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Copper, Nickel, and Iron in Plumage of Three Upland Gamebird Species from Non-Contaminated Environments

Glenn H. Parker

Department of Biology, Laurentian University, Sudbury, Ontario, Canada P3E 2C6

The usefulness of selected wildlife integumentary structures as potential bioindicators of environmental metal contamination has been clearly demonstrated. High levels of atmospheric contamination and particulate fallout characterizing the Industrial Basin of the copper-nickel smelting operations at Sudbury, Ontario, were shown to be reflected in the feather chemistry of resident ruffed grouse populations (Rose 1981; Rose and Parker 1982). Of considerable concern, however, is the paucity of information on background concentrations of elemental metals that could be considered normal for non-contaminated environments. Non-migratory species which can be collected both from within and beyond industrially disturbed environments would appear to hold the greatest potential for establishing background concentrations and assessing levels of environmental contamination based on plumage chemistry. The present report examines concentrations of copper, nickel and iron in the plumage of three tetraonid species collected from remote and undisturbed areas in Northern Ontario and Quebec.

MATERIALS AND METHODS

Tail feathers of ruffed grouse (Bonasa umbellus), spruce grouse (Canachites canadensis) and willow ptarmigan (Lagopus lagopus) shot by hunters during November and December 1979 were employed. The latter samples were derived from ptarmigan populations located 5 km north-east of Great Whale River in Northern Quebec. Spruce and ruffed grouse samples were obtained from birds harvested near Gogama, Ontario (McLeod Township) and from Manitoulin Island, Ontario (Robinson and Billings Townships), respectively. All three collection sites are located at distances in excess of 100 km from mineral mining-smelting operations or other major sources of industrially-emitted pollutants and as such represent environments with no known record of metal contamination.

As carcasses were not available for examination, plumage samples were not classified according to sex and age.

In preparing samples for digestion, only retrices were included and care was taken to avoid any feathers which had been damaged by shot. Feathers of individual birds were washed in 1% Triton X and rinsed twice in deionized-distilled water using an ultrasonicator. Samples were then oven-dried for 24 hrs at 90°C. Whole-feather analysis was chosen rather than vane-only analysis as recommended by Kelsall (1970). Clipped samples weighing approximately 1 gram (to nearest mg) were digested using 2:1 volumes of HNO_3 and 72% $HCLO_4$ with the application of heat. Sample residues were redissolved and brought to volume in 10 ml volumetric flasks using 1% HNO_3. Samples subjected to the above procedures but containing no biological material served as blanks.

Concentrations of Cu, Ni and Fe were determined by atomic absorption spectrophotometry using a Perkin-Elmer Model 703 spectrophotometer in the flame mode. Calibration curves were prepared from 1000 ppm stock solutions diluted to provide working standards containing 1 and 5 ppm metal in accordance with standard procedures prescribed by Perkin-Elmer (1971). Concentrations are reported in micrograms per gram ($ug.g^{-1}$) of oven-dry material.

Data were analyzed using a one-way analysis of variance and significantly different subsets identified by means of Duncan's Multiple Range Test (Steel and Torrie 1980). Differences were deemed significant at the 95% level of confidence ($p \leq 0.05$).

RESULTS AND DISCUSSION

Mean concentrations of Ni, Cu and Fe in retrices of willow ptarmigan, ruffed grouse and spruce grouse are presented in Table 1.

Of the three metals examined, Ni values were consistently the lowest with 79% of all birds showing levels less than 1 $ug.g^{-1}$. No significant interspecies differences were observed in Ni levels ($F = 2.69$; $p > 0.05$).

Copper levels averaged 6-8 fold higher than Ni concentrations, with all but three values falling between 4 and 8 $ug.g^{-1}$. Mean Cu concentrations shown by the three game species studied were not significantly different ($F = 3.18$; $p > 0.05$).

Although showing considerably greater intra- and inter-species variability as judged from coefficients of variation, Fe values were observed to be substantially higher than levels of either Cu or Ni. Species differences were also noted in the Fe content of plumage ($F = 22.34$; $p < 0.05$). Levels in spruce grouse averaged 69.14 ± 8.17 $ug.g^{-1}$ and were found to be significantly higher ($p < 0.05$) than mean values determined for ptarmigan and ruffed grouse (19.04 ± 3.19 and 32.01 ± 5.37 $ug.g^{-1}$, respectively).

Metal concentrations determined in this study are in good agreement with the generally low levels reported in the plumage of birds from relatively undisturbed environments. Levels determined

Table 1. Metal concentrations ($ug.g^{-1}$ dry wt) in plumage of gamebirds from non-contaminated environments.

METAL	SPECIES		
	Willow Ptarmigan (n=22)	Ruffed Grouse (n=11)	Spruce Grouse (n=14)
Copper:			
mean	5.54_a	5.88_a	6.79_a
±St. error	0.21	0.72	0.28
range	4.38 - 8.12	3.16 - 12.00	5.02 - 8.12
C.V. (%)	15	40	15
Nickel:			
mean	0.91_b	0.74_b	1.09_b
±St. error	0.08	0.01	0.12
range	0.31 - 1.90	0.68 - 0.83	0.67 - 1.75
C.V. (%)	41	6	42
Iron:			
mean	19.04_c	32.01_c	69.14_d
±St. error	3.19	5.37	8.17
range	5.30 - 70.78	8.08 - 81.19	23.56 - 139.50
C.V. (%)	79	56	44

Mean values with same subscript are not significantly different ($p > 0.05$); C.V. = coefficient of variation.

in ruffed grouse closely approximated the mean values of 4.9 $ug.g^{-1}$ Cu, 0.5 $ug.g^{-1}$ Ni and 37.7 $ug.g^{-1}$ Fe reported earlier for this species based on birds collected from a non-contaminated site in Blewett Township near Gogama, Ontario (Rose and Parker 1982). Based on levels in newly-emerged retrices characterized by minimal exposure to environmental contaminants, these means were deemed to represent base levels reflective of the degree to which dietary metals had been endogenously incorporated into the feathers during growth. Retrices of ruffed grouse in the present study, although subject to exogenous contamination by environmental minerals over a 2-3 month post-moult period, showed metal levels remarkably comparable to the base levels established for the Blewett birds. Such agreement confirms that conditions of minimal environmental contamination existed at the Manitoulin Island collection site and substantiates the view that the plumage metal concentrations reported herein indeed represent base levels indicative of endogenous incorporation at the time of feather replacement.

Mean base levels determined in this study compare favourably with the few values reported for gamebird species by other laboratories. Scanlon et al. (1980) reported background levels of 4.2 $ug.g^{-1}$ Ni in the primary feathers of ruffed grouse taken by hunters in Virginia. Nickel concentrations in the primary flight feathers of wild turkeys (Meleagris gallopava) harvested from this same area were generally less than 1 $ug.g^{-1}$ dry weight (Scanlon et al. 1979) and thus consistent with the mean values of 0.74 to 1.09 $ug.g^{-1}$ reported in the present study. Nickel concentrations in feathers of ring-necked pheasants (Phasianus colchicus) from Illinois have been reported by Anderson and Stewart (1970) but are difficult to compare as overall means were not presented and the data were based on concentrations in ash. Slightly higher Cu concentrations of 8 and 10 $ug.g^{-1}$ but comparable Ni levels of 0.2 and 1.6 $ug.g^{-1}$ dry weight have been reported for the primary feathers of black/mallard ducks collected from northern Saskatchewan and Manitoulin Island, respectively (Ranta et al. 1978).

Of the three elements assayed, Fe consistently showed the greatest variability in levels present. Substantial variation in plumage Fe levels was likewise reported for ruffed grouse from Blewett Township (Rose and Parker 1982). In view of the ubiquitous nature of Fe in soils, this marked variability may reflect, in part, a high degree of variation in environmental Fe levels both within and between the study sites investigated. In this context the extent to which the higher Fe levels recorded in spruce grouse plumage represents a species-related difference rather than a reflection of highly localized iron contaminating conditions within the Gogama environment must be viewed with caution. Owing to the inherent high variability, whatever its origin(s), iron concentrations within the plumage of free-ranging birds would appear to hold only marginal potential for assessing conditions of environmental contamination.

With the single exception of higher Fe values in spruce grouse plumage, metal concentrations in the three game species studied were remarkably similar. Such similarity supports the view that the deposition of these elemental metals into the plumage during growth is not only a physiologically-controlled process (see Rose and Parker 1982) but one which may be universally common to phylogenetically related species. Given that this conjecture is indeed true, the results of the present study suggest a solution to the problem of biomonitoring environmental metal burdens over geographical areas which extend beyond the range and habitat of a single bioindicator species; in such cases a closely related species known to be characterized by similar base levels of the metals in question could serve to provide the necessary information.

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