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HEAVY METAL CONCENTRATIONS IN KIDNEYS OF URBAN GRAY SQUIRRELS

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Abstract: Concentrations of lead and zinc in the kidneys of 180 urban gray squirrels were determined by spectrophotometry and found similar for all age groups; however, concentrations of cadmium increased up to two years of age. Values for 12 rural squirrels were significantly lower than those of the urban animals. There were no differences in mean concentrations of the metals when urban squirrels were grouped by the land usage pattern of the sites in which they were captured. Grouping squirrels by human socioeconomic strata for the city revealed that squirrels in low socioeconomic areas have significantly higher levels of lead than animals residing in middle or high socioeconomic areas.

INTRODUCTION

Gray squirrels, *Sciurus carolinensis*, are an important segment of the urban wildlife fauna in many communities of the eastern United States. As such, these highly adaptable synanthropic animals constitute 1) a potential source of disease for man and his pets, and 2) a potential monitor of urban environmental status.⁴ Therefore, the Florida Department of Health and Rehabilitative Services (HRS) instituted a multifaceted investigation into the health, diseases and environmental monitor potential of the gray squirrel in the City of Jacksonville (pop. 574,000) in northeast Florida. Under the direction of the Veterinary Public Health Section, the study was conducted from January through December, 1974. Results of the investigation have been partially reported elsewhere.^{5,9,10} The present report is limited to baseline concentrations of cadmium, zinc and lead in the kidneys of the squirrels.

MATERIALS AND METHODS

Jacksonville (2200 km²) is the most spacious city in the continental United States. The city is the largest commercial port and distribution center on the south

Atlantic seaboard as well as an important financial and insurance center. Light industry such as paper and paint production and three U.S. Navy installations are located within the city.

Gray squirrels were captured in wire cage traps placed on or near mast-bearing trees of the genera *Quercus* and *Carya* located in the urbanized portion (456 km²) of the city. There were 36 collection sites, with three sites per month being sampled. Five squirrels were removed from each site. In addition, 12 squirrels were shot in Gulf Hammock Wildlife Management Area, Levy County, on the gulf coast of Florida. The approximate age of each squirrel was determined by the eye-lens weight technique.⁸

Due to the many facets of the overall study, only the kidneys of the squirrels were available for analysis of cadmium, zinc and lead concentrations. Kidneys were digested in 5 ml of concentrated nitric acid for 24 hr at 23 C. The resultant digest was then boiled and filtered through nitric acid washed glass wool. The filtrate was adjusted to 10 ml with distilled water. Concentrations of the metals were determined by atomic absorption spectrophotometry.¹

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RESULTS AND DISCUSSION

Of the 180 squirrels live-trapped in the city, 73 were males and 107 were females. Eighty percent of the animals were less than two years of age. Kidney burdens of zinc and lead were similar for all age groups (Table 1), however, concentrations of cadmium increased up to the age of two years. The 12 squirrels from Gulf Hammock Wildlife Management area were all 1 and 2 years of age and had significantly (*t* test *P* .05) lower values for each metal than their Jacksonville cohorts.

When urban squirrels were grouped by type of land usage (Table 2), the only difference noted was that those squirrels from school grounds had lower cadmium levels. This difference was probably caused by the fact that squirrels from two of the schools were young animals,

mostly less than a year of age. Since the kidney burden of cadmium appears to increase with age, these 10 squirrels may have significantly influenced the total sample of 20 animals resulting in the lowered mean for the group.

Within land usage groupings, several differences were noted. Squirrels from one cemetery had a mean zinc concentration of 65.84 ppm $\pm$ 7.84. The concentrations of all five squirrels were in excess of 49 ppm (49.20 - 93.80 ppm). Probable cause for these high levels is presently unknown, although water and chemical sprays were ruled out.

In addition, squirrels from four sites had elevated mean lead concentrations, i.e. greater than 3.00 ppm. Three of these sites could not be related to motor vehicle traffic patterns, although all three lay directly along the flight approaches

TABLE 1. Kidney Concentrations of Cadmium, Zinc and Lead in Gray Squirrels (All Values in ppm Wet Weight).

Age (yrs)	No. Squirrels	Cadmium Mean $\pm$ S.E.	Zinc Mean $\pm$ S.E.	Lead Mean $\pm$ S.E.
Jacksonville				
<1	75	3.91 $\pm$ 0.85	27.72 $\pm$ 1.21	1.32 $\pm$ 0.17
1	69	9.10 $\pm$ 0.95	29.68 $\pm$ 1.80	1.28 $\pm$ 0.24
2	20	14.93 $\pm$ 2.28	30.54 $\pm$ 2.49	1.18 $\pm$ 0.31
3	10	15.90 $\pm$ 4.43	25.99 $\pm$ 3.14	0.47 $\pm$ 0.16
4	6	15.91 $\pm$ 3.70	23.04 $\pm$ 2.69	0.86 $\pm$ 0.33
Gulf Hammock				
1	5	2.04 $\pm$ 1.07	14.32 $\pm$ 1.64	0.20 $\pm$ 0.02
2	7	4.63 $\pm$ 1.86	18.61 $\pm$ 1.43	0.26 $\pm$ 0.04

TABLE 2. Kidney Concentrations of Cadmium, Zinc and Lead in Urban Gray Squirrels in Relation to Land Usage Pattern (All Values in ppm Wet Weight).

Land Usage	No. Squirrels	Cadmium Mean $\pm$ S.E.	Zinc Mean $\pm$ S.E.	Lead Mean $\pm$ S.E.
Residential	85	7.94 $\pm$ 1.09	26.46 $\pm$ 1.00	1.10 $\pm$ 0.20
Park	55	8.97 $\pm$ 1.15	31.87 $\pm$ 1.68	1.17 $\pm$ 0.14
School	20	5.96 $\pm$ 1.24	25.48 $\pm$ 0.18	1.58 $\pm$ 0.37
Cemetery	20	9.11 $\pm$ 2.58	31.90 $\pm$ 5.28	1.55 $\pm$ 0.48

to a military airfield, each being less than 4.9 km from the ends of the same runway. The mean lead concentrations for the sites were 3.14 ppm, 3.00 ppm and 5.33 ppm. The site with the highest mean concentration was nearest the airfield. The runway in question is at present used sparingly, being too short for most jet and turbojet aircraft. Prior to the advent of the kerosene fueled airplanes, however, propeller driven aircraft, powered by leaded gasoline containing 4.6 ml of lead per gallon, made extensive use of the runway. Therefore, to determine if the squirrels, or their food sources were obtaining residual lead from the soil, the top four cm of soil from the squirrel collection sites were analyzed for lead content. The concentrations obtained were less than 70 ppm and compared favorably with soil lead concentrations from other squirrel collection sites. Also, lead concentrations in water supplies available to the squirrels were negligible. Consequently, the source of lead for the squirrels at these three sites remains undetermined.

The fourth site at which squirrels had elevated lead concentrations (mean 4.08 ppm) was a cemetery adjacent to and lower than an approach to one of the major bridges in the city. Vehicular traffic on the bridge is approximately 1,276,000 units per month and the distance from the bridge approach to the cemetery is approximately 46 meters. Further investigation, however, revealed that water faucets at the cemetery contained .009 to 0.345 ppm of lead compared to values ranging from 0.001 to 0.008 ppm for water supplies at other squirrel collection sites. Because the concentration of lead in certain faucets exceeded the 0.050 ppm allowable level for drinking water, it was felt that this was the most likely source of lead for the squirrels as they readily drink from all dripping water faucets. In addition, the cemetery is on the same water supply as the surrounding residential area. The extent of the lead in the water supply in the residential area was investigated by appropriate state and local governmental agencies and found to be .004 to .020 ppm.

Thirty-three of the 36 collection sites were situated in what is termed the central city. This portion of the city has been classified into three socioeconomic strata (Fig. 1) by a HRS health planning analyst using 1970 census data.⁹ Mean metal concentrations in the kidneys of all squirrels captured in each stratum compared to values for squirrels captured in the other socioeconomic strata are given in Table 3. From these data it would appear that squirrels from the middle socioeconomic stratum have significantly lower mean lead concentrations than those animals from low or high socioeconomic strata. However, if the four sites (3 in high, 1 in low strata) with elevated mean lead concentrations discussed above are discounted, then the mean lead concentrations for each stratum become, 0.76 ± 0.33 ppm for high, 0.73 ± 0.14 ppm for middle and 1.17 ± 0.18 ppm for low. Therefore, it might be concluded that the normal mean lead concentrations in the kidneys of squirrels from middle and high socioeconomic strata are significantly (*t* test *p*. 05) lower than the normal concentrations in squirrels from the low socioeconomic stratum. How this observation relates to lead concentrations of the human residents of these strata remains to be determined, however it is in agreement with data on urban dogs from Illinois.⁸

The only index of lead poisoning in the squirrels measured was hematocrit. For the 20 squirrels in the entire investigation with lead concentrations in excess of 3.00 ppm (3.00 - 10.86 ppm) hematocrits were not significantly different from animals with concentrations below that level. Three squirrels had cadmium concentrations greater than 42 ppm (42.77, 45.90, 59.50 ppm); however none had proteinuria indicative of renal damage.

The sources of lead, zinc and cadmium for the squirrels can be both dietary and pulmonary, although the relative importance of each is unknown. While the concentrations of these metals in food of the squirrels has not been measured, during 1973 the atmosphere in Jacksonville contained an average of $0.80 \mu\text{g}/\text{M}^3$ of lead and $<0.001 \mu\text{g}/\text{M}^3$ of cadmium.

Throughout the study, the desirability of establishing values for these metals in blood and other body tissues⁷ was appreciated. However, as with any multifaceted investigation and maximum uti-

lization of animals captured, compromises in objective must be accepted.² The results obtained will serve as baselines against which future environmental changes can be measured.

TABLE 3. Kidney Concentration of Cadmium, Zinc and Lead in Gray Squirrels in Relation to Socioeconomic Strata of Central Jacksonville (All Values in ppm Wet Weight).

Socioeconomic Stratum	No. Squirrels	Cadmium Mean $\pm$ S.E.	Zinc Mean $\pm$ S.E.	Lead Mean $\pm$ S.E.
Low	45	9.32 $\pm$ 1.68	29.84 $\pm$ 1.78	1.52 $\pm$ 0.26
Middle	50	7.85 $\pm$ 1.13	24.13 $\pm$ 3.59	0.73 $\pm$ 0.14
High	70	8.53 $\pm$ 1.11	30.54 $\pm$ 1.69	1.41 $\pm$ 0.11

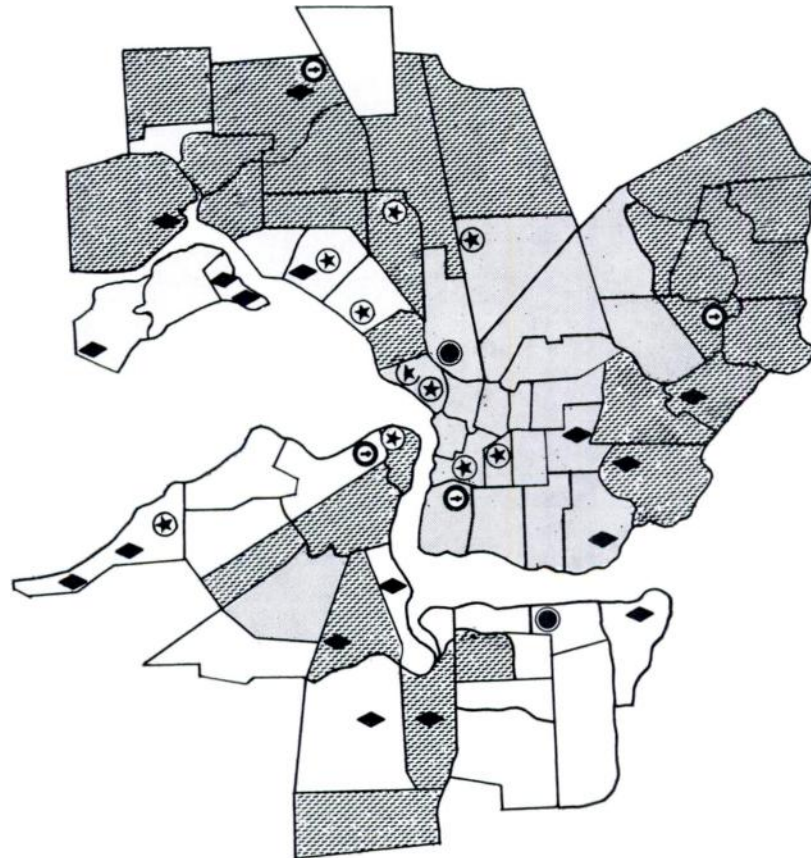


FIGURE 1. Socioeconomic Stratification of Central Jacksonville (gray—low; dots—middle; white—high) and Location of Census Tract of 33 Squirrel Trapping Sites (diamonds—residential; circle and star—park; circle and cross—cemetery; ringed circle—school).

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