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Concentrations of Trace and Other Elements in the Organs of Wild Rats and Birds from the Northern Guinea Savanna of Nigeria

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In regions of human activities, where metals enter local aquatic ecosystems from the atmosphere and through wastewater outfalls, metal concentrations in food chains can exceed natural background levels and be above the threshold levels for sensitive species (Fimreite 1974). Accordingly, metal levels in the organs and tissues of livestock (Underwood 1977) and wildlife (Underwood 1977; Szefer and Falandysz 1986) have been extensively studied. However, there are no reports of metal concentrations in the organs and tissues of wild animals from the Northern Guinea savanna of Nigeria.

The mole rat (Africanthus niloticus, L) and village weaver bird (Ploceus cucullatus, L) contribute significantly to farm crop losses from sowing to harvest. The mole rat feeds on nuts, stems and seeds of all farm crops, while the weaver bird feeds on seed grains. The major farm crops of the Guinea savanna include yam and potato tubers, cocoyams, and the cereals maize, guinea millet, and rice. Because there are no industries capable of causing metal contamination in the study area, the present study was undertaken to determine the natural baseline levels of metals for wild rats and birds from this environment.

MATERIALS AND METHODS

Suckling and adult wild mole rats (Africanthus niloticus), and adult village weaver birds (Ploceus cucullatus) used in this study were collected in the dry season between 1983 and 1984 during ecological surveys of the Kubani valley near Zaria in the Northern Guinea savanna of Nigeria. The organs examined included the liver and heart from village weaver birds and the kidney and liver from wild mole rats.

Each organ was oven dried in a porcelain crucible to a constant weight at 65 C and then ashed in a furnace at 454 C until the dried material became white. The ash was allowed to cool in a desiccator for 12 hours. The ash was then dissolved in 3 ml of 36% hydrochloric acid and allowed to cool for 1 h before bringing to 50 ml with distilled water. The concentrations of Zn, Cu, Fe, Mg and Ca were determined by atomic absorption (APHA 1985) (Perkin Elmer model 406). Sodium and potassium were determined by flame photometry.

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Phosphorus was determined by the phosphomolybdate method. Standards containing known amounts of these metals and blank samples were subjected to the same procedure to estimate recovery rates and to check for contamination. The average recovery was 96 to 97 percent. The concentrations of all metals are expressed in μg/g dry weight.

The data was analyzed using multivariate profile analysis. Paraphrasing Morrison (1976), the p commensurable responses (element concentrations) collected from independent sampling units (animals) are grouped according to k treatments (age-sex groups). If the model for the ith observation on the hth response under treatment j is $x_{ijh} = \Phi_{jh} + e_{ijh}$, then the vector of residuals $\mathbf{e}'_{ij} = [e_{ij1},...,e_{ijp}]$ of the ijth sampling unit has the multinormal distribution with null mean vector and some unknown nonsingular covariance matrix. In this paramaterization the design matrix consists of ones in the jth column of the successive blocks of $N_1,...,N_k$ rows and zeros elsewhere. Under these assumptions, the multivariate general linear model provides tests of the three profile hypotheses of equal treatment levels, equal response means, and parallelism of the treatment mean profiles.

RESULTS AND DISCUSSION

The results are summarized in Table 1. The highest concentrations of Na, Ca, Mg, P, and Fe were found in the livers of adults whereas K and Zn were highest in the kidneys of the adult and suckling rats, respectively. However, the lowest concentrations of all metals studied tended to be found in the male suckling rats. In addition, the concentration of Cu in the kidneys of suckling male and adult female rats were similar. This was also true for Mg levels in the kidneys of suckling male and adult female rats.

With the exception of K and Ca ($P < 0.01$), there were no sex or age-related significant differences for metals in the kidneys. For the liver of suckling rats, there were no sex differences in metals studied except for Cu and Fe. However, the adults differed significantly between sexes for all metals studied. For both sexes, there were significant differences between suckling and adult rats for all metals studied. Phosphorus was significantly correlated with Mg in kidneys of rats of both ages and sexes. Magnesium was significantly correlated with Na and K in the kidneys of juveniles of both sexes but not in adults of either sex. Potassium was significantly correlated with Fe in the kidneys of only males of both ages. In both organs, Na was correlated with K in males of both ages and in female juveniles but not adults. Other correlations were significant only in one age or one sex, and were not considered further.

Bonferroni probabilities of Pearson coefficients for log-transformed concentrations in the liver showed significant correlations in each age and sex group between Na and Mg; K and Ca; and Fe and Zn. In females of each age, but not males, liver Ca concentrations were correlated with and Mg and P. In the kidney, Na was correlated with K in each group, with Fe in males of each age, and with juveniles in each sex. In each group, phosphorus was correlated with K (except for female juveniles) and Mg.

For the birds, the highest concentrations of Na, K, Ca, P and Fe were found in the livers of females whereas the highest concentrations of Mg, Zn, and Cu were found in the hearts of the males. The lowest concentrations of all metals studied were found in the female hearts except for Zn and P which was lowest in male livers and hearts, respectively.

There were significant differences between the sexes for K, Ca, Mg, Cu and Fe in the liver, There was also weaker statistical evidence that Na was significantly different ($P = 0.09$). However, the P and Zn concentrations in the liver did not differ significantly between male and female birds. The concentrations of all metals in the heart differed significantly between sexes, although the statistical evidence for Cu was weaker ($P = 0.09$).

Bonferroni probabilities of Pearson coefficients of log transformed concentrations showed significant correlations ($P < 0.05$) in the hearts of females but not males: : Na with K, Ca, Mg, P; K with P, Cu; Ca with Mg, P, Cu; P with Cu. In the liver, significant correlations obtained in males for K with P, and for Ca with Mg and Cu, and in females for Na with K and Fe with Zn.

We know of no published data of metal concentrations in the organs of wild rats and birds from the northern Guinea Savanna of Nigeria. These data therefore represent initial baseline findings of metal levels in these species from this environment.

The higher levels of most metals found in the liver of adult than suckling wild rats may reflect a better dietary utilization within the food chain since the ambulatory rodent is capable of wider exploitation of its ecological niche than sucklings or younger rodents. A similar explanation might hold for other species. The higher levels of Zn in suckling rats and similar levels of Cu in both age groups suggest that the fetus is an excellent parasite capable of extracting these vital essential trace elements for its metabolism. Both Zn and Cu are essential for the physiological functions of mammalian cells. Among other necessary functions, zinc is necessary for growth and metabolism of many enzymes and hormones (Underwood 1977). Copper is essential for haematopoisis (Underwood 1977) and deficiency results in anemia in young mammals. A higher concentration of an essential element in a suckling animal may therefore serve the special purpose of providing for growth needs during the suckling period. Studies have shown that there is increased absorption of iron during gestation to meet the needs for fetal growth. And like Fe, a large store of Cu at birth and in very young animals (Jessop 1961) serves a similar function in the suckling animal since both metals are reported to be very low in milk (Underwood 1977).

Major output of many metals is feces, with the liver as the major metabolic site. Sodium and potassium function in maintaining osmotic pressure and the acid-base equilibrium, and in water metabolism in general. Magnesium is essential for carbohydrate metabolism while P is necessary for both carbohydrate and fat metabolism in animals. The significant positive correlations between metal concentrations in the livers of both adult and suckling rats irrespective of sex suggests the major role played by the liver in metabolism. In contrast, the significant correlations in the kidneys of young rats may be related to the high homeostatic function of the young nephrons. Egg production requires substantial amounts of Fe, Ca and Na. When dietary sources of these are low, metabolic demands can exceed supply and lead to low body levels. Adrenal hormones cause the kidney to conserve Na but increase the excretion of K. However, due to limited storage, excess Na is rapidly excreted. The kidney also has limited capacity to conserve K even when the diet is deficient. Phosphorus is not deficient in animal food since phosphoric acid derivatives are widely distributed in plant and animal tissues. Severe kidney disease in birds leads to loss of body stores of Ca but not P (Wallace 1963).

Table 1. Concentrations of Mineral Elements in Various Organs of Male and Female Wild Rats and Wild Birds from Zaria, Northern Guinea Savannah of Nigeria

Organ	Species	Sex		Mean Concentration (ug/g dry weight)							
				Na	K	Ca	Mg	P	Cu	Fe	Zn
Liver	Rat	Male	Suckling								
	(n=58)	(n=29)	(n=15)	47	32	31	97	99	17	145	3
				(15)	(18)	(12)	(62)	(88)	(4.4)	(1.7)	(0.22)
			Adult	73	79	82	162	229	18	340	14
			(n=14)	(6.6)	(5.0)	(11)	(21)	(17)	(1.3)	(30)	(0.78)
		Female	Suckling	47.5	37.5	37.5	97.5	160	30	340	3.8
		(n=29)	(n=16)	(3.8)	(6.9)	(6.9)	(10.0)	(26.0)	(3.9)	(52)	(0.33)
			Adult	77	54.5	44	146	450	21	170	17
			(n=13)	(5.7)	(5.0)	(3.1)	(12.0)	(65.5)	(1.3)	(30)	(0.11)
	Bird	Male		95.0	69.0	79.0	227	249	43	417	13
	(n=26)	(n=15)		(11)	(8.5)	(79)	(19.5)	(15)	(3.9)	(35)	(0.10)
		Female		72	115	360	215	320	31	550	14
		(n=11)		(5.50)	(7.20)	(11.4	(19.1)	(47.3)	(3.8)	(61)	(0.52)
Kidney	Rat	Male	Suckling	15	11	11	18	32	40	250	23
	(n=58)	(n=29)	(n=15)	(2.0)	(3.2)	(1.7)	(4.5)	(6.8)	(1.7)	(54)	(5.4)
			Adult	11	80	33	51	30	26	218	19
			(n=14)	(0.85)	(10.4)	(3.78)	(5.10)	(2.60)	(4.3)	(19)	(3.0)
		Female	Suckling	13	83	35	54	33	26.6	230	20
		(n=29)	(n=16)	(1.60)	(8.80)	(3.10)	(4.60)	(3.30)	(3.6)	(14)	(5.2)
			Adult	14	12	69	18	32	40	300	20
			(n=13)	(2.40)	(3.50)	(11.0)	(4.20)	(7.20)	(2.5)	(73)	(3.4)
Heart	Bird	Male		13.7	97	14.6	23.9	23.5	49	400	26
	(n=24)	(n=13)		(11)	(20)	(21)	(27)	(48)	(7.3)	(58)	(4.2)
		Female		59	45	58	97	124	30	220	52
		(n=11)		(12.4)	(12.0)	(14.0)	(22.0)	(47.0)	(8.1)	(49)	(0.7)

The concentrations of metals measured in the present study were lower than those reported in squirrels (McKinnon et al. 1976), white-footed mice (Anthony and Kozlowski 1982) and white-tailed deer (Wolf et al. 1982) in the United States. Ducks (Szefer and Falandysz 1986) and waterfowl (Simpson et al. 1979) from Europe also had higher levels of trace metals than the Weaver birds in this study. The lower levels in animals from Nigeria may be more a reflection of the higher environmental levels of these metals in the United States and Europe than of species differences.

The present results provide baseline data for any future environmental assessment studies for metal excesses or deficiencies in this environment. The results will be useful in future health studies which assess the nutritional needs of humans and grazing livestock in this ecosystem.

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