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Heavy Metal Concentrations in Tissues of Mink in Virginia

Martin C. Ogle,[1] Patrick F. Scanlon,[1*] Roy L. Kirkpatrick,[1] and Jack V. Gwynn[2]

[1]Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061 and [2]Virginia Commission of Game and Inland Fisheries, 2503 Brunswick Road, Charlottesville, VA 22903

Mink (*Mustela vison*) are found statewide in Virginia and throughout the United States. Wetland areas such as streams, lakes and marshes are critical habitat for mink (Linscombe *et al.* 1982). As predators they are opportunistic feeders (Errington 1954), and they eat a wide variety of foods including small mammals, fish, frogs, crayfish, birds and eggs (Burt and Grossenheider 1976).

Several contaminants have been studied in captive ranch mink due to the potential for adverse affects on reproduction and subsequent economic losses in the mink fur industry. Very low concentrations of PCB's have been found to cause death or to interfere with reproduction in mink (Platnow and Karstad 1973; Aulerich and Ringer 1977). Mercury poisoning has been reported in wild mink and may be an unrecognized cause of mink mortality (Wobeser and Swift 1976). Aulerich *et al.* (1974) found mink to be very sensitive to methyl mercury but less so to inorganic mercury ($HgCl_2$). Aulerich and Ringer (1970) found that mink are comparatively resistant to the effects of most organochlorine pesticides. However, little work has been done on heavy metal concentrations (other than mercury) in mink. Aulerich *et al.* (1982) studied the effects of supplemental dietary copper in mink but did not determine the natural concentrations of this metal in wild populations of mink. They found no toxic effects of copper even at daily basal diet supplementation of 200 μg/g.

The present study was undertaken to determine concentrations of lead, cadmium, zinc and copper in wild mink populations from Virginia and to determine if differences existed in heavy metal concentrations among sexes, ages and locations of capture. Mink were chosen for this study because their high trophic status and opportunistic feeding patterns make them potential indicators of heavy metal pollution. Also, according to trend estimates by the Virginia Game Commission and Inland Fisheries (1982), mink populations have been decreasing in certain parts of the state.

*Author whom correspondence should be addressed.

MATERIALS AND METHODS

Mink carcasses were obtained from Virginia trappers during the 1981-82 and 1982-83 trapping seasons. Location of trapping allowed 4 general areas in Virginia to be delineated: Southwest (SW), Central (C), North (N), and East (E). Mink carcasses were frozen as soon as possible at collection centers and later transferred to VPI & SU for necropsy. Ages of mink were determined by cementum annuli analyses supported by baculum and femur characteristics (Ogle 1984). Bone, kidney and liver samples were dissected for heavy metal analyses. Sample preparation and atomic absorption spectrophotometry procedures (flame mode) were those of Scanlon *et al.* (1980). Detection limits were 1.0 µg/g for lead and 0.1 µg/g dry weight (d.w.), for cadmium, zinc and copper. A 3-way Analysis of Variance using Type III sums of squares (SAS 1982) was used to test for differences among sexes, areas and ages in lead, cadmium, zinc and copper concentrations. Because a low percentage of bone samples had detectable lead differences in bone lead concentrations by sex, area and age were tested using a X^2 test with 4 catagories of lead concentrations (< detection, 1.00 - 1.99 µg/g, 2.00 - 2.99 µg/g, and ≥ 3.00 µg/g). Differences were considered significant at the $P<0.05$ level. Data from both trapping seasons were not pooled because trapping locations within areas did not correspond exactly between seasons.

RESULTS AND DISCUSSION

Means (±S.E.), ranges, and significant differences by sex, area and age of lead, cadmium, zinc and copper concentrations in liver, kidney and bone samples of mink trapped during the 1981-1982 and 1982-83 seasons are presented in Table 1. Lead concentrations were similar to or lower than those found in many other species in a variety of trophic levels. Mean bone lead concentrations were similar to or lower than mean bone lead concentrations in river otters (*Lutra canadensis*) from Virginia (Anderson 1981; Anderson-Bledsoe and Scanlon 1983) Mean kidney and liver lead concentrations of mink were lower than those of otters. Diters and Nielsen (1978) found a mean liver lead concentration of 6.2 µg/g (wet weight) in 14 raccoons (*Procyon lotor*) from Connecticut. One raccoon, which had a liver lead concentration of 35 µg/g, had died of lead poisoning. The maximum liver lead concentration in mink from Virginia was 12.7 µg/g, d.w. but only 6% of all liver samples had detectable lead concentrations. The maximum bone lead concentration was 21.2 µg/g, d.w.

Table 1. Lead, cadmium, zinc and copper concentrations in bone, kidney and liver samples of mink trapped in Virginia during the 1981-83 trapping seasons and significant ($P<0.05$) differences and interactions shown by listed variables as follows: by sex (S), age (A), and area (R).

Metal & Tissue & Year	N	%>det.[1] limit	Mean±SE	Min.	Max.	Sign.[2] Difference	Sign.[3] Interaction
1981-82							
BONE							
Pb	129	64	1.87±0.23	0.00	21.15	A	
Zn	129	100	113.47±1.45	54.01	157.53		
Cu	110	89	1.15±0.06	0.00	2.78		
KIDNEY							
Pb	108	3	0.06±0.04	0.00	2.60		
Cd	108	100	1.21±0.20	0.12	15.99	R,A	S*R
Zn	108	100	88.77±1.80	59.99	173.40		
Cu	108	100	21.02±0.97	6.65	71.03		S*R,R*A
LIVER							
Pb	125	6	0.12±0.05	0.00	3.38		
Cd	125	74	0.38±0.05	0.00	3.48	R,A	S*R
Zn	125	100	102.25±2.21	64.24	194.44		S*R*A,S*R
Cu	125	100	36.71±1.76	10.84	116.07	A	
1982-83							
BONE							
Pb	198	45	1.12±0.11	0.00	9.59	A	
Zn	198	100	123.61±1.60	79.68	215.74	S	
Cu	198	100	1.64±0.17	0.13	29.74		
KIDNEY							
Pb	178	11	0.23±0.06	0.00	5.22		
Cd	178	100	1.02±0.10	0.11	11.66	R,A	R*A
Zn	178	100	93.42±1.30	48.24	165.28		
Cu	170	100	31.04±1.84	11.08	196.67	A	R*A
LIVER							
Pb	199	6	0.18±0.08	0.00	12.74		
Cd	199	72	0.33±0.02	0.00	2.43	R,A	R*A
Zn	199	100	123.24±3.28	54.68	304.17	A	R*A
Cu	199	100	34.88±1.94	19.17	193.56		S*R,R*A

[1] % > detection limit. Detection limits were approximately 1 µg/g for Pb and 0.1 µg/g for Cd, Zn, and Cu.
[2] Significant differences by listed variables ($p<0.05$)
[3] Significant interactions by listed variables ($p<0.05$)

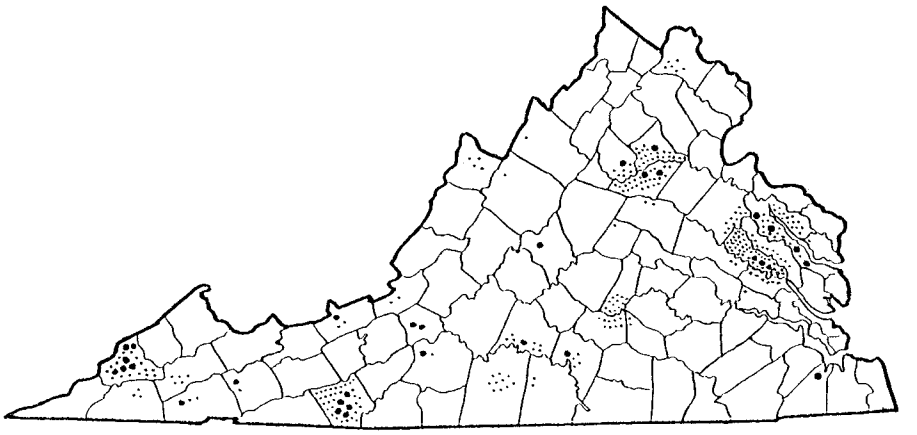

Figure 1. Capture locations in Virginia of mink with bone lead concentrations ≥ 3 µg/g (large dots) and of all other mink (small dots), 1981-83.

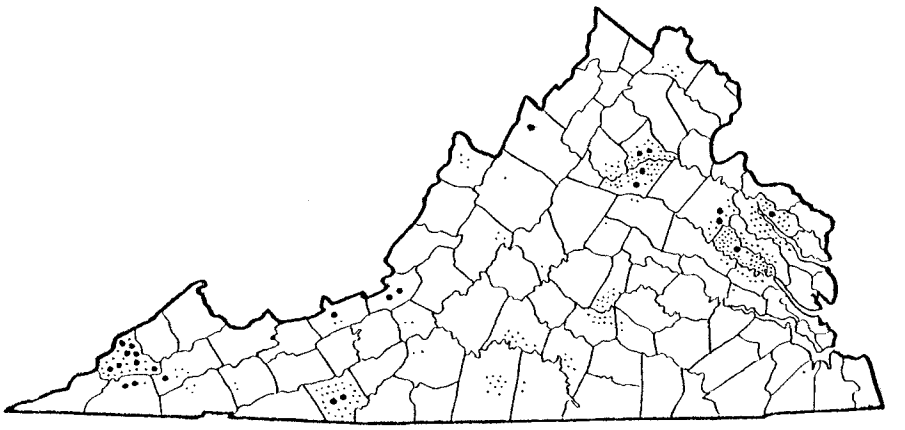

Figure 2. Capture locations in Virginia of mink with kidney cadmium concentrations ≥ 2 µg/g (large dots) and of all other mink (small dots) 1981-83.

No significant differences in bone lead concentrations were observed between sexes or among areas. However, the SW area tended to have a lower proportion of samples below the lead detection limit and more samples with lead concentrations ≥ 3 µg/g than the other 3 areas (Figure 1). Tissue lead concentrations in white-tailed deer (*Odocoileus virginianus*) have been found to vary significantly with ecoregions (Kocan *et al.* 1980) and general geographic regions (Woolf *et al.* 1982). Lead concentrations in gray squirrels (*Sciurus carolinensis*) varied with human socioeconomic regions (McKinnon *et al.* 1976) Woolf *et al.* (1982) found liver lead concentrations did not differ significantly between sexes of deer.

Significant differences in bone lead concentrations among ages were observed in mink during both trapping seasons. Lead concentrations in bone accumulated with increasing age. Mink of 3 years or older more often had ≥ 3 µg/g lead in bone, and juveniles more often had undetectable lead concentrations than would be expected. Scanlon *et al.* (1983) found that adult pine voles (*Microtus pinetorum*) had significantly higher lead concentrations than juveniles from orchards that had been treated with lead arsenate several years before the study.

Overall cadmium concentrations in mink kidneys and livers were slightly higher than those reported by Anderson-Bledsoe and Scanlon (1983) in otters, and by Anthony and Kozlowski (1982) in white-footed mice (*Peromyscus leucopus*) and meadow voles (*Microtus pennsylvanicus*) trapped in control areas and areas irrigated with sewage. Liver cadmium concentrations in mink were similar to those found in white-tailed deer from Illinois (Woolf *et al.* 1982). Mean kidney cadmium concentrations reported in other species range from 2.48 µg/g (wet weight) in raccoons from Florida (Hoff *et al.* 1977) to 39.7 µg/g in field mice (*Apodemus sylvaticus*) from an abandoned smelter waste site in Wales (Johnson *et al.* 1978).

Liver and kidney cadmium concentrations did not differ significantly between male and female mink. Woolf *et al.* (1982) also found no significant sex differences in liver cadmium concentrations in white-tailed deer. Cadmium concentrations in mink from the SW area were higher than in other 3 areas of the state during both seasons (Figure 2). The SW area had considerable mining activities. Otters are absent from this area which may explain the lower cadmium concentrations found in kidneys and livers of otters from a statewide sample (Anderson-Bledsoe and Scanlon 1983). Kidney cadmium concentrations accumulated with age in samples from both years. Significant increases of cadmium in kidneys with age have been reported in other species (McKinnon *et al.* 1976 Kocan *et al.* 1980 Woolf *et al.* 1982).

McKinnon *et al.* (1976) found no overt signs of cadmium toxicity in 3 gray squirrels from urban areas in Florida with kidney cadmium concentrations of 42.77 to 59.5 µg/g wet weight. In comparison, the maximum kidney cadmium concentration in Virginia mink was 15.99 µg/g d.w. and only 3 others were above 5 µg/g d.w. Friberg *et al.* (1974) cites several studies which suggest that the critical kidney cadmium concentration above which renal dysfunction becomes evident in animals is approximately 200 µg/g wet weight. However, they also cited studies that reported that rats chronically exposed to cadmium developed hypertension when kidney cadmium concentrations were as low as 40 µg/g wet weight.

Zinc concentrations found in Virginia mink were similar to those found in many other species, but were approximately one quarter the values observed in mink by Aulerich *et al.* (1982) during a copper toxicity experiment (mean liver zinc concentrations were 488-530 µg/g, d.w.). It is possible that the high copper concentrations found in the Michigan study induced the synthesis of metallothionein which aided in the retention of zinc. In other studies, mean zinc concentrations range from approximately 25 µg/g wet weight in gray squirrels (McKinnon *et al.* 1976) to over 176 µg/g, d.w. in otters (Anderson-Bledsoe and Scanlon 1983). Mean kidney zinc concentrations less than 25 µg/g were found in white-footed mice and meadow voles from areas irrigated with sewage (Anthony and Kozlowski 1982).

Bone zinc concentrations were significantly higher in female mink than in males during the 1982-83 season. Females also tended ($P = 0.067$) to have higher bone zinc concentrations during 1981-82. Kidney and liver zinc concentrations did not differ between sexes during either season. Woolf *et al.* (1982) found no significant differences between sexes in liver zinc concentrations of white-tailed deer. Liver zinc concentrations of mink from the central area were significantly higher than other areas in 1982-83 but not in 1981-82. However, the capture sites of mink in the central area during the two seasons do not closely correspond. Johnson *et al.* (1978) found only small differences (some of which were not significant) in total body zinc burdens of field mice from smelter waste sites and control areas despite marked differences in soil zinc concentrations. Zinc concentrations in mink in the present study did not differ significantly with age.

As has been found in other studies, copper concentrations varied widely in the present study. Aulerich *et al.* (1982) found mean liver copper concentrations of 293 µg/g, d.w. in control mink and 340-479 µg/g, d.w. in mink given various levels of supplemental copper daily in the diet. Other studies have found copper

concentrations ranging from 3.2 µg/g in otter kidneys (Anderson-Bledsoe and Scanlon 1983) to 109 µg/g in white-tailed deer livers from Illinois Woolf *et al*. 1982). Copper concentrations in the latter study ranged from 0 to 456 µg/g.

Kidney copper concentrations were significantly higher in the central area than in other areas of Virginia during 1982-83. This was the same area and year in which significantly higher liver zinc concentrations were found. There were significant differences in copper concentrations by age during 1981-82, but no pattern was evident; 2 year old mink had significantly lower liver copper concentrations than other ages. Woolf *et al*. (1982) found that liver copper concentrations varied significantly with age and sex in white-tailed deer, but they suggested that locality differences may have accounted for the observed age and sex differences.

Significant interactions between the variables of sex, area and age did occur and were especially prevalent for copper concentrations (Table I). These interactions must be considered when interpreting the differences in metal concentrations due to each separate variable. However, many of the significant interactions seem to be due to single or a few extreme observations. Therefore, the differences in metal concentrations due to the main effect variables, as discussed above, are probably valid.

Although metal concentrations in mink are roughly comparable to those reported in a number of other species, interpretation is difficult. Species differences occur in absorption, storage and excretion of all heavy metals and in homeostasis of zinc and copper. In addition, exposure may vary with position in food chains. For instance Blair *et al*. (1977) found that within an area, shrews tended to have higher lead, cadmium, and zinc concentrations than white-footed mice or meadow voles. Within the same species, metal concentrations may vary significantly with locality. Sex and age differences also may confound interpretation of metal concentrations. Differing food habits must also be considered.

Mink occupy a position at the top of food chains but show litle evidence of a major accumulation of heavy metals in Virginia. They are however a short lived species (Ogle 1984) and the majority of this sample was young of the year. Cadmium especially tends to increase with age and significant cocentrations were found in this sample despite the low average age. The fact that significantly higher concentrations of cadmium were found in mink from the Southwestern portion of the state--that portion most disturbed by mining--may warrant further investigation.

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