SERUM CHEMISTRY AND HEMATOLOGY OF BLACK BEARS: PHYSIOLOGICAL INDICES OF HABITAT QUALITY OR SEASONAL PATTERNS?

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We evaluated the use of serum chemistry and hematological variables as indices of habitat quality for adult (≥ 4 yr) female black bears (*Ursus americanus*) in northeastern Minnesota. Blood samples ($n = 182$) collected from 48 adult females during 1970–1976 showed seasonal variation ($P < 0.05$) for four of five hematologic characters and seven of 13 serum chemistries. Body mass, red-blood-cell count, mean corpuscular-volume, serum-urea nitrogen, uric acid, thyroxine, and cortisol were different ($P < 0.05$) among years of differing food availability. Discriminant functions developed from samples from late summer, autumn, and early hibernation provided 75–80% accuracy in classifying observations into year classes of good and poor food production. Our results suggested that blood characteristics can be indicators of nutritional condition and habitat quality after seasonal rhythms are controlled. We recommend use of blood-profile data to empirically test the utility of our discriminant functions.

Key words: *Ursus americanus,* black bear, discriminant function, habitat, hematology, serum chemistry

Nutritional status is a major factor influencing age at primiparity, litter size, breeding interval, and cub survival in black bears (Bunnell and Tait, 1981; Elowe and Dodge, 1989; Jonkel and Cowan, 1971; Rogers, 1976, 1983). Indicators of nutritional status may thus be useful predictors of black bear productivity and habitat quality. The use of metabolic and endocrine indicators to assess nutritional condition and habitat quality has shown potential in several wild mammals (Seal, 1978). Recent evidence suggests that blood characteristics may be useful indicators of nutritional status of black bears (Franzmann and Schwartz, 1988; Hellgren et al., 1989; Schroeder, 1987). Franzmann and Schwartz (1988) used discriminant analysis to select blood variables useful for condition evaluation in black bears in Alaska. They suggested that a discriminant function to classify bears into broad categories based on blood characteristics may provide an index to habitat quality.

Black bears also undergo dramatic seasonal changes in nutritional condition and physiology. Seasonal fluctuations in fat reserves, body mass, blood characteristics, and metabolism track changing composition and quality of diet (Eagle and Pelton, 1983; Franzmann and Schwartz, 1988; Hellgren et al., 1989; Nelson et al., 1983; Schroeder, 1987). However, the relative contributions of nutrition and endogenous-physiological rhythms in effecting these seasonal changes

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are unknown, because the effects of season and nutrition are confounded. Data from multiyear studies are necessary to separate the effect of seasonal rhythms in physiology from habitat-generated changes in nutritional condition.

We examined physiological data collected from a population of bears from northeastern Minnesota from 1970 to 1976 (Rogers, 1987) to determine if blood variables in black bears are indicators of body condition and habitat quality or merely one of a suite of characters, including body weight, animal condition, and food intake, that covary in a circannual rhythm. Data were analyzed with regard to yearly fluctuations in availability of fruits and hazelnuts because those foods have been linked to reproductive success of bears (Rogers, 1976, 1987) and are important sources of energy in preparation for hibernation and lactation. Specifically, our objectives were to test for the effects of season, year, and food resources on blood characteristics of black bears, and to use blood characteristics to discriminate physiological responses of bears to years of variable food supplies.

STUDY AREA

The study was conducted in the Superior National Forest in northeastern Minnesota (47°45'N, 91°30'W). Study area characteristics summarized here are from Rogers (1987). The growing season averaged 118 days between mid-May and mid-September. Forests were mixed coniferous-deciduous communities containing components of the boreal forest and the temperate deciduous forest. Availability of foods for bears varied greatly among years. Major foods included emerging vegetation in May, colonial insects and vegetation in June, fruit and vegetation in July, fruit and hazelnuts (*Corylus cornuta*) in August, and rapidly declining fruit, colonial insects, and vegetation in late August and September. Snow cover was continuous from November to April, with bears hibernating from October to April (Rogers, 1987).

METHODS

A pole syringe and a combination of phencyclidine hydrochloride (0.2 mg/kg) and promazine hydrochloride (0.5 mg/kg) were used to immobilize bears in dens or bears captured in barrel traps or snares. Body mass and blood samples (40–80 ml) were collected from 182 captures of 48 adult (≥4 yrs) female black bears. Serum and whole blood was analyzed at the Veterans Administration Hospital in St. Paul, Minnesota. Values for red blood cell count (RBC), white blood cell count (WBC), hemoglobin (Hb), mean corpuscular volume (MCV), hematocrit (HCT), and mean corpuscular hemoglobin concentration (MCHC) were determined from whole blood (Seal et al., 1967). Serum was analyzed for concentrations of glucose, urea nitrogen, cholesterol, triglycerides, calcium, phosphorus, total protein, total bilirubin, sodium, potassium, creatine phosphokinase (CPK), aspartate aminotransferase (SGOT), lactate dehydrogenase (LDH), alkaline phosphatase (ALP), uric acid, thyroxine (T4), and cortisol by methods described previously (Seal et al., 1967, 1972a, 1972b). Samples from the years 1970 to 1976 were used in these analyses and not all determinations were made for each sample. Intervals between drug injection, immobilization, and blood collection were not recorded, but generally blood was collected 10–30 min after induction (DelGiudice et al., 1991). As most active animals were captured with barrel traps and all denned bears were immobilized by a pole syringe, analyses were restricted to these groups of animals. Data from animals captured with foot snares were not used, as we suspected that the factors associated with limb restraint that cause biochemical differences between foxes trapped with foothold traps and those trapped with box traps (White et al., 1991) also may have been operating in snared versus barrel-trapped bears.

The dataset for each blood variable was tested for normality. Non-normally distributed variables (MCV, MCHC, bilirubin, uric acid, T4, ALP) were rank-transformed and analyses conducted on transformed data.

Data were analyzed for effects of season, year, and food source. Seasons were separated according to plant phenology and diet as follows: early summer, June; late summer, 1 July–19 August; autumn, 20 August–30 September; early hibernation, 1 October–31 December; late hibernation, 1 January–18 April (Rogers, 1987). Only first-capture data were used from bears captured twice during a particular season to maintain independence. Data from bears recaptured in dif-

ferent seasons or different years were considered independent for the purposes of analysis.

Food resources were classified as abundant or scarce, based on relative abundance of berries and nuts from 30 permanent transects each year during 1974–1977 and by visual estimates during field operations during those and remaining years (Rogers, 1987). Years were classified as good or poor, depending upon these estimates of fruit and hazelnut production in late summer and autumn (Rogers, 1987). Physiological data from good years and poor years were pooled separately. For purposes of analysis, we designated a year as 1 July–30 June because fruit and nut production can influence reproductive success in January and body mass the following spring (Rogers, 1976, 1987).

Bears were further classified as wild or supplemental, depending upon major food source. Bears in the wild category were those that were never captured or relocated at garbage dumps or that did not repeatedly eat bait (beef fat) in and around barrel traps. Bears occupying territories that did not include a dump did not cross other female territories to use a dump. Bears in the supplemental category were those that ate at garbage dumps or repeatedly ate bait.

Reproductive status was not considered in this report. Previous data (DelGiudice et al., 1991; Hellgren et al., 1990; Storm et al., 1988) have shown little effect of reproductive status on blood characteristics. Hematocrit decreases ($P < 0.05$) during post-implantation pregnancy (M. R. Vaughan, in litt.); therefore, all blood data from pregnant individuals sampled during December and January were removed from analyses.

Because our primary purpose was to examine the effects of year and season, and a three-way analysis of variance (food, season, year) was not possible because of empty cells, we analyzed the data in a series of two-way analyses of variance (ANOVA, PROC GLM—SAS Institute, Inc., 1988). The first set of analyses were two-way ANOVA with food and season as main effects and the food by season interaction; and with food and year and the food by year interaction to examine the effect of food source (wild or supplemental food) on blood characteristics. Sample size for each season for pooled good and poor years, respectively, were: early summer, 16 and 21; late summer, 14 and 13; autumn, 11 and 6; early hibernation, 17 and 16; late hibernation, 31 and 37.

Characteristics not exhibiting a significant ($P \le 0.05$) food by year or food by season interaction or food main-effect were then pooled across food source to conduct a two-way ANOVA with year and season as main effects and the year by season interaction. Only data from wild bears were used for variables exhibiting a food by season or food by year interaction, or food main effect. Variables not included in these analyses because of sensitivity to handling stress included serum enzymes (CPK, SGOT, LDH), WBC, and glucose. Tukey's studentized range test was used for comparing means.

Stepwise discriminant analysis (PROC STEPDISC—SAS Institute, Inc., 1988) then was used to select blood variables that provided separation between good and poor years within each season. Because of missing data, triglycerides, total protein, bilirubin, sodium, potassium, uric acid, cholesterol, and cortisol were not included in stepwise discriminant analyses for some seasons. Log transformations of nonnormal variables (see above) were used in these analyses. Multivariate analyses of variance, using variables selected by stepwise discriminant analysis, were conducted to compare (significance level of $P = 0.05$) good and poor years within each season. Finally, a linear discriminant function was developed with a jackknife procedure (PROC DISCRIM—SAS Institute, Inc., 1988) to distinguish bears during years of different food abundance using all data from 1970 to 1976. In addition, data from 1 randomly chosen poor year and 1 good year were used to test the classification accuracy of a discriminant function developed with the remaining 5 years of data.

RESULTS

Only body mass and total protein varied ($P < 0.05$) by food source in both two-way ANOVA involving food source as a main effect, with supplemental bears having heavier weights ($\bar{X} \pm SE = 69.9 \pm 2.5$ kg, $n = 56$ versus 63.1 ± 1.3 kg, $n = 127$) and lower concentrations of total protein (7.8 ± 0.1 g/dL, $n = 40$ versus 8.1 ± 0.1 g/dL, $n = 57$) than wild bears. Serum-urea nitrogen exhibited a significant ($P < 0.05$) food by season interaction. Serum-urea nitrogen was lower for supplemental bears during the summer months, but similar during autumn

1,934
4,227
———
26,161 ÷ 34+41 = 3488 mg/dL   Cholesterol during hibernation

TABLE 1.—*Body mass and blood characteristics of adult female black bears in northern Minnesota, 1970–1976, affected by season* (P < 0.05), *independent of food source (wild, supplemental) or year effects.*

Character	Early summer[a]			Late summer			Autumn			Early hibernation			Late hibernation		
	n	$\bar{X}$	SE	n	$\bar{X}$	SE	n	$\bar{X}$	SE	n	$\bar{X}$	SE	n	$\bar{X}$	SE
Body mass (kg)	38	59.3	1.7C[b]	27	68.2	3.2B	17	83.2	3.4A	33	75.7	2.9AB	68	57.7	1.4CD
Hb (g/dL)	38	14.7	0.3C	25	15.4	0.3C	17	18.8	0.5A	34	18.8	0.5A	65	17.3	0.3B
RBC ($10^6/\mu$L)	38	6.8	0.2C	23	6.9	0.2C	17	8.6	0.3AB	34	8.9	0.3A	65	8.0	0.1B
HCT (%)	38	44.6	0.9C	24	45.3	1.1C	17	55.4	1.3A	33	55.4	1.4A	65	50.9	0.8B
MCV (μm^3)[c]	38	66.3	1.0A	24	66.1	1.8AB	17	65.5	2.3AB	30	62.2	1.0B	62	64.5	0.7AB
Urea nitrogen (mg/dL)	37	16.3	1.2A	27	15.6	1.5A	17	12.6	1.7AB	36	15.4	1.3A	68	9.5	0.5B
Cholesterol (mg/dL)	20	248	9 B	15	281	11 A	17	322	16 A	34	351	13 A	41	347	21 A
Triglycerides (mg/dL)	5	169	48	0			3	320	130	9	355	48	11	235	22
Phosphorus (mg/dL)	26	5.3	0.2A	24	5.8	0.2A	17	5.6	0.4A	35	4.0	0.1B	57	3.8	0.1B
ALP (IU/L)[c]	27	14.9	1.3A	24	27.7	4.4A	16	16.8	3.5A	23	4.6	0.4B	54	6.5	0.5B
Uric acid (mg/dL)[c]	16	1.7	0.1A	15	1.8	0.1A	14	1.7	0.1A	25	1.3	0.1B	30	1.1	0.1B
Cortisol (μg/dL)	29	3.8	0.7B	23	5.4	1.6AB	15	6.5	0.9AB	30	5.6	0.6AB	62	6.9	0.4A

[a] Seasons defined as follows: early summer—June; late summer—1 Jul–19 August; early autumn—20 August–30 September; early hibernation—1 October–31 December; late hibernation—1 January–18 April.

[b] Values in the same row followed by different letters are significantly different ($P < 0.05$).

[c] Analysis performed on rank-transformed data.

and hibernation to wild bears. Bilirubin ($P = 0.080$) and ALP ($P = 0.086$) tended toward year by season and food by season interactions, respectively. Bilirubin showed no distinguishable pattern, while ALP tended to be lower in supplemental bears during the summer months and similar during autumn and hibernation to wild bears.

Using two-way ANOVA (year by season), four of five hematologic characteristics varied seasonally ($P < 0.001$), with peak values for HCT, RBC, and Hb in autumn and early hibernation and a nadir in early summer before ripening of mast and berries (Table 1). Hematologic data suggested a seasonal rhythm independent of estimated mast and berry production (Fig. 1). Body mass varied seasonally ($P < 0.001$) in a similar pattern as HCT, Hb, and RBC. Seven of 13 serum chemical and endocrine characteristics also varied ($P < 0.05$) seasonally (Table 1). Phosphorus, MCV, ALP, uric acid, and serum-urea nitrogen were lower during hibernation periods, whereas cholesterol and cortisol concentrations were higher during hibernation. Only Hb was affected by a significant ($P = 0.008$) year by season interaction, being higher during good years during all active periods, but similar between good and poor years during hibernation.

Six blood characteristics varied significantly ($P < 0.05$) between good and poor years (Table 2). With the exception of serum-urea nitrogen, each characteristic was affected by year in both two-way analyses (year by food, year by season) and not affected by an interaction. Serum-urea nitrogen, MCV, and cortisol were higher in poor years, while RBC, thyroxine, and uric acid were higher in good years. Body mass tended to be greater ($P = 0.07$) in good years than in poor years.

Multivariate analyses of variance indicated differences ($P < 0.05$) between yearly group means for all seasons (Table 3). Two or three variables were selected each season by stepwise discriminant analysis and provided discrimination ($P \leq 0.15$) between good and poor years of mast and berry production. Most selected variables provided for separation for more than one season.

Classification accuracy for linear discriminant functions for 1970–1976 data ranged from 69 to 78% using the unbiased jacknife procedure (Table 4). Accuracy dropped slightly when smaller, independent test datasets (1970—good year; 1972—poor year) were used to assess accuracy, but did reach 80% during late summer. Late summer, autumn, and early hibernation were the seasons with the highest rates of correct classification in both analyses.

DISCUSSION

Seasonal variations in blood variables in the present study were consistent with previous reports. Serum lipids (cholesterol, triglycerides) varied on a seasonal basis (Table 1), with highest levels during autumn (before denning) and hibernation. Nelson et al. (1973), Ahlquist et al. (1984), Franzmann and Schwartz (1988), and Hellgren et al. (1989) reported similar observations, whereas Matula et al. (1980), Schroeder (1987), and Hellgren et al. (1990) found no seasonal variation in lipid constituents.

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FIG. 1.—Seasonal changes in mean values of Hb (top), RBC (middle), and HCT (bottom) in adult female black bears in northern Minnesota, 1970–1976, 48°N (solid lines). Data from black bears in Great Dismal Swamp (GDS), Virginia-North Carolina, 36°N (dotted lines) are provided for comparison (adapted from Hellgren et al., 1989). Numbers above horizontal axis represent number of bears sampled during each season in Minnesota. Horizontal hashmarks represent seasons, defined as ES (early summer), June; LS (late summer), 1 July–19 August; F (autumn), 20 August–30 September; EH (early hibernation), 1 October–31 December; LH (late hibernation), 1 January–18 April. Hatched bars represent years of poor mast and berry production.
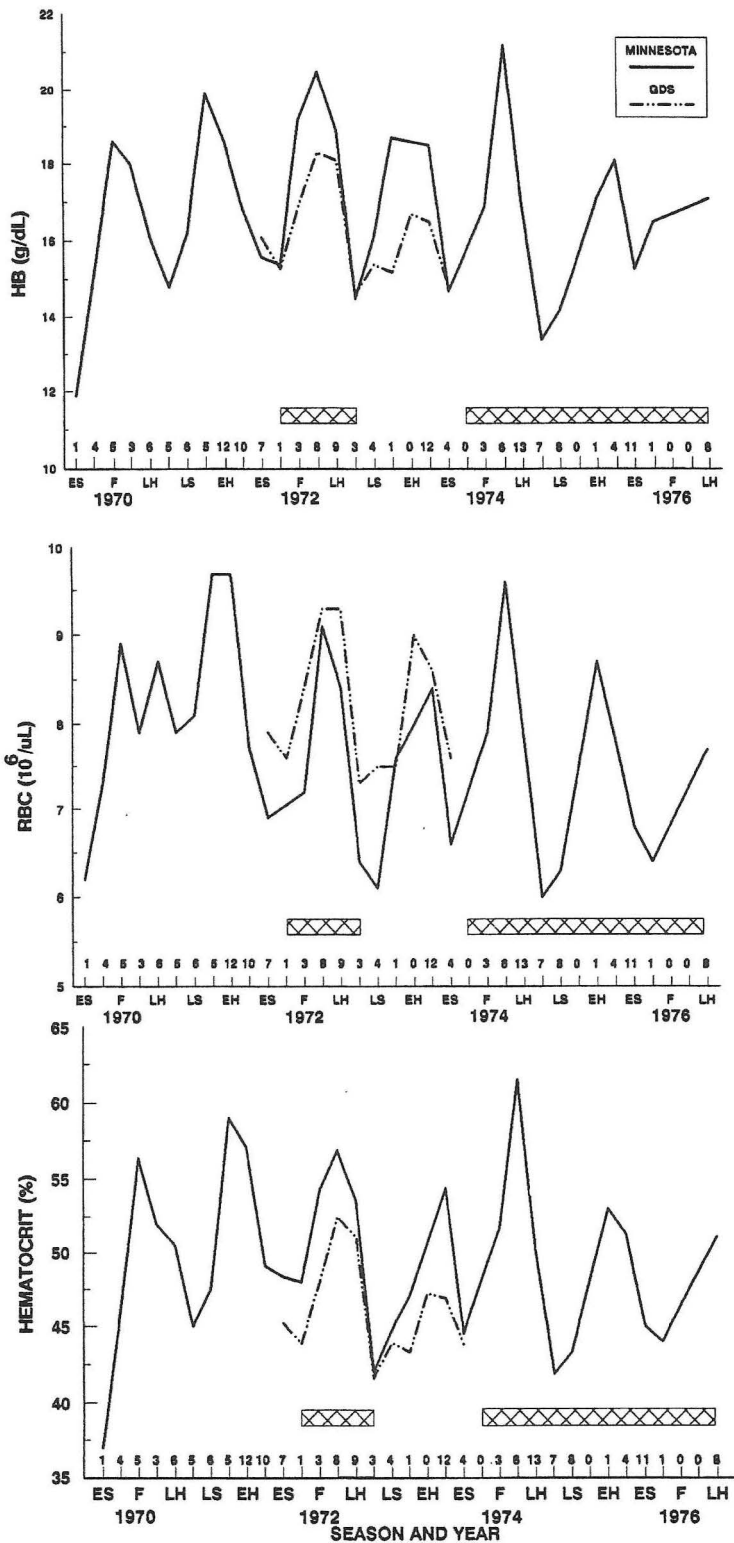
TABLE 2. — *Body mass and blood characteristics of adult female black bears in northern Minnesota, 1970–1976, differing between good and poor years of mast and berry production.*[a]

Character	Good years			Poor years		
	n	$\bar{X}$	SE	n	$\bar{X}$	SE
Body mass (kg)	89	68.4	1.7	93	62.1	1.6
RBC ($10^6/\mu$l)	85	8.2	0.2	85	7.6	0.1
MCV (μm^3)	84	63.3	0.8	86	66.3	0.6
Urea nitrogen (mg/dL)	89	12.6	0.7	89	14.2	0.8
Uric acid (mg/dL)[b]	74	1.6	0.1	24	1.0	0.1
Thyroxine (ng/ml)[b]	87	3.5	0.2	88	2.5	0.4
Cortisol (μg/dL)	78	6.7	0.2	74	7.6	0.1

[a] Years defined by Rogers (1987): 1970, 1971, and 1973 were good years; 1972 and 1974–1976 were poor years.
[b] Analysis performed on rank-transformed data.

Serum concentrations of cortisol were higher during late hibernation than during summer (Table 2). Similar observations have been made on captive (Palumbo et al., 1983) and wild bears (*Ursus americanus* — Harlow et al., 1990), despite greater handling stress in active bears. Stress initiates hormonal mechanisms that culminate in release of glucocorticoids. Harlow et al. (1990) proposed that cortisol concentrations were elevated in black bears during winter as a metabolic adaptation to enhance lipid mobilization during hibernation.

Hematologic characteristics varied annually in a regular waveform pattern (Fig. 1) for the 7-year duration of the study. These data extend the observations of Hellgren et al. (1989), who reported similar patterns over 26 months for black bears in Virginia and North Carolina (Fig. 1). It is interesting to note differences in the amplitude of the seasonal pattern in hematologic characteristics for latitudes ranging from 36 (Virginia-North Carolina) to 48 (northern Minnesota) to 60°N (Alaska — Franzmann and Schwartz, 1988). For example, seasonal levels of HCT varied from 41.4 to 48.0% ($P < 0.001$) in the most southerly population (Hellgren et al., 1989), 44.6 to 55.4% in Minnesota (this study), and from 44.1 to

TABLE 3. — *Results of multivariate analyses using blood characteristics to compare good and poor years*[a] *of mast and berry production. Data are for adult female black bears in northern Minnesota from 1970 to 1976.*

Season	Multivariate analysis of variance				Blood variables in analysis[b]
	d.f.	Wilks λ	F	P-value	
Early summer (June)	3,22	0.59	5.06	0.008	RBC, ALP,[c] Urea nitrogen
Late summer (1 July–19 August)	3,19	0.50	6.46	0.003	ALP,[c] Hb, HCT
Autumn (20 August–30 September)	2,14	0.56	5.54	0.017	RBC, Urea nitrogen
Early hibernation (1 October–31 December)	2,28	0.61	9.05	0.001	Hb, RBC
Late hibernation (1 January–18 April)	3,42	0.68	6.54	0.001	thyroxine,[c] ALP,[c] MCHC[c]

[a] Years defined by Rogers (1987): 1970, 1971, and 1973 were good years; 1972 and 1974–1976 were poor years.
[b] Variables selected by stepwise discriminant analysis. See text for explanation of abbreviations.
[c] Analyses performed on log-transformed data.

TABLE 4.—*Accuracy of linear discriminant functions developed from blood characteristics in classifying adult female black bears into good or poor years of mast and berry production (Rogers, 1987).*

	Accuracy						
	Good year		Poor year		Total		
Season	n	% Correct	n	% Correct	n	% Correct	Variables selected
Early summer							
Jackknife[a]	16	69	10	70	26	69	
Test data[b]	5	80	3	33	8	63	RBC, ALP,[c] Urea nitrogen
Late Summer							
Jackknife	14	79	9	78	23	78	
Test data	4	100	1	0	5	80	ALP,[c] Hb, HCT
Autumn							
Jackknife	11	73	6	83	17	78	
Test data	5	100	3	33	8	75	RBC, Urea nitrogen
Early hibernation							
Jackknife	16	75	15	80	31	77	
Test data	4	50	8	88	12	75	Hb, RBC
Late hibernation							
Jackknife	26	73	20	80	46	76	
Test data	6	100	7	42	13	69	T_4,[c] ALP,[c] MCHC[c]

[a] All data from 1970 to 1976, inclusive, used to develop discriminant function and classify observations with a jackknife procedure.

[b] Data from 1971 and 1973–1976 used to develop discriminant function. Data from years 1970 (good year) and 1972 (poor year) used to test classification accuracy of function.

[c] Analyses performed on rank-transformed data.

57.4% ($P < 0.05$) in Alaska (Franzmann and Schwartz, 1988). Changes in RBC and Hb show similar latitudinal trends.

Mechanisms responsible for the rhythm in hematologic values are complex and may include annual changes in erythropoietic function, food intake, and compartmentalization of body water. Increases in hematologic values from summer to autumn and early hibernation are associated with increased food intake, improved nutritional condition and perhaps changes in erythropoiesis preparatory to hibernation. Decreases in HCT, Hb, and RBC values in spring and summer may reflect decreases in body mass and nutritional condition that black bears undergo during the spring period of negative foraging (Poelker and Hartwell, 1973), during which time black bears cannot maintain body mass by feeding on succulent emerging vegetation. Cameron and Luick (1972) found that decreases in body condition of reindeer (*Rangifer taran-*

dus; i.e., fat reserves and lean body mass) were accompanied by decreases in total blood, red cell, and plasma volumes. Decreases in hematologic values also may be influenced by changes in plasma volume. In white-tailed deer (*Odocoileus virginianus*), plasma volume increases in summer, at least partially because of the role of plasma water in dissipating body heat through increased vascularization of the skin (Jacobsen, 1978). The consistent timing of hematologic changes in black bears, independent of observed variation in major food supplies (also seen in wild canids—Seal and Mech, 1983), and the latitudinal variation of this pattern suggest an endogenous metabolic rhythm in hematologic function. Research under controlled-experimental conditions is necessary to elucidate the relationships among photoperiod, fat deposition and mobilization, dynamics of body water, and hematologic values in black bears.

The multivariate analysis in the present

study was designed to develop discriminant functions that used blood profiles to classify samples from a population of black bears into categories tied to subjective determinations of available food supply (e.g., good and poor years of mast and berry production). Jackknifing and withholding data during model construction to use as an independent data set are recommended procedures for validation of the discriminant function model (Rexstad et al., 1990; Taylor, 1990). Hawley (1987) classified bison (*Bison bison*) and cattle into diet-ration groups based on blood composition and argued for the use of discriminant function analysis to distinguish between broad nutritional groups. Previous discriminant analysis with blood data of bears has provided functions that only classify bears by season (Franzmann and Schwartz, 1988; Hellgren et al., 1989). We examined nutritional indicators (e.g., Hb, HCT) for black bears to determine whether they could be used to distinguish years of varying food abundance within individual seasons.

Blood characteristics selected as important discriminating variables (Tables 3 and 4) were variables previously reported to be useful as nutritional indices, namely RBC, Hb, HCT, and ALP (Franzmann and Schwartz, 1988; Hellgren et al., 1989; Schroeder, 1987). Although hematologic values varied on a circannual basis, the amplitude of that rhythm appeared to be affected by variation in food supply (Fig. 1), particularly for RBC, which was significantly higher in good years (Table 2), and Hb, which was higher in good years during active periods (significant year by season interaction, $P = 0.008$). Perhaps a flush of nutritious foods in late summer and autumn amplified obligatory seasonal changes in erythropoietic function (Fig. 1). Although red blood cells in large mammals have a life expectancy of 90–120 days (Swenson, 1984), a change in erythropoietic function resulting from changes in nutritional plane could have rapid effects on hematologic values because the RBC population represents a continuum

of ages from 1 to 120 days and a significant proportion of the population is turning over daily. Changes in total-body water and water compartmentalization associated with alterations in stored body fat (Cameron and Luick, 1972) also may contribute to changes in red-cell volume. RBC, Hb, and HCT have been directly related to nutritional plane in captive collared peccaries (*Tayassu tajacu*) (Lochmiller et al., 1985, 1986, 1988), but the relationship in white-tailed deer (*O. virginianus*) is inconsistent (Warren et al., 1982) and confounded by hemoconcentration during nutritional deprivation (DelGiudice et al., 1991).

Our data suggest that blood characteristics are both discriminators of habitat quality and indicators of seasonal metabolic rhythms. It is likely that black bears evolved endogenous circannual cycles in metabolism in response to predictable seasonal changes in food supplies (Johnson and Pelton, 1980; Seal and Mech, 1983). Further, annual variation in food supply can adjust the amplitude of the cyclic pattern, especially for specific hematologic characteristics. Thus, certain blood constituents may serve as indicators of habitat quality within a given area and season.

In other species, ALP has been reported to vary with energy and gross nutritional plane (Hawley, 1987; Lochmiller et al., 1986, 1988), but the mechanisms are not clearly understood. In our study, ALP was higher in summer and hibernating periods of poor years of mast and berry production.

Serum concentrations of urea nitrogen have a strong positive relationship with dietary protein intake under conditions of normal kidney function and adequate energy intake in monogastrics (Atinmo et al., 1974; Corn and Warren, 1985; Lochmiller, 1984). During autumn, urea-nitrogen concentrations were lower in good years than in poor years (Table 4). This difference may have resulted from two factors: consumption of a higher energy, lower protein diet in good years relative to poor years, as observed by Elowe and Dodge (1989); or in-

adequate energy intake in poor years causing tissue-protein catabolism and increases in urea-nitrogen concentrations.

Serum concentrations of T_4 were higher in good years than poor years; T_4 was selected as a discriminating variable during late hibernation. Concentrations of thyroid hormone are good indicators of metabolic rate, as the thyroid gland regulates metabolic activity (McGilvery, 1983), and have been positively related to energy intake (Lochmiller et al., 1985, 1986, 1988; Seal et al., 1972b). Our T_4 data suggest that bears were on a higher energy plane in good years. Although we failed to demonstrate seasonal differences in concentrations of serum T_4, Azizi et al. (1979) showed that thyroid function was lower during hibernation than during active periods. They also documented that T_4 concentrations decreased throughout the hibernating period, concomitant with decreasing energy stores. It is unclear why T_4 was selected as a discriminating variable in late hibernation. Perhaps bears hibernating following years of good mast production have higher T_4 concentrations than after poor years because of larger fat reserves.

We recommend the use of hematologic and serum-biochemical data from late summer, autumn, or early hibernation as one tool in the assessment of condition and habitat quality in bear populations. Late summer and autumn seasons are especially critical, as black bears become hyperphagic to maximize energy storage prior to hibernation and lactation. In addition, classfication rates for discriminant functions developed during these seasons were ≥75% (Table 4). Classifications resulting from discriminant analysis of human blood data used for clinical evaluation generally are in this range (Sher, 1977; Werner et al., 1982). This level of accuracy may be acceptable for management purposes (Franzmann and Schwartz, 1988), e.g., if ≥75% of bears sampled in a given year are classified as in good condition, then these data should be considered as one line of evidence for a good year of food production. Independent measurements of food abundance also are recommended.

It is appropriate to note that the ability to discriminate between good and poor years of food production does not necessarily mean that bears during poor years were only in poor condition, as blood values were within the normal range for both sets of years. The data do document a physiological difference in the population of bears between good and poor years. We recommend use of other physiological data to empirically validate the functions developed in our study (Appendix I). Further tests are needed to determine the utility of these functions beyond the Great Lakes Region.

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APPENDIX I—*Coefficients of functions used to classify seasonal blood samples of adult (≥4 years) female black bears in northern Minnesota into good or poor year classes of mast and berry production (Rogers, 1987). Data inclusive from 1970 to 1976 used to develop discriminant function (without jackknife procedure).*

Season	Variable	Year class	
		Good	Year
Early summer	RBC	7.60	6.39
(June)	ALP[a]	9.16	11.78
	Urea nitrogen	0.21	0.08
	Constant	−40.27	−37.09
Late summer	ALP[a]	4.54	6.97
(1 July–19 August)	Hb	6.21	3.92
	HCT	0.13	0.62
	Constant	−58.31	−53.53
Autumn	RBC	6.37	5.15
(20 August–30 September)	Urea nitrogen	0.13	0.29
	Constant	−29.80	−21.87
Early hibernation	Hb	6.91	8.08
(1 October–31 December)	RBC	−0.26	−1.05
	Constant	−62.53	−78.04
Late hibernation	T_4[a]	29.70	28.10
(1 January–18 April)	ALP[a]	88.40	90.60
	MCHC[a]	1,905.00	1,919.00
	Constant	−3,430.00	−3,482.00

[a] Analyses performed on log-transformed data.