CADMIUM IN MOOSE TISSUES: COMPARISON OF DATA FROM MAINE, U.S.A. AND FROM TELEMARK, NORWAY

Patrick F. Scanlon

Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

Karen I. Morris and Alan G. Clark

Department of Inland Fisheries and Wildlife, 284 State Street, State House Station 41, Augusta, ME 04333

Norvald Fimreite and Syverin Lierhagen

Telemark Distriktshøgskole, 3800 Bø i Telemark, Norway

Abstract: Cadmium (Cd) was measured in kidneys, livers, and bones of moose (*Alces alces*) from the 1980 hunting season in Maine. Cadmium was measured in kidneys, livers, and skeletal muscle of moose from 3 areas of Telemark, Norway harvested during the 1983 and 1984 hunting seasons. Concentrations of Cd (µg/g dry wt.) were highest in kidneys. Liver concentrations were lower, muscle concentrations were very low, and Cd was minimally detectable in bones. Among moose from Maine, concentrations of Cd in kidney varied from <0.1 to 77 µg/g. Liver concentrations varied from <0.1 to 55 µg/g. Both values varied significantly ($P < 0.05$) with age. Among Telemark moose, mean kidney concentrations of those from the 3 study areas varied from 8.3 to 20.5 µg/g, mean liver concentrations varied from 1.79 to 2.07 µg/g, mean muscle concentrations ranged from 0.03 to 0.13 µg/g. Concentrations varied with area and were highest from an area near an industrial center. Cadmium concentrations are discussed relative to data from domestic cattle.

Moose (*Alces alces*) are a natural resource of major significance in both Maine and Norway. In Maine, a hunting season was reinstituted in 1980 and annual hunting seasons have been in place since 1982. In Norway the moose harvest by landowners and hunters has increased steadily since the 1940's. In 1984 the national harvest of moose was 25,000 (Statistisk Sentralbyrå 1985) and an indication of the importance of the species is that more than 10% of red meat production comes from moose. Given the numbers of moose harvested, their use as food, and their large size, exposure to contaminants has serious implications to the well-being of a very important species. Considerable potential exists to transfer contaminants from moose to human consumers. Given that moose tend to inhabit remote forested areas and that they may live to ages greater than 10 years, the species could be a useful species for indication of contaminants of their habitats.

The present report is concerned with concentrations of cadmium (Cd) in tissues of moose from Maine and a comparison of the concentrations found with those in moose from Telemark, Norway.

MATERIALS AND METHODS

In 1980 liver, kidney and bone samples were recovered from hunter-killed moose in Maine. Age, sex, and location (i.e., one of 3 moose management units in Maine) of moose were recorded. Age was determined by cementum annuli counts in teeth. Tissues were freeze dried, ashed, dissolved in acid, diluted and had Cd concentrations determined by atomic absorption spectrophotometry using flame techniques. Procedures followed were those of Scanlon *et al.* (1980). Concentrations of Cd were calculated as µg/g dry weight. Data on Cd

concentrations were analyzed by sex, age and location using the SAS General Linear Model procedure and Tukey's HSD test (SAS 1982).

Samples taken in Norway were recovered from hunters in 3 Kommunes of Telemark (Bamble, Bo, and Vinje) in 1983 and 1984. Liver, kidney and skeletal muscle tissues were oven-dried, dissolved in acid, diluted and assayed for Cd by atomic absorption spectrophotometry using flameless techniques (Scanlon *et al.* 1985). Concentrations of Cd were determined as µg/g dry weight. Data were analyzed by location and age where known using the General Linear Model procedure and Tukey's HSD test (SAS 1982). Age of moose were determined by cementum annuli counts in teeth by Direktoratet for Vilt og Ferskvannfisk, Trondheim, Norway.

RESULTS AND DISCUSSION

Overall mean concentrations of cadmium of moose from Maine was 5.64 ± 0.57 g/g d.w. in livers and 26.76 ± 4.31 µg/g d.w. in kidneys (Table 1). Concentrations in either organ did not vary with area of collection. Concentrations of Cd in bones were usually below the limit of detection for the flame mode of the atomic absorpotion spectrophotometer. Kidney Cd varied ($p < 0.05$) with sex of moose and both kidney and liver Cd increased ($p < 0.05$) with age. Interpretation of the effect of sex on cadmium concentrations is difficult as the sample size of females was small due to the ability of hunters to select mostly adult male moose in this first hunting season. When moose were divided into 2 age-classes, 0.5 to 4.5 years and 5.5 years plus older moose, there was a significant effect of age-group, of sex, and a significant sex x age interation due to lower mean Cd concentrations in the females of the older age-group. More data are needed to expand on

Table 1. Mean cadmium concentrations (µg/g dry weight) in tissues of moose from Maine (1980).

Tissue		Median	Mean	S.E.
Liver	160	3.71	5.64[a]	0.57
Kidney	22	23.86	26.76[b]	4.31
Bone	176	0.01	0.01	0.00

a = significant ($p < 0.05$) difference due to age.
b = significant ($p < 0.05$) difference due to age.

Table 2. Mean (± S.E.) cadmium concentrations (µg/g d.w.) in tissues of moose from 3 Kommunes of Telemark, Norway from the 1983 and 1984 hunting seasons.

Kommune	N	Tissue	Cd
Bamble	13	Liver	2.07 ± 0.30[a]
	13	Kidney	20.52 ± 2.61[a]
	11	Muscle	0.13 ± 0.02[a]
Bø	14	Liver	1.28 ± 0.18[b]
	14	Kidney	8.36 ± 1.15[b]
	12	Muscle	0.03 ± 0.01[b]
Vinje	21	Liver	1.79 ± 0.24[a,b]
	20	Kidney	9.08 ± 0.76[b]
	17	Muscle	0.03 ± 0.02[b]

a,b = means for tissues not followed by a common letter superscript are significantly different.

any effect of sex on Cd concentrations.

Concentrations of Cd in moose from Norway (Table 2) were lower than those from Maine. Those from the industrialized Kommune (Bamble) were significantly higher than in the corresponding tissues of moose from the more rural Kommunes. Cadmium concentrations tended to increase with age. Concentrations of Cd were relatively low

in skeletal muscle tissues. Maine moose had higher Cd concentrations in corresponding tissues. Maine moose had higher Cd concentrations in corresponding tissues than in roe deer (*Capreolus capreolus*) taken from the same areas of Norway as the moose discussed here (Scanlon *et al.*1985). The Cd values for Maine moose were lower than values for New Brunswick moose in 1985 (Arnold Boer, Fredericton N.B. personal communication). They were higher than those reported for moose, reindeer (*Rangifer tarandus*) and red deer (*Cervus elaphus*) from several parts of Norway (Frøslie *et al.* 1984), than those of pronghorn (*Antilocapra americana*) and mule deer (*Odocoileus hemionus*) in Montana (Munshower and Neuman 1979), and those of fallow deer (*Dama dama*) and red der in Spain (Hernández *et al.* 1985). Cadmium values in Maine moose were comparable to those in white-tailed deer (*Odocoileus virginianus*) in Oklahoma (Kocan *et al.* 1980) and considerably lower than in white-tailed deer from within 20 km of a Pennsylvania zinc smelter (Sileo and Beyer, 1985).

Cadmium is a non-essential trace element and toxic effects have included effects on the renal, central nervous and reproductive systems. Cadmium has been implicated in arteriosclerosis and growth inhibition. In mallards on restricted food intake, Cd exasperated effects of undernutrition on metabolic processes (DiGiulio and Scanlon 1985) and Cd increased the concentration of copper in livers of mallards indicating interference with the metabolism of copper and thus with copper-associated enzymes (DiGiulio and Scanlon 1984). Ingestion of cadmium seems of particular significance to species with restrictions of intake, particularly seasonal restrictions of intake with associated changes in metabolism.

Sources of cadmium in the environment include fall-out from air contamination due to industrial processes. Acid rain could cause increased release of Cd from rocks and soils with greater uptake in plants thereby contaminating forage sources of moose. Data from the areas in Norway where moose reported on here were recovered, indicated that rowan (*Sorbus aucuparia*) leaves, a significant source of forage for moose, had concentrations of Cd ranging from 0.059 to 0.221 µg/g dry weight (Scanlon *et al.* 1985). These concentrations were low relative to Cd concentrations in basal rations and rations incorporating poultry waste and feedlot wastes fed to cattle in which Cd concentrations in livers, kidney and skeletal muscle were measured (Westing *et al.* 1985 a,b). In the Westing *et al.* (1985a) work, poultry litter (6.07 µg/g Cd, dry weight) was mixed with corn silage 0.84 µg/g, dry weight. After cattle were fed a 70% silage:30% waste mixture for 210 days, liver, kideny and muscle concentrations of Cd were 1.05, 2.11, and 0.99 µg/g d.w., respectively. Only kidney Cd concentrations exceeded control values of cattle fed corn silage (1.20, 1.53, and 0.79 µg/g d.w. for liver, kidney, and muscle, respectively). The concentrations of Cd in liver and kidney were very low in comparison to those of moose despite the high Cd concentrations fed to even the control cattle, yet muscle concentrations of cattle greatly exceeded those of moose. The relatively short-term treatment and the young age of the cattle, compared to moose studied in Maine and Norway, and the lower muscle Cd content of moose with much higher kidney Cd content of moose may indicate interspecific differences between cattle and cervid species in retention of Cd which warrants further investigation.

The World Health Organization (WHO) recommends that humans not

consume more than 0.5 mg Cd per week. Because of this, it would be unwise to consume significant quantities of moose kidney. Consider 500 g of moose kidney containing the mean concentration of Cd in Maine (c. 25 µg/g dry weight). Such a quantity of kidney would contain 3.1 mg Cd based on kidney tissue being 25% dry matter (kidneys of mallards, *Anas platyrhynchos*, average 23.4% dry matter, Scanlon 1982). Thus, 500 g of kidney would represent a 6-week maximum allowance of Cd based on WHO recommendations. Accordingly, consumption of moose kidney warrants considerable caution especially if multiple sets of kidneys are available to individual consumers.

The mean liver concentration of Maine moose (5.64 µg/g d.w.) would contain 1.69 mg Cd per kg based on a 30% dry matter estimate of liver (mallard liver has a mean dry matter content of 32.67%, Scanlon 1982). Consumption of moose liver in large quantities should be restricted to avoid exceeding WHO recommendations for Cd ingestion.

Data from the Norwegian moose indicate that concentrations of Cd in skeletal muscle (means ranged from 0.03 to 0.13 µg/g d.w.) are low despite relatively high liver and kidney concentrations of Cd. Skeletal muscle at an estimated dry matter content of 25% (mallards had 23.5% dry matter, Scanlon 1982) would contain 7.5 µg/kg and 32.5 µg/kg Cd at 0.03 and 0.13 µg/g d.w., respectively, and would require a weekly consumption of 67 and 15 kg skeletal muscle, respectively, to approach the WHO recommended maximum consumption of Cd.

ACKNOWLEDGEMENTS

We thank the following most sincerely: Hunters and biologists in Maine for provision of specimens; Johan Aas and hunters in Telemark for collection of specimens in Norway; Viltdirektoratet, Trondheim, Norway for estimates of age of moose; Karen Lynn Anderson and Martin C. Ogle for assistance with laboratory analyses; Sandra L. MacPherson and Mary Beth Moss for data processing; Carol W. Linkous for typing; Norges Teknisk Naturvinenkapelige Forskningrad, Oslo, and the Virginia Agricultural Experiment Station Hatch Act project 202870 for financial support.

REFERENCES

DIGIULIO, R. T., and P. F. SCANLON. 1984. Effects of cadmium and lead ingestion on tissue concentrations of cadmium, lead, copper, and zinc in mallard ducks. Sci. Total Environ. 39:103-110.

_____, and _____. 1985. Effects of cadmium ingestion and food restriction on energy metabolism and tissue metal concentrations in mallard ducks (*Anas platyrhynchos*). Environ. Res. 37:433-444.

FRØSLIE, A., G. NORHEIM, J. P. RAMBACK, and E. STEINNES. 1984. Levels of trace elements in liver from Norwegian moose, reindeer and red deer in relation to atmospheric deposition. Acta. Vet. Scandinavia 25:333-345.

HERNÁNDEZ, L. M., M. J. GONZÁLEZ, M. C. RICO, M. A. FERNÁNDEZ, and G. BALUJA. 1985. Presence and biomagnification of organochlorine pollutants and heavy metals in mammals of Doñana National Park (Spain), 1982-1983. J. Environ. Sci. Health B20:633-650.

KOCAN, A. A., M. G. SHAW, W. C. EDWARDS, and J. H. EVE. 1980. Heavy metal concentrations in the kidneys of white-tailed deer in Oklahoma. J. Wildl. Dis. 16:593-596.

MUNSHOWER, F. F. and D. R. NEUMAN. 1979. Metals in soft tissues of mule deer and antelope. Bull. Environ. Contam. Toxicol.

MUNSHOWER, F. F. and D. R. NEUMAN. 1979. Metals in soft tissues of mule deer and antelope. Bull. Environ. Contam. Toxicol. 22:827-832.

SAS. 1982. SAS user's guide: statistics. SAS Institute, Cary, NC. 584 pp.

SCANLON, P. F. 1982. Wet and dry weight relationships of mallard (*Anas platyrhynchos*) tissues. Bull. Environ. Contam. Toxicol. 29:615-617.

_____, N. FIMREITE, and S. LIERHAGEN. 1985. Heavy metal concentrations in Norwegian moose, roe deer, and a forage species. Society of Environmental Toxicology and Chemistry, Sixth Annual Meeting Abstracts, p. 87.

_____, V. D. STOTTS, R. G. ODERWALD, T. J. DIETRICK, and R. J. KENDALL. 1980. Lead concentrations in livers of Maryland waterfowl with and without ingested lead shot present in gizzards. Bull. Environ. Contam. Toxicol. 25:855-860.

SILEO, L. and W. N. BEYER. 1985. Heavy metals in white-tailed deer living near a zinc smelter in Pennsylvania. J. Wildl. Dis. 21:289-296.

STATISTISK SENTRALBYRÅ. 1985. Statistik årbok 1985: Norges offisielle statistikk B530. Statistisk Sentralbyrå Oslo, Norway 104:528 pp.

WESTING, T. W., J. P. FONTENOT, W. H. McCLURE, R. F. KELLY, and K. E. WEBB, JR. 1985a. Characterization of mineral element profiles in animal waste and tissues from cattle fed animal waste. I. Heifers fed broiler litter. J. Anim. Sci. 61:670-681.

WESTING, T. W., J. P. FONTENOT, and K. E. WEBB, JR. 1985b. Characterization of mineral element profiles in animal waste and tissues from cattle fed waste. II. Steers fed cattle feedlot waste. J. Anim. Sci. 61:682-691.