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BLOOD CONSTITUENTS AND THEIR RELATION TO DIET IN URBAN AND RURAL HOUSE SPARROWS[1]

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Abstract. To determine whether habitat-related differences in diets of House Sparrows (*Passer domesticus*) were reflected in their blood, we measured hematocrits and plasma concentrations of cholesterol, albumin, uric acid, and blood urea nitrogen (BUN) of sparrows from urban and rural habitats in Centre County, Pennsylvania, during the breeding season. We also determined the protein and fat content of food samples recovered from sacrificed birds. Significantly elevated plasma cholesterol and BUN levels in House Sparrows from the urban area reflected the higher fat and protein content of the urban diet. Albumin and uric acid levels were also higher in urban than in rural birds, but not significantly so. Blood values were further influenced by age, sex, and date of collection. The analysis of blood may be useful in assessing the quality of diets eaten by wild birds.

Key words: House Sparrow; Passer domesticus; *blood constituents; hematocrit; cholesterol; albumin; uric acid; blood urea nitrogen (BUN).*

INTRODUCTION

The composition of blood reflects the physiological state of an animal and can therefore be useful in assessing its health and nutrition (Cook 1937, Kronfeld and Medway 1969). Although the factors affecting blood composition of humans and domestic animals have received considerable attention, relatively little is known about blood constituents of wild birds or the effects of nutrition on blood values.

As part of a study of the food habits of House Sparrows (*Passer domesticus*) from urban and rural habitats in central Pennsylvania (Gavett and Wakeley 1986), we collected blood samples from birds that were sacrificed for stomach contents. We tested these samples for several blood characteristics that are affected by nutrition in other avian and nonavian species (LeResche et al. 1974, Sturkie 1976). We also measured the protein and fat content of foods eaten by urban and rural sparrows. Our objectives were to determine the effects of habitat, age, sex, and time of collection on blood constituents of House Sparrows, and to determine if habitat-related differences in blood composition were related to the quality of the birds' diets.

STUDY AREA AND METHODS

The study area was located in Centre County, Pennsylvania (40°50'N, 77°50'W; elevation 300 to 360 m) and consisted of separate urban and rural sites (Gavett 1983). The business district and adjacent residential neighborhoods of the Borough of State College constituted the urban site. The rural area consisted of nine small farms located 8 to 16 km from State College.

From 29 May to 28 July 1981, we captured 322 House Sparrows in mist nets or Potter traps and sacrificed them to obtain blood samples and stomach contents. At least 50 birds from each habitat (urban or rural) were collected during each of three time periods: 29 May to 10 June (Time Period 1), 22 June to 2 July (Period 2), and 18 to 28 July (Period 3). Approximately 1.0 to 1.5 ml of blood were collected by heart puncture with a 2.5-cm, 21-ga needle and a 2-ml evacuated collecting tube containing ethylenedinitrilo tetra-acetic acid (EDTA) as an anticoagulant. Blood samples were collected between 0600 and 1500 and were kept on ice for up to 9 hr until returned to the laboratory, where the hematocrit, or packed cell volume, was determined before they were centrifuged to obtain the plasma. Plasma was frozen for later analysis.

Colorimetric tests were used to determine the albumin, total cholesterol, blood urea nitrogen (BUN), and uric acid content of plasma samples. These constituents were chosen because they are known to reflect nutritional status (Bell and Sturkie 1965, LeResche et al. 1974, Sturkie 1976) and, at least in mammals, are stable during stress and short-term dietary changes (LeResche et al. 1974). Kits for the determination of albumin, cholesterol, and BUN were supplied by Sigma Chemical Company, St. Louis, Missouri. A Lancer kit (Lancer Division of Sherwood Medical, St. Louis) was used to measure uric acid. Absorbances were determined with a Beckman DU spectrophotometer using a flow-through cell or microcuvets. A sample of Monitrol I (Dade Division of American Hospital Supply Corp., Miami, Florida), a quality-control standard prepared from human blood, was run with each batch of samples, and the batch was tested again if the value for the control was not within 10%

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TABLE 1. Means, standard deviations, and ranges of selected blood constituents of urban and rural House Sparrows from Centre County, Pennsylvania.

Constituent	Urban			Rural		
	n	Mean ± SD	Range	*n*	Mean ± SD	Range
Hematocrit (%)	145	47.4 ± 5.7	26.0–59.0	168	48.3 ± 6.2	25.0–61.0
Total cholesterol (mg/dl)	147	249.0 ± 62.1	115.0–469.0	155	221.9 ± 57.2	98.0–435.0
Albumin (g/dl)	147	1.66 ± 0.30	1.06–2.55	155	1.59 ± 0.31	1.02–2.44
Uric acid (mg/dl)	146	17.3 ± 4.6	6.0–33.0	154	16.6 ± 4.9	6.3–36.0
Blood urea nitrogen (mg/dl)	80	3.87 ± 2.43	0.68–15.94	84	2.46 ± 1.36	0.45–8.09

of its rated concentration. In addition, all reactions were periodically checked against a calibration curve made with known concentrations of standard to test the accuracy of the instruments.

Analysis of variance (Neter and Wasserman 1974) was used to examine the effects of habitat, sex, age, and time period on the level of each blood constituent. Blood urea nitrogen values were log-transformed to stabilize the variances. The General Linear Models procedure of the Statistical Analysis System (Helwig and Council 1979) was used for the analysis. Means and standard deviations of blood values were calculated by the SAS Univariate procedure (Helwig and Council 1979).

To estimate the protein and fat content of the birds' diets, food samples obtained from their stomachs were combined by habitats and time periods. Quantities of food samples were not sufficient to subdivide by age or sex of birds. Samples were dried, ground in a Wiley mill, and thoroughly mixed before 0.5-g portions were analyzed for protein by a standard Kjeldahl procedure and for fat by ether extraction (Williams 1984). Chemical analyses of each combined sample of food items were performed twice and values were averaged.

RESULTS

BLOOD CONSTITUENTS

For all blood characteristics except hematocrit, average values were higher in urban than in rural sparrows (Table 1). Analysis of variance (Table 2) indicated significant effects ($P < 0.05$) of habitat, sex, age, or time period on each blood characteristic.

TABLE 2. Results of analyses of variance on blood constituents of House Sparrows.

Constituent	Significant effects or interactions[a]	*P*
Hematocrit	Sex/age	<0.001
Total cholesterol	Habitat	0.013
	Sex	0.039
	Sex/age	0.001
Albumin	Time	0.001
	Age	<0.001
	Habitat/time/sex	0.013
Uric acid	Time/sex/age	0.016
Blood urea nitrogen	Habitat	<0.001

[a] $P < 0.05$.

Hematocrit. Hematocrits were influenced only by a sex-and-age interaction ($P < 0.05$). Opposite trends occurred in adults and immatures (Fig. 1). Hematocrits of immature birds were greater in females than in males; yet in adults, those of females were less than those of males. One exception was for rural adults in Period 3 (females had slightly higher hematocrits than males).

Total cholesterol. Habitat, sex, and an interaction between sex and age affected the level of plasma cholesterol in sparrows ($P < 0.05$; Table 2). Cholesterol levels were generally higher in urban than in rural birds (Fig. 2). Among males, adults had higher cholesterol levels than immatures; whereas the opposite was often true among females.

Albumin. Time, age, and a three-way interaction among habitat, time, and sex significantly influenced plasma albumin values ($P < 0.05$; Table 2). In most cases, adults had higher albumin levels than immatures, and adult females had higher levels than adult males (Fig. 3). Blood levels of albumin generally increased from Period 1 to Period 3, except in immature females from the rural area. Those of urban and rural sparrows were not significantly different.

Uric acid. Habitat, sex, age, or time alone did not affect the uric acid levels of House Sparrows significantly (Table 2). However, a three-way interaction of time, sex, and age was important ($P < 0.05$). Levels in adult females increased over time, whereas those in males decreased (Fig. 4). These trends generally were reversed in immatures.

Blood urea nitrogen. We measured BUN in fewer samples than we did the other blood constituents due to the large sample volume needed for tests. No samples from immature females from the urban area were analyzed for BUN in Periods 1 and 2. Habitat was the only significant determinant of BUN level in House Sparrows ($P < 0.05$; Table 2). Means for urban birds were higher than those for rural birds

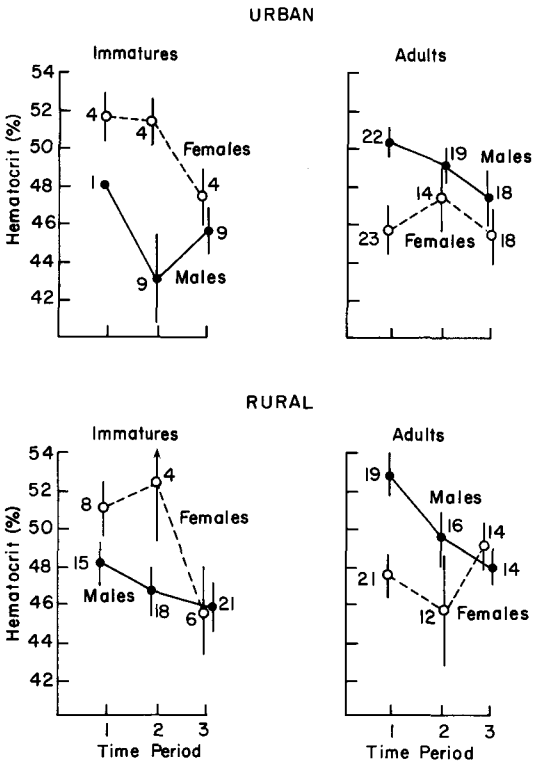

FIGURE 1. Mean hematocrits of House Sparrows in relation to habitat, sex, age, and time period (1 = 29 May to 10 June; 2 = 22 June to 2 July; and 3 = 18 to 28 July). Numbers indicate the number of blood samples tested. Vertical bars are ±1 SE; arrows represent truncated bars.

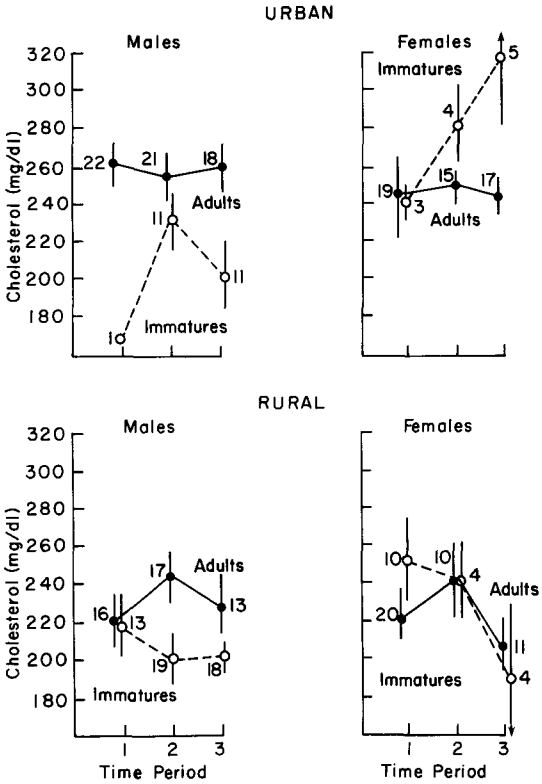

FIGURE 2. Mean plasma total cholesterol levels of House Sparrows in relation to habitat, sex, age, and time period. Numbers, time periods, and symbols as in Figure 1.

for all factor levels, except for those of adult males during Period 1 (Fig. 5).

ANALYSIS OF FOOD SAMPLES

The diet of urban House Sparrows consisted mainly of commercial birdseed, especially milo (*Sorghum vulgare*) and millet (*Panicum miliaceum*), and elm (*Ulmus americana*) mast. Rural birds fed heavily on corn (*Zea mays*). Both groups of birds ate a variety of insects, particularly beetles (Gavett and Wakeley 1986).

Food collected from sparrows captured in the urban area contained consistently more fat and protein than that obtained from rural sparrows (Table 3). Highest levels of both nutrients were found in urban birds during Period 2. Lowest levels occurred in the rural area during Periods 1 (fat) and 2 (protein). Although differences in digestibility of food items undoubtedly affected the nutrient content of samples collected from sparrows, these biases should have been consistent among time periods and habitats.

DISCUSSION

House Sparrows from the urban study area had significantly higher plasma cholesterol and BUN levels than did rural birds. These differences were consistent with the higher average fat and protein content of foods eaten by urban sparrows. Cholesterol and BUN levels in House

TABLE 3. Average protein and fat composition (% dry weight) of food samples obtained from captured House Sparrows. The number of stomachs from which food samples were combined for analysis is shown in parentheses. Each nutrient value is the mean of two measurements.

Time period	Fat (%)		Protein (%)	
	Urban	Rural	Urban	Rural
1 (29 May to 10 June)	9.38 (50)	3.73 (63)	18.69 (50)	16.41 (63)
2 (22 June to 2 July)	15.14 (52)	4.39 (50)	24.84 (52)	13.36 (50)
3 (18 to 28 July)	6.72 (52)	6.22 (55)	22.62 (52)	17.57 (55)
Mean	10.41 (154)	4.78 (168)	22.05 (154)	15.78 (168)

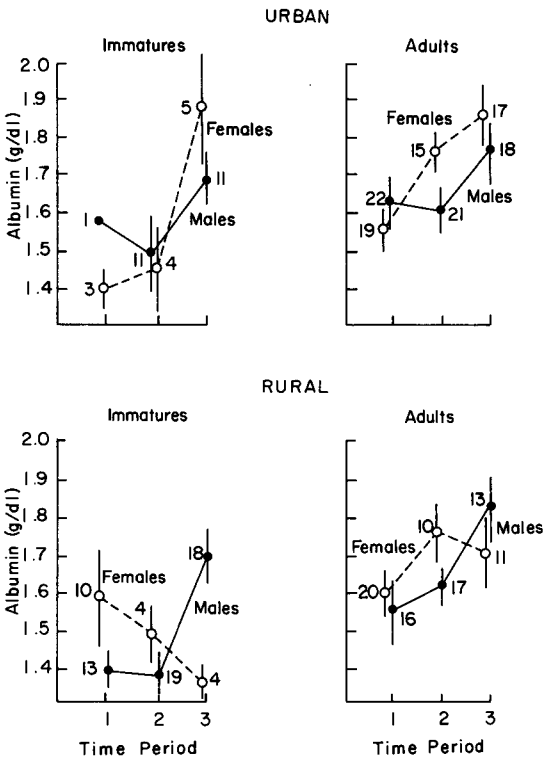

FIGURE 3. Mean plasma albumin levels of House Sparrows in relation to habitat, sex, age, and time period. Numbers, time periods, and symbols as in Figure 1.

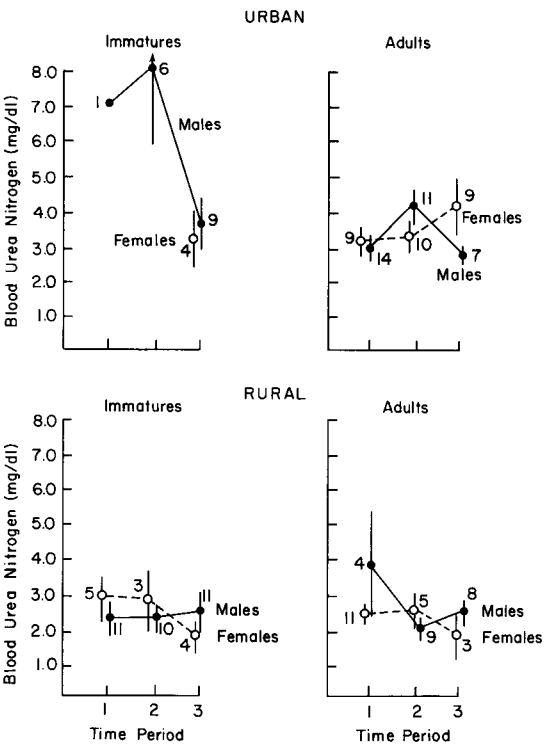

FIGURE 5. Mean blood urea nitrogen levels of House Sparrows in relation to habitat, sex, age, and time period. Numbers, time periods, and symbols as in Figure 1.

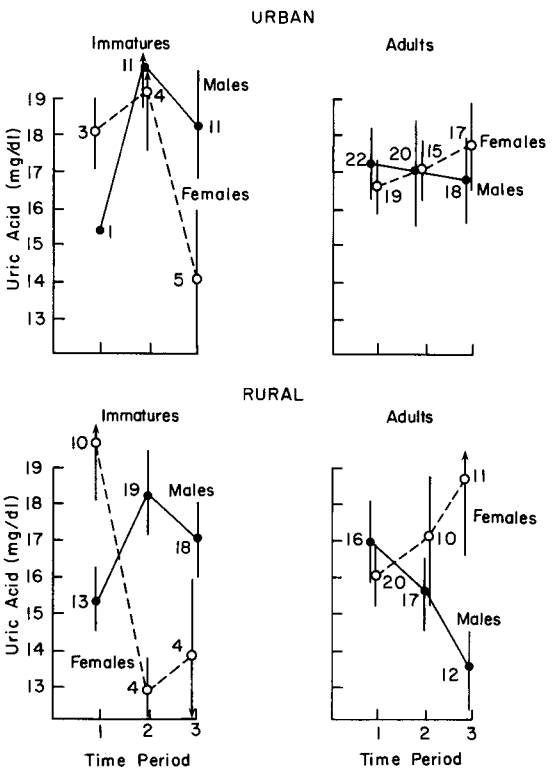

FIGURE 4. Mean plasma uric acid levels of House Sparrows in relation to habitat, sex, age, and time period. Numbers, time periods, and symbols as in Figure 1.

Sparrows thus appear to reflect the quality of the diet. However, no significant differences were found between urban and rural sparrows in hematocrits or in the levels of plasma albumin or uric acid, despite previous studies linking these blood characteristics to nutrition. With the exception of BUN, all blood constituents were significantly influenced by sex, age, or time of collection.

Average values of avian hematocrits in the literature include 35 to 46% for cranes, raptors, quail, and geese (Gee et al. 1981); 37 to 43% for several galliformes (Balasch et al. 1973); and 33 to 53% for a variety of passerines (Palomeque et al. 1980). The significant effect of an age-and-sex interaction on hematocrits of House Sparrows was likely due to varying levels of sex hormones (Kern et al. 1972, Sturkie 1976, Gee et al. 1981).

Plasma cholesterol levels are highly variable in birds (Johnson et al. 1959, Kern et al. 1972), and House Sparrows were no exception. Total cholesterol ranged from 98 to 469 mg/dl with a mean of 235.0 mg/dl, which was high compared with values reported for other species (Kokatnur et al. 1958, Leveille and Sauberlich 1961, Kern et al. 1972, Gee et al. 1981, Parrish and Mote 1984).

Adult male House Sparrows had slightly higher cholesterol levels than adult females in

both urban and rural areas. In chickens, serum cholesterol levels of laying hens generally exceed those of adult males, nonlaying females, or immature birds, due to increased mobilization of blood lipids for yolk formation (Bell and Sturkie 1965, Sturkie 1976). Gee et al. (1981) reported that cholesterol levels were different between sexes of nonbreeding raptors, cranes, geese, and quail; whether males or females had higher levels depended upon the species.

Serum cholesterol in chickens is increased by high levels of dietary fat, particularly when insufficient levels of protein are ingested (Kokatnur et al. 1958, Leveille and Sauberlich 1961, Yeh and Leveille 1973). Urban House Sparrows had significantly higher cholesterol levels than did rural birds, reflecting the higher average fat content of their diet, in spite of their higher protein intake.

Levels of plasma albumin in House Sparrows were influenced by many interacting factors, making trends difficult to discern. Adult House Sparrows generally had higher albumin levels than immatures, and levels in adult females were often higher than in adult males. Gee et al. (1981) found significant sexual differences in the albumin levels of several avian species and suggested that they were hormone-related. In egg-laying chickens, plasma proteins that eventually are stored in the yolk of developing eggs increased as a result of endogenous estrogen secretion (Bell and Sturkie 1965, Sturkie 1976).

Dietary deficiency in protein can cause serum albumin levels to decrease (Kronfeld and Medway 1969, Birke et al. 1970, LeResche et al. 1974). In fact, the albumin content of the blood has been directly related to the amount of protein in the diet of growing chicks (Leveille and Sauberlich 1961). However, the albumin levels of raptors receiving high-protein diets were not elevated (Gee et al. 1981). Overall, urban House Sparrows, which consumed more protein in their diets than did rural birds, had only slightly higher albumin levels in their blood.

Uric acid is the primary nitrogenous waste product of birds, and uric acid levels in the blood are known to be extremely variable (Bell and Sturkie 1965, Sturkie 1976). The mean uric acid level in House Sparrows was higher than values reported for most other species (Bell et al. 1959, Featherston 1969, Lewis et al. 1979, Gee et al. 1981, Parrish and Mote 1984). The significant effect of an interaction among time, sex, and age on uric acid levels in sparrows may have been due to differences in the birds' sex and reproductive status. Bell et al. (1959) found that nonlaying chickens had lower uric acid levels than did layers, and Gee et al. (1981) reported that adult males of several species had lower levels than adult females.

High levels of dietary protein can increase blood uric acid levels (Bell et al. 1959, Featherston 1969). However, the uric acid levels of House Sparrows from the urban area were not significantly higher than those of rural birds (Table 1), in spite of the higher amount of protein in the urban diet (Table 3).

Urea plays a minor role in the nitrogen metabolism of birds and is therefore maintained at fairly constant levels in the blood under most conditions (Bell et al. 1959, Bell and Sturkie 1965). For avian species, protein is the only dietary item that has an important influence on BUN (Gee et al. 1981). Our average BUN values for House Sparrows were similar to those reported by Parrish and Mote (1984).

CONCLUSIONS

The levels of certain blood constituents in urban and rural House Sparrows appear to reflect the quality of their diets. The significantly higher BUN and plasma cholesterol levels of urban sparrows were consistent with their higher protein and fat intake. Higher (but not significantly so) albumin and uric acid levels in the plasma of urban birds may also have been the result of the higher protein content of their diets. The study of blood is potentially useful for evaluating the quality of diets consumed by free-living birds and therefore the suitability of their habitats. However, additional information is needed about the normal blood composition of both captive and wild birds and about how it is affected by nutrition and health.

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