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Environmental Contamination and Toxicology

Mercury in Hair of Muskrats *(Ondatra zibethicus)* and Mink *(Mustela vison)* from the U. S. Department of Energy Oak Ridge Reservation

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Muskrats *(Ondatra zibethicus)* are semi-aquatic rodents found throughout most of North America. Muskrats construct extensive burrow systems in the banks of streams (Errington 1937) and are potentially exposed to environmental contaminants through dermal and dietary sources (Halbrook et al. 1993). Muskrats are primarily herbivorous (Perry 1982), which may limit their exposure to contaminants, as most plants contain relatively low concentrations of contaminants (Radvanyi and Shaw 1981; Talmage and Walton 1993). However, riverine muskrats are known to prey on freshwater mussels, and have even been reported to prevent recovery of endangered mussels in the Clinch River of Virginia and Tennessee (Neves and Odum 1989). Mussels and clams are known to bioaccumulate contaminants to levels several thousand times that of surrounding water (Nelson et al. 1995), and these contaminants could potentially be bioaccumulated by predatory muskrats.

Previous studies of contaminant levels in muskrats have shown that muskrats bioaccumulate heavy metals (Everett and Anthony 1977; Halbrook et al. 1993). Contaminant levels in muskrats are also of interest because muskrats area common prey of mink *(Mustela vison),* and mink are among the most sensitive mammals known to environmental contaminants, including Hg (Aulerich et al. 1974; Wren 1986). Mink are exclusively carnivorous (Whitman 198 1) and have been shown to bioaccumulate Hg up to 10 times the levels found in predatory fish (Kucera 1983). The objectives of this study were to determine hair Hg levels in muskrats and mink inhabiting contaminated sites on the U. S. Department of Energy Oak Ridge Reservation (ORR) and to compare these levels to those found in animals from surrounding areas. Hair was chosen to monitor Hg levels in muskrats and mink because hair was easily collected from live animals and because hair Hg levels have been correlated to the more biologically important kidney and liver Hg levels in a number of species (Cumbie 1975; Halbrook et al. 1994).

MATERIALS AND METHODS

This study was conducted on ORR in the Ridge and Valley physiographic province in Oak Ridge, Tennessee. ORR is a 14,000 ha site housing three large research and manufacturing facilities, the Y-12 Plant, K-25 Site, and Oak Ridge National Laboratory (ORNL). Contaminant levels were investigated in muskrats and mink inhabiting the three largest waterways originating on ORR, East Fork Poplar Creek

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(EFPC), Bear Creek (BC), and White Oak Creek (WOC). These three creeks have been contaminated with Hg from historical activities at the Y-12 Plant and ORNL. Hg levels in water, sediment, and fishes were highest on EFPC, much lower on BC, and lowest on WOC. Muskrats were collected from the Clinch River and K-1007 pond, a large pond near the K-25 site, (REF sites) for comparison to the more contaminated sites. Roadkilled mink were collected whenever possible from the two counties (Roane and Anderson) encompassing ORR for comparison to ORR mink. One roadkill was collected from a bridge over BC and was assumed to be a resident of BC. All other roadkills were collected >5 km from contaminated creeks and were assumed to represent background levels of Hg.

Muskrats were captured in two door Tomahawk livetraps (Tomahawk Live Trap Co., Tomahawk, Wisconsin) baited with carrots or apples. Muskrats were anesthetized with an intramuscular injection of ketamine (Ketaset, Fort Dodge Laboratones, Inc., Fort Dodge, Iowa) and xylazine (Rompun, Movay Corporation, Shawnee, Kansas). Sex and age class were determined, standard mammal body measurements were taken, and a numbered monel ear tag was placed in each ear. A 0.5- 1.0 g hair sample was collected from the inguinal and lumbar regions. Anesthetic effects of xylazine were reversed with an intramuscular injection of yohimbine (Sigma Chemical Co., Gaithersburg, Maryland), and upon recovery, muskrats were released at the site of capture.

Mink were captured in unbaited two door Tomahawk livetraps using barrier tunnels (Eagle and Sargeant 1985). Captured mink were transported to The University of Tennessee College of Veterinary Medicine and were anesthetized with an intramuscular injection of medetomidine (Dormitor, Orion Corp., Turku, Finland) and ketamine. A 1.0 -2.0 g hair sample was collected from the abdominal and caudal areas, sex and age class were determined, standard mammal body measurements were taken, and a numbered monel ear tag was placed in each ear. Mink were then intubated and maintained on an oxygen/isoflurane mixture to safely prolong anesthesia, and the effects of medetomidine were reversed with atipamezole (Antisedan, Orion Corp., Turku, Finland). Radiotransmitters were implanted intraperitoneally under aseptic conditions to allow home range and residency status of mink to be determined. All methods used in this study were approved by the ORNL Animal Care and Use Committee.

Hair samples were frozen at -20°C as soon after collection as possible, usually within 2 hr. Hair was washed to remove gross external contaminants by placing the sample in a 250 ml polyethylene bottle filled with deionized water and one drop of non-ionic shampoo. The bottle was placed on a wrist-action shaker for 20 minutes, the sample was removed and rinsed several times in deionized water, dried at 60°C, and refrozen. Hair samples were shipped to one of two analytical laboratories under contract with ORNL (Lockheed Analytical Services, Las Vegas, Nevada or Southwestern Research Institute, San Antonio, Texas), and were digested in sulfuric and nitric acids and analyzed for Hg by cold vapor atomic absorption spectroscopy. Blanks, duplicates, and spiked samples were analyzed with each batch of 20 samples. Recoveries of spiked samples ranged between 92% and 114%.

The nonparametric Kruskal-Wallis test was used to detect differences in Hg levels among the four sites. Differences in Hg levels between sexes and age classes were determined using the nonparametric Mann Whitney U-test. Significance was declared at $P < 0.05$.

RESULTS AND DISCUSSION

Fifty-eight (58) muskrats were captured a total of 114 times. Hg was detected in 75% of all muskrat hair samples, 90% of adult muskrat hair samples and 45% of juvenile muskrat hair samples. Adults from REF sites had higher hair Hg levels than juveniles (P=O.02), but adults from EFPC and WOC did not have higher Hg levels than juveniles (P=-0.78 and P=0.37, respectively). No juveniles were collected from BC for comparison to adults. No differences were detected between sexes from any of the individual sites nor from all sites combined (P=0.90).

Hg concentrations in muskrats varied among the sites for both adults and juveniles (Table 1). Both adult and juvenile muskrats from EFPC, the stream with the highest Hg levels, had higher Hg levels than muskrats from other sites (P=0.003 and P=0.001, respectively). Differences were not detected in Hg levels among adults from BC, WOC, and REF sites, but differences were detected between juveniles from WOC and REF sites (P=0.001).

Juvenile muskrats from contaminated ORR waterways and adult muskrats from EFPC accumulated Hg in hair to levels above that of REF sites. Although statistical differences were not found among adult muskrats from the less contaminated sites on ORR (BC and WOC) and the REF sites, mean hair Hg levels were slightly higher on BC and WOC (Table 1). Hair Hg levels from all sites on ORR, as well as from adult muskrats from REF sites, were higher than levels reported for muskrats from a locally contaminated site in Wisconsin, which averaged 0.06 ppm (Sheffy and St. Amant 1982). Thus, REF sites were probably at least somewhat contaminated with Hg.

Four mink were livecaptured, one from EFPC, two from BC, and one from WOC, and eight roadkilled (REF) mink were collected. Hg was detected in all mink hair samples (Table 2). As with muskrats, mink hair Hg levels followed environmental levels, with the EFPC mink having the highest level followed by BC, WOC, and REF mink. Due to the small number of mink captured, statistical comparisons between streams could not be made. However, mink from contaminated streams on ORR, which had a mean of 29.1 ppm Hg, had higher levels of Hg than mink from surrounding areas (P=0.02), which had a mean of 5.15 ppm. Sheffy and St. Amant (1982) considered 1-5 ppm of hair Hg to represent background levels for mink, which is consistent with the level found in REF mink. As expected, mink from EFPC, BC, and WOC had levels above background. The one juvenile mink from EFPC had over 2.5 times the highest level reported in the literature, which was 41.2 ppm (Sheffy and St. Amant 1982), and over 3 times more hair Hg than a mink known to have died from mercury poisoning (34.9 ppm, Wobeser and Swift 1976). The EFPC mink was known to survive at least 15 weeks after the hair sample was collected. The toxicity of Hg has been shown to be moderated by uptake of Se (Magos and Webb 1980), but hair Se levels were relatively low in this mink (0.69 ppm) and Se levels were not above background in fishes collected from EFPC. Thus, it was unlikely that Se had ameliorated the high Hg level in this case.

Not surprisingly, mink had much higher hair Hg levels than muskrats. Adult muskrats from BC (n= 10) had a mean of 0.24 ppm Hg in hair, while adult mink from BC (n=3) had a mean of 11.0 ppm Hg in hair. Adult muskrats from REF sites (n= 10) has a mean of only 0.13 ppm Hg, while REF mink (n=7) had a mean of 5.15 ppm Hg. This difference was likely due to differences in trophic levels between the species. Muskrats are mostly herbivorous, while mink are exclusively carnivorous and are top level consumers in stream ecosystems. Fishes comprise

Table 1. Mercury concentrations in hair of adult and juvenile muskrats from oak Ridge Reservation and reference (REF) sites. Results reported in mg/kg (ppm) dry weight. Means with different letters are significantly different ($P<0.05$).

	EFPC	BC	WOC	REF
Adult				
n	14	10	5	10
Mean	3.87[a]	0.24[b]	0.24[b]	0.13[b]
SE	1.17	0.09	0.10	0.02
Range	0.08-22.6	0.03-1.07	0.05-0.65	0.05-0.27
Juvenile				
n	5	0	3	12
Mean	1.55[a]	-	0.13b	0.09[c]
SE	0.72	-	0.03	0.01
Range	0.05-4.10	-	0.05-0.18	0.05-0.13

EFPC = East Fork Poplar Creek, BC = Bear Creek, WOC = White Oak Creek, REF = Reference sites (Clinch River and K1007 pond)

approximately 25 - 50% of mink's diet, and fishes can bioaccumulate Hg to almost 5000 times the level found in water (Hoffman and Curnow 1979).

Although muskrats did not accumulate Hg to levels nearly as high as mink, muskrats may be useful indicators of aquatic Hg levels. Muskrats have a large geographic range, which would make comparisons among different sites possible throughout most of North America. Muskrats have small home ranges, typically less than 300 m of stream (Errington 1937), which allows muskrats to provide very site specific information about contaminants. Muskrats are also much more abundant than mink and are probably not as physiologically sensitive to Hg. Therefore, muskrats may be abundant in sites too contaminated to support mink. Nine (9) muskrats were captured in the upper reaches of EFPC, which are the most contaminated 1.2 km of stream on ORR, which provides evidence that muskrats are at least somewhat tolerant of Hg contamination. A laboratory study of contaminant accumulation in muskrats, such as those done on mink (Aulerich et al. 1974), would provide valuable information about the effects of contaminants on muskrats and the potential use of muskrats and indicators of environmental contamination.

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Table 2. Mercury concentrations in hair of mink from Oak Ridge Reservation and surrounding (REF) sites. Results reported in mg/kg (ppm) dry weight.

	EFPC	BC	WOC	REF
n	1	3	1	7
Mean	104.0	11.0	8.80	5.15
SE	-	1.97	-	1.29
Range	-	8.00 -14.7	-	0.64 -10.1

EFPC = East Fork Poplar Creek, BC = Bear Creek, WOC = White Oak Creek, REF = Reference (roadkilled) mink

REFERENCES

Aulerich RJ, Ringer RK, Iwamoto S (1974) Effects of dietary mercury on mink. Arch Environ Contam Toxicol 2:43-51

Cumbie PM (1975) Mercury in hair of bobcats and raccoons. J Wildl Manage 39:419-425

Eagle TC, Sargeant AB (1985) Use of excavations, decoys, and barrier tunnels to capture mink. J Wildl Manage 49:40-42

Ernington PL (1937) Habitat requirements of stream-dwelling muskrats. Trans N Amer Wildl Conf 2411-416

Everett JJ, Anthony RG (1977) Heavy metal accumulation in muskrats in relation to water quality. Trans Northeastern Fish Wildl Conf 33:105-116

Halbrook RS, Kirkpatrick RL, Scanlon PF, Vaughan MR, Veit HP (1993) Muskrat populations in Virginia's Elizabeth Rivet Physiological condition and accumulation of environmental contaminants. Arch Environ Contam Toxicol 25:438-445

Halbrook RS, Jenkins JH, Bush PB, Seabolt ND (1994) Sublethal concentrations of mercury in river otters: monitoring environmental contamination. Arch Environ Contam Toxicol 27:306-310

Hoffman RD, Curnow RD (1979) Mercury in herons, egrets, and their foods. J Wildl Manage 43:85-93.

Kucera E (1983) Mink and otter as indicators of mercury in Manitoba waters. Can J Zool 61:2250-2256

Magos L, Webb M (1980) The interactions of selenium with cadmium and mercury. CRC Crit Rev Toxicol & 1-42

Nelson WG, Bergen BJ, Cobbs DJ (1995) Comparison of PCB and trace metal bioaccumulation in the blue mussel, *Mytilus edulis,* and the ribbed mussel, *Modiolus demissus,* in New Bedford Harbor, Massachusetts. Environ Toxicol Chem 14:513-521

Neves RJ, Odum MC (1989) Muskrat predation on endangered freshwater mussels in Virginia. J Wildl Manage 53:934-941

Perry HR (1982) Muskrats. In: Chapman J A, Feldhamer G (eds) Wild Mammals of North America: Biology, Management, and Economics. John Hopkins University Press, Baltimore, Maryland

Radvanyi A, GG Shaw (1981) Heavy metal contamination of foods and tissues of muskrats in northern Manitoba. In: Chapman J A, Pursley D (eds) Proc Worldwide Furbearer Conference. Worldwide Furbearer Conference, Inc, Frostburg, Maryland

Sheffy TB, St. Amant JR (1982) Mercury burdens in furbearers in Wisconsin. J Wildl Manage 46:1117-1120

Talmage SS, Walton BT (1993) Food chain transfer and potential renal toxicity of mercury to small mammals at a contaminated terrestrial field site. Ecotoxicology 2: 243-2.S6

Whitman JS (1981) Ecology of the mink *(Mustela vison)* in west-central Idaho. MS Thesis. University of Idaho, Moscow, Idaho

Wobeser G, Swift M (1976) Mercury poisoning in a wild mink. J Wildl Dis 12: 335-340

Wren CD (1986) A review of metal accumulation **and** toxicity in wild mammals. 1. Mercury. Environ Res 40:210-244