF)	1.8	4	0.35
Housatonic (CDEF)	1.7	7	0.21
Westfield (DEF)	1.7	4	0.10
Quinnebaug (EF)	1.6	6	0.24
Deerfield (EF)	1.4	3	0.18
Connecticut (EF)	1.4	8	0.20
Buzzard's Bay (EF)	1.3	2	0.75
North Coastal (F)	0.75	3	0.09

[a]Watersheds followed by the same letter have means that were not different (Tukey's HSD, $P > 0.05$).

Table 2. PCBs (ppm, wet-weight) in river otters from watersheds in Massachusetts, 1986-1987.

Watershed	$\bar{x}$	*n*	SE
Housatonic (A)[a]	3.0	7	1.48
Buzzard's Bay (AB)	2.6	2	1.04
Merrimack (AB)	2.6	6	1.67
Concord (AB)	2.5	4	1.86
Charles (ABC)	2.3	3	1.26
Connecticut (BCD)	2.0	8	1.53
French (CDE)	1.7	4	3.78
Parker (DEF)	1.4	3	1.43
North Coastal (DEF)	1.4	3	1.29
Nashua (EFG)	1.2	7	1.42
Neponset (EFGH)	0.99	2	1.20
Chicopee (FGH)	0.74	12	1.31
Westfield (FGH)	0.68	4	1.42
Deerfield (FGH)	0.64	3	1.32
Millers (GH)	0.57	8	1.52
Taunton (GH)	0.51	3	1.35
Ipswich (GH)	0.49	6	1.79
Quinnebaug (GH)	0.40	6	1.40
Blackstone (H)	0.32	2	7.90
Farmington (H)	0.28	3	0.63

[a]Watersheds followed by the same letter have means that were not different (Tukey's HSD, $P > 0.05$).

Fecundity

No relationships could be detected between contaminant residues and corpora lutea counts (Hg: $P = 0.19$, $r^2 = 0.15$; PCBs: $P = 0.15$, $r^2 = 0.32$).

DISCUSSION

Mercury

Massachusetts river otters do not appear to be at risk from mercury exposures in watersheds sampled in this study. Dead mercury-poisoned river otters in other studies had liver mercury residues of 33.4 to 96.0 ppm wet weight (O'Connor and Nielson 1981, Wren 1985). Samples of river otters from apparently healthy populations contain liver mercury residues of 0.001 to 8.95 ppm (Sheffy and St. Amant 1982, Kucera 1983, Wren et al. 1986, Foley et al. 1988).

Mercury levels documented in Massachusetts river otters fall within the range of values reported for apparently healthy populations. We found differences in mercury accumulation by otters among watersheds in Massachusetts. Foley et al. (1988) suggested that mercury accumulation is determined more by regional influences than by local point-source discharges. Although differences in otter mercury levels among New York watersheds were not significant, correlations between mercury levels detected in fish and both mink and otter mercury levels were significant by watershed (Foley et al. 1988).

PCBS

PCB residue data for Massachusetts river otters suggest high environmental variability (geometric mean = 1.0 ppm, SE = 0.568, range 0.0 to 22.0). This variability could be related to the effects of point sources for PCB discharges.

Age group comparisons

Wren et al. (1987*a*) documented placental transfer of mercury in mink based on elevated mercury levels in neonates on day of whelping. Mercury levels declined in neonates by 5-weeks of age. Juvenile river otters harvested during November in Massachusetts are probably 7-8 months old based on an estimated peak parturition period between March and April (Melquist and Dronkert 1987). Juveniles may not have accumulated enough mercury or PCBs in their livers to be reflective of environmental contamination levels.

Watershed comparisons

The relatively low concentrations of mercury residues in otters among watersheds in Massachusetts suggest that otters are not exposed to mercury-poisoning differentially by watershed. However, Wren et al. (1987*a*) documented toxic effects in adult mink fed diets containing methylmercury in combination with PCBs and suggested that synergistic or additive effects from chronic exposure to a wide range of environmental contaminants pose a greater health threat than exposure to single metals or chemicals. Therefore, it is useful to evaluate watersheds that rank high for both mercury and PCBs. Massachusetts watersheds that ranked high for PCBs (Table 2) were not those that ranked high for mercury. The Charles watershed had the highest residues of mercury and the fifth-highest PCB residues (out of 20 watersheds). The Concord and Merrimack watersheds had high mean PCB residues and the fifth- and seventh-highest mercury residues, respectively.

Environmental variability

PCB residues in Massachusetts river otters were highly variable (geometric mean = 1.0 ppm, CV = 1.4). Increased variability with increasing sample size is not unusual for contaminant residue data because they are typically non-normally distributed (Schmitt 1981). Because of increased variability with increasing sample size, we believe that watershed variance is indicative of effects of local point sources of contamination (Foley et al. 1988), rather than an artifact of sample size.

Population effects

Individual animals may be adversely affected by PCB contamination in Massachusetts (range 0.0 to 22.0 ppm). However, the range of average concentrations/watershed (0.28 – 3.0 ppm) suggests that PCB residues probably have limited effects on otter populations in Massachusetts. Levels of PCB contamination that induce reproductive impairment or mortality in river otters are unknown. Liver PCB levels between 2.0 and 3.0 ppm in mink have been associated with impaired reproduction (Wren et al. 1987*b*).

Foley et al. (1988) compared PCB residues in mink and otter with residues in fish. They found that mink paired with contaminated fish by geographic location had PCB levels that were an order of magnitude lower than otter paired geographically with contaminated fish. Hence, otters from areas where contaminants in fish are high seem to survive with higher body burdens of PCBs than mink when exposed to high PCB levels in their food. Also, mink may be more sensitive to PCB contamination, or are exposed less to it, or bioaccumulate PCBs slower than otters. Evidence from food habit studies (Eagle and Whitman 1987, Melquist and Dronkert 1987), laboratory studies (Hornshaw et al. 1983, Wren et al. 1987*a*,), and field studies (Henny et al. 1981, Foley et al. 1988,) support these hypotheses.

Comparison with other studies

The range of PCB residue levels reported from otters in Oregon, USA (Henny et al. 1981) is similar to that reported from Massachusetts. PCB residue levels reported from otters in Alberta, Canada (Somers et al. 1987) and Louisiana, USA (Fleming et al. 1985) are consistently lower than those reported from Massachusetts and may represent environments lower in PCBs. Residue data from this study do not suggest that Massachusetts watersheds represent exceptional circumstances with respect to mercury and PCBs, with the exception of PCBs in the Housatonic River.

Watershed comparisons

There seemed to be an association between river otter PCB levels and PCB levels in otter habitats. The Housatonic and Buzzard's Bay are considered to be the most PCB contaminated watersheds in Massachusetts (R. Maietta, Massachusetts Division of Water Pollution Control, personal communication). The Merrimack River historically was one of the most polluted rivers in the United States due to former industrial activity. The Farmington watershed includes the water supply for Hartford, Connecticut, USA and is considered to be one of the cleanest river basins in Massachusetts. Residue data from river otters in Massachusetts appear representative of watershed background levels.

MANAGEMENT IMPLICATIONS

River otters can be useful in evaluating background watershed levels of mercury and PCBs, and (1) provide a cost-effective mechanism for prioritizing intensive sampling efforts, (2) provide information from areas where no data exist, and (3) justify more intensive sampling. Samples should be restricted to adult river otters, and guidelines on sample size should be developed that relate number of samples to stream kilometers.

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