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State of New Jersey

DEPARTMENT OF ENVIRONMENTAL PROTECTION

DIVISION OF
FISH, GAME AND WILDLIFE
GEORGE P. HOWARD
DIRECTOR

PLEASE REPLY TO:
CN 400
TRENTON, NEW JERSEY 08625

M E M O R A N D U M

DATE: November 30, 1988

TO: Frank Faranca, Case Manager, Div. of Hazardous Site Mitigation

FROM: William Stansley, Wildlife Toxicologist, Div. of Fish, Game and Wildlife

SUBJECT: Liver Cd Concentrations in Deer from Earle Weapons Station

At the request of Mr. John Bowyer of your office, I have enclosed a copy of the study on liver Cd concentrations in whitetail deer in New Jersey. As noted in the report, elevated liver Cd concentrations were measured in deer from the Earle Naval Weapons Station. The three individual values (µg/g dry wt.) are: 20.9, 19.0 and 23.2. All three animals belong to the oldest age group sampled (2 1/2+ years).

A health advisory regarding the consumption of deer liver in New Jersey has been issued recently. In addition to the public announcement, our office has apprised officials at Earle of our findings so that those base personnel who hunt deer could be notified.

If possible, I would appreciate a copy of the data that you have on soil Cd concentration at the site.

sas
c: D. Roscoe

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LIVER CADMIUM CONCENTRATIONS IN WHITE-TAILED DEER IN NEW JERSEY

Prepared By: William Stansley
NJ Division of Fish, Game and Wildlife

Abstract

Liver cadmium concentrations in 86 deer from six different areas in New Jersey ranged from 0.07 - 23.2 ug/g dry weight. The mean concentration was 4.02 ug/g. Cadmium was found to accumulate in the livers of older animals. Significant differences in liver cadmium concentration were observed in deer from different parts of the state. Deer from three of the areas surveyed had concentrations that were higher than those reported in the literature for normal populations. Four deer had unusually high liver cadmium concentrations (19.0 - 23.2 ug/g) that suggest exposure to highly contaminated environments. Concentrations in some animals raise concerns about the health of the animals and also about the health of those people who consume deer liver.

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METHODS AND MATERIALS

Samples of deer liver were collected from hunters at five check stations and from the Atlantic County Game Preserve (designated as station 999) during the 1986 - 87 hunting season. Figure 1 shows the areas from which the deer used in this study were taken. Deer from the following zone(s) were sampled at each check station:

station 11 : zones 37, 52

station 31 : zones 7, 8, 10

station 52 : zone 39

station 66 : zone 53

station 74 : zones 2, 3, 6

station 999 : zone 46

An attempt was made to collect livers from three different age classes (1/2yr., 1 1/2 yr., 2 1/2 yr. and older) at each station. Liver samples were stored in plastic bags and kept chilled until transported to the lab for cadmium analysis. Samples were stored in the lab at -20°C prior to analysis.

Portions of tissue weighing approximately two grams fresh weight were taken from thawed liver samples using stainless steel implements. Surface tissue was removed in order to minimize the possibility of contamination. Samples were transferred to 50 mL pyrex beakers and the fresh weight was determined. The samples were then dried overnight at 103°C, cooled in a dessicator and weighed again. The dried samples were charred in a muffle furnace at 250°C for one hour followed by ashing at 475°C for 24 hours. After cooling, 20 mL of distilled-deionized water and 2 mL of Ultrex nitric acid were added to each beaker and the samples were boiled gently for five minutes on a hot plate. The samples were then cooled, diluted to a final volume of 500 mL and analyzed by flameless atomic absorption spectrophotometry. All glassware used in the procedure was soaked overnight in 20% nitric acid, rinsed several times with distilled-deionized water, and dried prior to use.

Quality assurance measures included the use of digestion blanks, duplicate and spiked samples, analysis of reference material, and inter-laboratory comparisons. The results of the quality assurance analyses are reported in Appendix A.

All liver cadmium concentrations discussed in the text are expressed on a dry weight basis, unless otherwise noted. Data were log-transformed and statistically analyzed using the Statistical Analysis System (SAS Institute, Inc., 1987).

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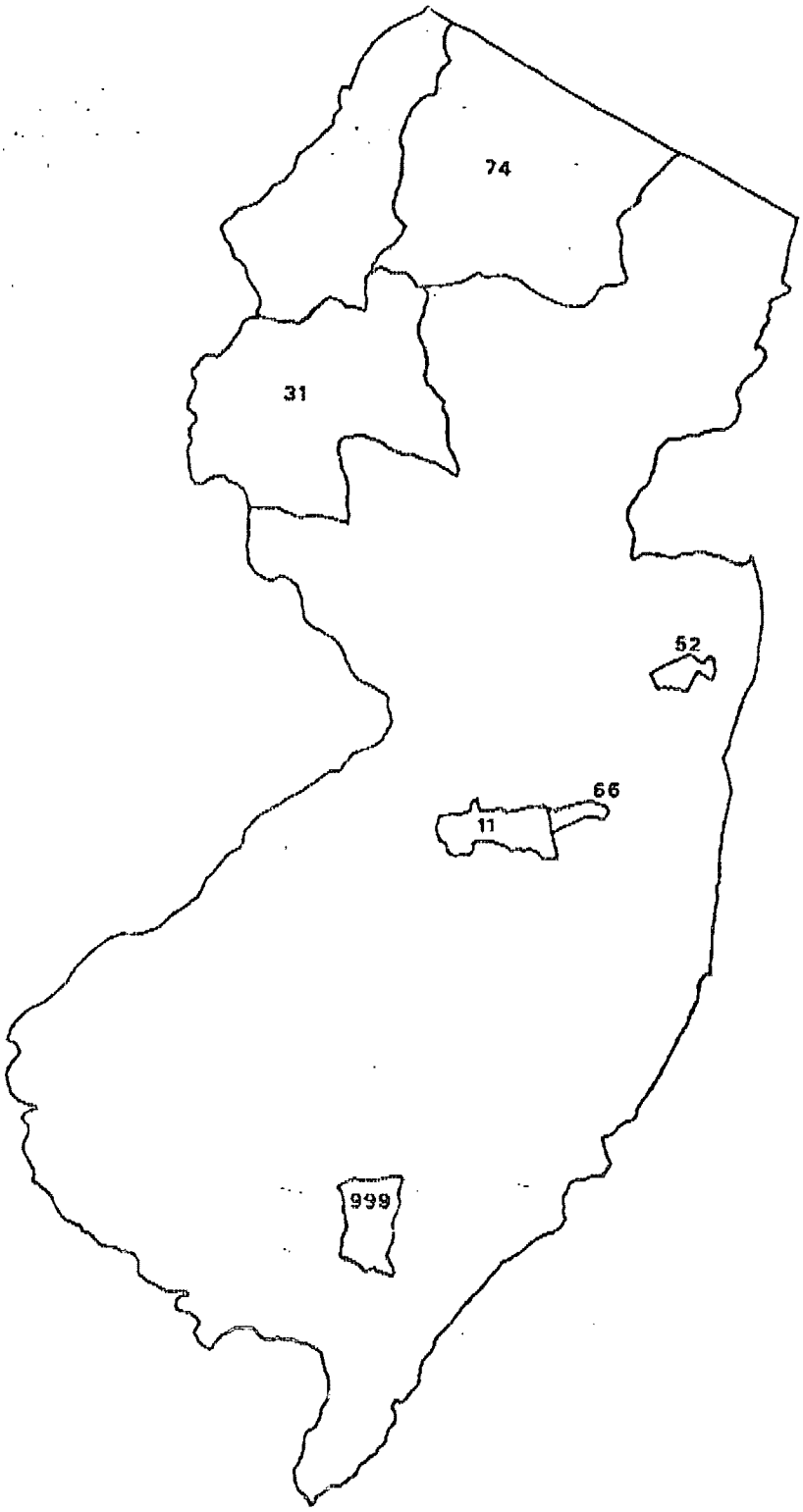

Figure 1. Areas surveyed in the deer liver cadmium study. The numbers shown designate check stations. The areas delineated are the deer management zones from which deer were sampled at each check station. See text for zone numbers.

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Results

A total of 86 liver samples were analyzed in this study. They exhibited a wide range of cadmium concentrations, from a low of 0.07 ug/g to a high of 23.2 ug/g, with a mean of 4.02 ug/g. The mean percent moisture of the samples was 69%.

Nested analysis of variance testing showed that liver cadmium concentration differed between locations (ie. stations; $P < 0.001$) and between age groups ($P = 0.008$). Mean liver cadmium concentrations at all stations are compared in Table 1. The age group composition of samples varied from station to station. In order to eliminate the effect that this variability might have on inter-station comparisons, liver cadmium concentrations within single age groups were compared between stations. Differences were not statistically significant between stations for 1/2 year old deer ($P=0.077$) or for 2 1/2 + year olds ($P=0.094$). Significant differences were observed between stations for 1 1/2 year old deer ($P < 0.001$). Stations 11 and 66 were omitted in the comparison of 1 1/2 year olds because of insufficient sample size (Table 2). The spatial variation in liver cadmium concentration demonstrated by comparisons within a single age group is very similar to that shown in Table 1, in which all age classes are considered together.

In order to examine the effect of age on liver cadmium concentration without the interference of spatial variation, concentrations in different age groups were compared within stations. In all cases where significant differences were observed, liver cadmium concentrations were higher in older animals (Table 3).

Liver cadmium concentrations in deer from three of the areas surveyed (stations 52, 66 and 999) were higher than values reported in the literature for deer from other parts of the country , while deer from the remaining three areas (stations 11, 31 and 74) had liver cadmium concentrations that were generally within the range reported in the literature (Table 4).

Discussion

Elevated cadmium concentrations are almost always associated with proximity to urban areas and industrial contamination (Eisler, 1985). Therefore, the finding of high liver cadmium concentrations in deer in New Jersey, compared to those in other states, is not surprising, given the degree of urbanization within the state. The spatial variability in liver cadmium concentrations observed in this study is probably related to the proximity of a given area to point sources of cadmium. The unusually high concentrations measured in four of the deer livers (19.0 - 23.2 ug/g) suggest the possibility of localized areas of heavy cadmium contamination. The only comparable concentrations found in the literature were those reported by Sileo and Beyer (1985) for deer shot in the vicinity of a zinc smelter in Palmerton, PA. Liver cadmium concentrations in deer shot within a 20 km radius of the smelter ranged from 1.9 - 18.1 ug/g (Sileo,

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Table 1. Cadmium concentrations (ug/g, dry weight) in deer livers from six areas in New Jersey.

Ch ck Station No.	n	Mean Cd Concentration[a] (range)
66	9	5.37 A[b] (1.16 - 19.6)
999	17	4.42 A (1.19 - 13.0)
52	18	2.47 AB (0.08 - 23.2)
74	16	1.72 BC (0.18 - 6.92)
31	13	0.80 CD (0.22 - 2.54)
11	11	0.75 D (0.07 - 3.34)

[a] Geometric mean

[b] Means with different letters are statistically different using Duncan's Multiple Range Test - alpha=0.05.

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Table 2. Cadmium concentrations (ug/g, dry weight) in 1 1/2 year old deer.

Station Number[a]	n	Mean Cd Concentration[b] (range)
999	3	5.00 A[c] (4.04 - 7.12)
52	3	3.40 AB (1.78 - 5.70)
74	5	2.11 B (1.58 - 3.11)
31	7	0.76 C (0.51 - 1.02)

[a] Stations 11 and 66 had insufficient numbers of 1 1/2 year old deer (<3) and were not considered in this comparison.

[b] Geometric mean

[c] Means with different letters are statistically different using Duncan's Multiple Range Test - alpha=0.05.

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Table 3. Liver cadmium concentrations (ug/g, dry weight) for individual age groups from each station.

Station Number	[a]Sig.	Age Group	n	Mean Cd Concentration[b] (range)
11	NS (P = 0.213)	1/2	7	0.55 (0.07 - 2.53)
		1 1/2	1[c]	0.11
		2 1/2 +	4	1.31 (0.61 - 3.34)
31	S (P = 0.022)	1/2	3	0.44 B[d] (0.22 - 1.04)
		1 1/2	7	0.76 AB (0.51 - 1.02)
		2 1/2 +	3	1.70 A (0.78 - 2.54)
52	NS (P = 0.621)	1/2	5	1.30 (0.68 - 3.71)
		1 1/2	3	3.40 (1.78 - 5.70)
		2 1/2 +	10	3.09 (0.08 - 23.2)
66	S (P = 0.010)	1/2	4	2.48 B (1.16 - 4.49)
		1 1/2	1[c]	4.75
		2 1/2 +	5	9.98 A (5.20 - 19.6)

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Table 3. Continued

Station Number	Sig.	Age Group	n	Mean Cd Concentration (range)
74	S (P = 0.025)	1/2	6	0.83 B (0.18 - 2.03)
		1 1/2	5	2.11 AB (1.58 - 3.11)
		2 1/2 +	5	3.38 A (1.99 - 6.92)
999	S (P < 0.001)	1/2	5	1.48 C (1.19 - 1.87)
		1 1/2	3	5.00 B (4.04 - 7.12)
		2 1/2 +	9	7.78 C (4.86 - 13.0)

[a] The significance of age-related differences in liver cadmium concentrations determined for each station by one-way ANOVA; NS = not significant (P > 0.05); S = significant

[b] Geometric mean

[c] Groups with n < 3 were not used in the statistical comparisons.

[d] Means with different letters within a station are statistically different using Duncan's Multiple Range Test (alpha = 0.05); test was performed only when ANOVA was significant at P < 0.05.

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Table 4. Liver cadmium concentrations (ug/g dry weight) in antelope, mule deer, white-tailed deer and moose in the United States.

Species	n	Mean Cd Conc.	Location	Source
Antelope	20	0.30 ± 0.15[a]	Montana	Munshower and Neuman (1979)
Mule deer	30	0.51 ± 0.53[a]	Montana	" " "
White-tailed deer	190	0.37 ± 0.03[b]	Illinois	Woolf et al. (1982)
White-tailed deer	4	11.6 (6.6 - 20.1)[c]	Pennsylvania <8 km from smelter	Sileo and Beyer (1985)
White-tailed deer	13	4.2 (3.1 - 5.8)[c]	Pennsylvania 10 - 20 km from smelter	" " "
White-tailed deer	5	1.9 (0.6 - 1.5)[c]	Pennsylvania >100 km from smelter	" " "
White-tailed deer	?	1.32 (0.44 - 3.32)[d]	Maine	Frakes (unpublished data)
Moose	?	6.96 (2.44 - 10.56)[d]	Maine	" " "

[a] 1 standard deviation

[b] standard error

[c] (limits of 95% confidence interval)

[d] (range)

pers. comm.). The area around the smelter is known to be grossly contaminated with cadmium, zinc and lead. The four deer having the highest liver cadmium concentrations in the current study were take from station 66 (zone 53; Lakehurst Naval Engineering Center) and station 52 (zone 39; Earle Naval Weapons Station).

The lack of statistically significant differences in liver cadmium concentration in 2 1/2 + year old deer from different areas may be due to the large variance in the data and the small sample sizes at each station. The 2 1/2 + age group is a composite of all animals age 2 1/2 and older . The pooling of data from several age groups introduces a source of variation that is not present in the 1/2 and 1 1/2 year age groups. The reason for the lack of statistically significant differences in liver cadmium in 1/2 year old deer is not clear. It may be that significant differences do not devolop until uptake has occured over a longer period of time.

The finding of higher liver cadmium concentrations in older deer is consistant with the findings of a survey of liver cadmium concentrations in white-tailed deer in Illinois (Woolf et al. 1982). However, Munshower and Neuman (1979) found evidence of cadmium accumulation in the kidneys of older antelope and mule deer but not in the livers of these animals.

High liver cadmium concentrations (mean 5.70 ug/g; range 1.19 - 13.0) were also found in deer from the Atlantic County Game Preserve (station 999), a relatively pristine area. The reason for these elevated concentrations is not known at present. Data on cadmium concentrations in the soil and vegetation are needed to determine whether or not unusually high levels exist in that area.

The high liver cadmium concentrations found in some of the deer in this study could be detrimental to the health of the animals. In mammals, the kidney is the major site of cadmium accumulation and damage (Anon., 1980). Although kidneys were not analyzed in this study, very high cadmium concentrations in kidney tissue would be expected in those deer with large liver cadmium burdens. In the Palmerton study, the deer with the highest liver cadmium concentration (18.1 ug/g) had a kidney cadmium concentration of 372 ug/g (Sileo, pers. comm.). Therefore, it is reasonable to assume that whole kidney cadmium concentrations on the order of 400 ug/g would occur in deer with liver cadmium concentrations of approximately 20 ug/g, as were found in this study. Cadmium concentrations of 200 ug/g (fresh weight) or greater in the renal cortex represent potentially life-threatening amounts (Eisler, 1985). Using an estimated moisture content of 70% for kidney tissue, a 400 ug/g (dry weight) concentration would convert to 120 ug/g (fresh weight). Given this amount of cadmium in whole kidneys, there is a strong possibility that some of the deer sampled in this study had cadmium concentrations in the renal cortex sufficient to cause kidney damage. Determinations of kidney cadmium concentrations, in conjunction with histological examination of renal cortex tissue for evidence of tubular damage, would be necessary to test this hypothesis.

Another concern raised by the high liver cadmium concentrations is the potential for human health effects in those

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peopl who eat deer liver. The Environmental Protection Agency (1980) recommended a maximum cadmium intake of 75 ug/day (525 ug/week) for protection against the chronic effects of cadmium. At the highest concentration measured in this study (23.2 ug/g dry weight, 7.19 ug/g fresh weight) the maximum recommended weekly cadmium intake would be contained in approximately 73 grams, or 2.6 ounces, of liver. Acute gastrointestinal effects can also result from cadmium ingestion. The National Academy of Sciences (1982) estimated the threshold emetic dose in humans to be approximately 3 mg. This amount would be contained in approximately 417 grams, or 0.9 lbs of liver at a concentration of 7.19 ug/g (fresh weight). The Maine Bureau of Health issued an advisory in 1986 concerning the consumption of deer and moose liver. They recommended that deer liver consumption be limited to 0.8 lbs at any one meal and 1.1 - 1.3 lbs per week. These recommendations were based on the highest liver cadmium concentration that they measured, which was 3.32 ug/g (approximately 1/7 that of the highest concentration measured in the present study). They further advised against the consumption of any moose liver (maximum measured concentration 10.56 ug/g). The calculations used by the Maine Bureau of Health in formulating these advisories are listed in Appendix C.

Finally, the high liver cadmium concentrations found in deer from stations 52 and 66 raises concern about the level of cadmium contamination in these areas. Based on available reports in the literature, it seems likely that liver cadmium concentrations on the order of 20 ug/g would only result from exposure to a heavily contaminated environment.

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