Physical Characteristics, Hematology, and Serum Chemistry of Free-ranging Gray Wolves, *Canis lupus,* in Southcentral Alaska

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Examination of morphometric characteristics and blood parameters has become a widely used tool for assessing the physiological and nutritional status of wild and captive animals. During 1976 through 1984, 155 Gray Wolves (*Canis lupus*) were chemically immobilized in south-central Alaska. Of those, we obtained physical measurements from 132 and blood samples from 121 individuals. Also, 208 carcasses of harvested and dead radiocollared Wolves were weighed and measured. We obtained blood samples from three of the fresh carcasses. We measured age, body weight, skull length and width, and upper and lower canine length. We analyzed blood serum for Ca, P, Fe, chlorides, creatinine, glucose, lactic dehydrogenase, alkaline phosphatase, glutamic oxalic transaminase, triglyceride, beta globulin, serum urea nitrogen, and uric acid. We obtained packed cell volume and hemoglobin values from whole blood. We classified samples by season, sex, and age. Seasonal differences were observed for physical measurements, packed cell volume, alkaline phosphatase, and serum urea nitrogen. Age differences were observed for physical measurements, hemoglobin, packed cell volume, alkaline phosphatase, P, Ca, creatinine, serum urea nitrogen, and percent femur bone marrow fat. However, differences among sexes were observed for physical measurements only. These data provide a baseline for physical condition, hematology, and serum chemistry for free-ranging Gray Wolves.

Key Words*:* Gray Wolf, *Canis lupus*, blood, chemistry, hematology, measurements, physical, serum, Alaska.

Examination of morphometric characteristics and blood parameters has become a widely used tool for assessing the physiological and nutritional status of wild and captive animals (e.g., LeResche et al. 1974; Seal and Mech 1983; DelGiudice et al. 1987; Franzmann and Schwartz 1988). Although baseline hematology and serum chemistry values for many species of captive animals exist, baseline values for free-ranging animals are also necessary to properly interpret data. It is also important to understand how factors such as age, sex, and season influence hematology and serum chemistry values.

Hematology and serum chemistry of captive Gray Wolves (*Canis lupus*) has been studied and described by Fox and Andrews (1973) and Constable (1998) in Alaska, Seal and Mech (1983) and DelGiudice et al. (1987) in Minnesota, Pospíšil et al. (1987) in the Czech Republic, and Drag (1995) in Missouri. Seal et al. (1975) and DelGiudice et al. (1991) in Minnesota, Messier (1987) in Quebec, and Constable et al. (1998) in Alaska studied and described hematology and serum chemistry of free-ranging Gray Wolves. Mech et al. (1984) reported changes in hematology and serum chemistry of a female Gray Wolf recuperating from near starvation in Minnesota. However, little baseline data exist for age, sex, and season for free-ranging Gray Wolf populations. The purpose of our study was to describe physical characteristics and report baseline hematology and serum chemistry values for age, sex, and season in free-ranging Gray Wolves of south-central Alaska.

Study Area

The study was conducted in an area of approximately 45 000 km^2, known as Alaska Game Management Unit 13, located approximately 125 km northeast of Anchorage, Alaska. The area was bisected by three major river systems including the Copper, Nelchina, and Susitna rivers. Primary prey species were Moose (*Alces alces*) and Barren-ground Caribou (*Rangifer tarandus granti*). Alternate prey species included Dall Sheep (*Ovis dalli*), Beaver (*Castor canadensis*), and Snowshoe Hare (*Lepus americanus*). Climate, topography, and other important aspects of the study area were described by Ballard et al. (1987, 1991b). Gray Wolf densities during this study ranged from 10.3/1000 km^2 in autumn 1975 to 2.6/1000 km^2 in spring 1982 (Ballard et al. 1987). Mean annual litter size in November ranged from 3.7 to 7.3 pups. The Wolf population was heavily exploited by humans (i.e., >40% of population) during the course of this study (Ballard et al. 1987).

The reference values we present here occurred during a period when both Moose and Caribou populations were increasing. Moose densities were highly variable in the study area and averaged about 603 to 741/1000 km^2 (Ballard et al. 1991b) and the population increased at a finite rate of increase of 1.03 to 1.06 annually (Ballard et al. 1986). Caribou populations during this time period increased from approximately 10 000 in 1976 to about 25 000 in 1984 (Bergerud and Ballard 1988). Winter conditions as reflected by snow depths were relatively moderate during this

time period except during 1978-1979 which was classified as severe (Ballard et al. 1991b).

Methods

We captured Gray Wolves for radiocollaring by darting them from a helicopter during 1976 through 1984 using methods described by Ballard et al. (1982, 1991a). We immobilized Wolves with phencyclidine hydrochloride, etorphine hydrochloride, or a combination of zolzepam hydrochloride and tiletamine hydrochloride following dosages and methods described by Ballard et al. (1982, 1991a). Induction times averaged 7.2 minutes (Ballard et al. 1991a). After immobilization each Wolf was radiocollared, weighed, sexed, eartagged, bled, and a number of physical measurements were recorded on standardized forms. Physical measurements included skull length (SL) and width (SW), and upper (UCL) and lower canine length (LCL). We measured canine length from the edge of the gum line to the tip of the tooth. Skull and tooth measurements were taken with calipers and recorded to the nearest mm.

Hunters and trappers were paid $10 (U.S.) per skinned Wolf carcass. Carcasses were weighed (CW) and then kept frozen until examined. Skulls were not boiled and cleaned before measuring to maintain similarity with live Wolf measurements. Also, the effects of freezing carcasses on physical measurements were likely minimal. We determined percent femur bone marrow fat (MF) by the dry weight method (Neiland 1970). Because this Wolf population was heavily exploited (Ballard et al. 1987) we were able to do comparisons with many individuals that had been radiocollared and harvested within the same year.

We collected blood samples from saphenous veins using the B-D Vacutainer system (Becton-Dickenson Co., Rutherford, New Jersey, USA). Generally blood was taken within 15 minutes of induction time and serum was separated each evening. Only three blood samples were collected from carcasses. Those samples were obtained within 15 minutes of harvest. We used one EDTA tube to preserve whole blood. Packed cell volume (PCV) was determined with uncoagulated whole blood using a microhematocrit centrifuge (Triac, Clay-Adams Co., Parisppany, New Jersey, USA) while hemoglobin (Hb) was estimated with an AO Hb-Meter (American Optical, Buffalo, New York, USA). Clotted blood was centrifuged within 36 h of collection and serum was then stored frozen at -17°C. We sent frozen serum to Pathologist Central Laboratory, Seattle, Washington, USA, where it was analyzed for the following via an auto-analyzer: calcium (Ca), phosphorous (P), iron (Fe), chlorides (CHL), creatinine (CRE), glucose (GLU), lactic dehydrogenase (LDH), alkaline phosphatase (SAP), glutamic oxalic transaminase (SGOT), triglyceride (TRI), serum urea nitrogen (SUN), and uric acid (UA). Protein fractions were determined by standard protein electrophoresis for beta globulin (BEG).

Because of unbalanced cells in our analyses, we pooled years, sorted blood and physical measurements by sex, age, and season, and conducted multiple analyses of variance. We conducted post-hoc comparisons with a Scheffe test (Sokal and Rohlf 1995). We determined correlations among variables by Spearman's rank correlation (Conover 1980). We classified ages as pup ($\leq$12 months), yearling (13 to 23 months), and adult ($\geq$24 months), while seasons were divided into autumn (September through November), winter (December through February), spring (March through May), and summer (June through August). Differences were considered significant when $P < 0.05$ unless otherwise specified.

Results

We immobilized 155 individual Gray Wolves during 1976 through 1984. From that total, we obtained 121 blood samples ($n = 121$ serum samples, $n = 117$ whole blood samples) and 132 live body weights (BW). Due to low sample sizes, we excluded yearling and summer data from the analyses. In addition, we weighed and measured a total of 208 carcasses. We obtained three blood samples from fresh carcasses ($n = 3$ serum samples, $n = 2$ whole blood samples).

Physical Characteristics

Mean BW differed by season ($F = 26.121$, 2 df, $P < 0.001$), sex ($F = 37.084$, 1 df, $P < 0.001$), and age ($F = 147.890$, 1 df, $P < 0.001$), and there were significant interactions between season and age ($F = 15.665$, 2 df, $P < 0.001$), and among season, sex, and age ($F = 3.231$, 2 df, $P = 0.043$). Lowest BW occurred for pups during autumn, while highest BW occurred for adult males during autumn and winter (Table 1). Adult males had higher BW than male pups during autumn and winter; adult females had higher BW than female pups during autumn and spring (Table 1). Body weights were not different between adult males and adult females among seasons (Table 1). Body weights between male and female pups was only significantly different during spring (i.e., males were heavier; Table 1). Body weights of male pups increased with seasons (i.e., over the course of the biological year); both winter and spring BW were higher than autumn weights, although winter and spring were not different (Table 1). In addition, BW of female pups increased with season though female pups were significantly heavier in the spring than during autumn (Table 1).

Mean CW exhibited similar trends by sex, age, and season as BW although sample sizes were too small to evaluate post-hoc differences (Table 1). Season ($F = 4.849$, 2 df, $P = 0.009$), sex ($F = 6.665$, 1 df, $P = 0.011$), and age ($F = 24.849$, 1 df, $P < 0.001$) each had a significant effect on CW and there were significant interactions between sex and age ($F = 3.950$, 2 df, $P = 0.046$), and among season, sex, and age

TABLE 1. Mean physical measurements ± 1 standard error by season, sex, and age for free-ranging Gray Wolves in south-central Alaska during 1976 through 1984. Sample size denoted in parentheses.

Physical measurements	Age	Sex	Season		
			Autumn	Winter	Spring
Live-body weight (kg)	Pup	Male	26.2 ± 2.3 (8)	37.9 ± 1.4 (10)	41.3 ± 1.4 (16)
		Female	23.5 ± 2.0 (7)	33.3 ± 2.5 (5)	33.3 ± 0.9 (20)
	Adult	Male	46.8 ± 1.5 (8)	48.1 ± 1.3 (11)	46.2 ± 0.9 (17)
		Female	38.9 ± 1.4 (13)	41.1 ± 1.2 (3)	42.4 ± 1.0 (14)
Carcass weight (kg)	Pup	Male	19.7 ± 2.7 (3)	30.7 ± 0.9 (51)	29.9 ± 2.5 (8)
		Female	25.0 ± 2.4 (3)	27.3 ± 0.6 (51)	25.3 ± 1.0 (7)
	Adult	Male	39.1 (1)	39.8 ± 0.9 (36)	33.5 ± 1.8 (8)
		Female	24.8 ±13.8 (2)	32.8 ± 0.7 (32)	33.8 ± 1.1 (6)
Skull length (cm)	Pup	Male	24.5 ± 0.8 (3)	26.2 ± 0.2 (58)	27.1 ± 0.3 (18)
		Female	24.5 ± 0.7 (5)	25.1 ± 0.2 (52)	25.5 ± 0.3 (14)
	Adult	Male	27.7 ± 0.3 (3)	27.8 ± 0.2 (39)	27.0 ± 0.4 (12)
		Female	24.8 ± 1.0 (3)	26.5 ± 0.2 (31)	26.4 ± 0.4 (12)
Skull width (cm)	Pup	Male	12.3 ± 0.5 (3)	13.5 ± 0.1 (58)	14.4 ± 0.2 (18)
		Female	12.4 ± 0.4 (5)	13.1 ± 0.2 (52)	14.0 ± 0.7 (14)
	Adult	Male	16.0 ± 0.6 (3)	14.8 ± 0.1 (35)	14.9 ± 0.3 (12)
		Female	13.4 ± 0.5 (6)	14.5 ± 0.3 (30)	14.3 ± 0.1 (11)
Upper canine length (cm)	Pup	Male	2.1 ± 0.2 (2)	2.5 ± 0.1 (38)	2.6 ± 0.1 (11)
		Female	1.9 ± 0.1 (5)	2.3 ± 0.1 (45)	2.3 ± 0.1 (10)
	Adult	Male	2.8 ± 0.04 (6)	2.9 ± 0.1 (32)	3.0 ± 0.1 (7)
		Female	2.3 ± 0.3 (3)	2.5 ± 0.1 (25)	2.5 ± 0.04 (6)

($F = 4.105$, 1 df, $P = 0.018$). Lowest CW occurred for pups during autumn, while highest weights were for adult males during autumn and winter (Table 1).

There were significant differences in average SL by season ($F = 5.008$, 2 df , $P = 0.007$), sex ($F = 23.574$, 1 df , $P < 0.001$), and age ($F = 22.331$, 1 df , $P < 0.001$), and there were significant interactions between season and age ($F = 3.769$, 2 df , $P = 0.024$) and among season, sex, and age ($F = 3.874$, 2 df , $P = 0.022$). Lowest mean SL was for pups during autumn and highest mean SL was for adult males during autumn and winter (Table 1). Males had higher mean SL than females during each season (Table 1). Mean pup SL increased from autumn through spring (Table 1).

Mean SW differed by season ($F = 3.831$, 2 df , $P = 0.023$), sex ($F = 7.692$, 1 df , $P = 0.006$), and age ($F = 32.160$, 1 df , $P < 0.001$), and there was a significant interaction between season and age ($F = 4.582$, 2 df , $P = 0.011$). Mean male SW was greater than female SW for all seasons and ages (Table 1). There were no differences in average adult SW among seasons (Table 1). Also, mean pup SW increased by season during the first year of life (Table 1).

Mean UCL differed by season ($F = 5.257$, 2 df , $P = 0.006$), sex ($F = 19.804$, 1 df , $P < 0.001$), and age ($F = 26.872$, 1 df , $P < 0.001$), and there were no significant interactions. Mean UCL was lower during autumn than during either winter or spring (Table 1). Mean male UCL was greater than that of females (Table 1). Mean UCL for adults was greater than that for pups (Table 1). There was no significant difference in mean LCL by season ($F = 0.002$, 1 df , $P = 0.964$), sex ($F = 1.707$, 1 df , $P = 0.218$), or age ($F = 0.828$, 1 df , $P = 0.382$), and there were no significant interactions. Mean LCL was 2.3 ± 0.07 cm ($n = 18$). Body weight was also correlated with the other physical characteristics, MF, and PCV (Table 2).

Hematology

Mean Hb concentration differed by age ($F = 7.671$, 1 df , $P = 0.007$) and there was a significant interaction between age and season ($F = 3.876$, 2 df , $P = 0.024$); differences were between pups and adults during winter and autumn (Table 3). Mean pup Hb concentrations increased throughout the year, whereas adult Hb concentrations remained relatively constant during the year (Table 3).

Average PCV differed by season ($F = 6.015$, 2 df, $P = 0.003$) and age ($F = 29.083$, 1 df, $P < 0.001$), and there was a significant interaction between season and age ($F = 10.375$, 1 df, $P < 0.001$). Adults during autumn had higher mean PCV than all other groups by season and age (Table 3). Mean PCV did not differ between adults and pups in winter and spring (Table 3). Packed cell volume was also correlated with Hb and BW (Table 2).

Serum Chemistry

Mean SAP concentration differed by season ($F = 6.557$, 2 df, $P = 0.002$) and age ($F = 19.621$, 1 df, $P < 0.001$), and there was a significant interaction between age and season ($F = 5.189$, 2 df, $P = 0.007$). Mean SAP concentration appeared greater in pups than adults during autumn, winter, and spring (Table 3). However, only during autumn were SAP concentrations significantly different between pups and adults (Table 3). Among pups, autumn and winter SAP concentrations were higher than spring, but only the autumn–spring comparison was significant. Among adults, seasonal

TABLE 2. Correlations among physical characteristics, hematology, and serum chemistry values for free-ranging Gray Wolves in south-central Alaska during 1976 through 1984.

	Characteristics	r_s	*n*	*P*
Body weight	Carcass weight	0.954	23	<0.001
	Skull length	0.665	67	<0.001
	Skull width	0.639	62	<0.001
	Upper canine length	0.583	47	<0.001
	Marrow fat	0.725	14	0.003
	Packed cell volume	0.271	97	0.007
	Hemoglobin	0.362	82	0.001
Marrow fat	Carcass weight	0.365	108	<0.001
	Skull length	0.281	108	0.003
	Skull width	0.494	108	<0.001
	Upper canine length	0.316	79	0.005
Serum alkaline phosphatase	Age	–0.516	91	<0.001
	Phosphorous	0.600	140	<0.001
	Calcium	0.511	142	<0.001
Beta globulin	Lactic dehydrogenase	0.500	91	<0.001
Packed cell volume	Hemoglobin	0.527	102	<0.001

TABLE 3. Mean blood characteristics ± 1 standard error by season and age for free-ranging Gray Wolves in south-central Alaska during 1976 through 1984. Sample size denoted in parentheses.

Blood characteristics	Age	Season: Autumn	Winter	Spring
Alkaline phosphatase (IU/L)	Pup	177.8 ± 33.1 (10)	141.9 ± 32.0 (15)	65.0 ± 6.9 (29)
	Adult	49.3 ± 6.1 (21)	90.0 ± 38.8 (12)	49.8 ± 6.7 (37)
Urea nitrogen (mg/dL)	Pup	26.2 ± 2.5 (10)	25.4 ± 6.0 (15)	46.1 ± 4.1 (29)
	Adult	45.4 ± 4.2 (21)	37.6 ± 7.4 (12)	52.9 ± 3.4 (37)
Hemoglobin (g/dL)	Pup	17.9 ± 0.4 (8)	18.0 ± 0.8 (10)	19.1 ± 0.2 (26)
	Adult	19.9 ± 0.07 (21)	18.9 ± 0.6 (11)	19.0 ± 0.3 (29)
Packed cell volume (%)	Pup	47.8 ± 2.2 (7)	44.2 ± 1.2 (12)	49.0 ± 1.1 (32)
	Adult	63.6 ± 2.0 (23)	55.1 ± 1.8 (11)	49.7 ± 1.3 (34)

SAP concentrations were not significantly different (Table 3). Serum alkaline phosphatase was also correlated to age, P, and Ca (Table 2).

Mean SUN concentration differed by season ($F = 6.746$, 2 df, $P = 0.002$) and age ($F = 10.382$, 1 df, $P = 0.002$), and there were no significant interactions. Mean SUN concentration was higher during spring than in winter; autumn SUN concentration was not different from spring or winter (Table 3). Mean adult SUN concentration was higher than that of pups, regardless of season or sex (Table 3).

Mean P ($F = 6.595$, 1 df, $P = 0.012$), Ca ($F = 6.036$, 1 df, $P = 0.016$), and CRE ($F = 4.189$, 1 df, $P = 0.043$) concentrations differed by age with no significant interactions. Pup P concentrations were higher than adults, regardless of season or sex, as were Ca concentrations (Table 4). Mean adult CRE concentration was higher than that of pups, regardless of season or sex (Table 4). There were no significant differences in mean values of BEG, CHL, GLU, Fe, LDH, SGOT, TRI, or UA by season, sex, or age, and there were no significant interactions (Table 5). Measures of BEG were also correlated with LDH concentrations (Table 2).

Bone Marrow Fat

Mean MF differed by age ($F = 5.062$, 1 df, $P = 0.027$). Mean pup MF was less than adult MF (Table 4). There were no differences in mean MF by season ($F = 0.351$, 1 df, $P = 0.555$) or sex ($F = 0.000$, 1 df, $P = 0.989$) and there were no significant interactions. Percent bone marrow fat was also correlated to BW, CW, SL, SW, and UCL (Table 2).

Discussion

Average BW of free-ranging Gray Wolves in south-central Alaska was greater than captive Gray Wolves in Minnesota (VanBallenberghe and Mech 1975; Seal and Mech 1983; Mech 2006) probably reflecting subspecies differences (Mech 1970). The relationship between CW and BW may allow managers to gain reliable biological data from harvested individuals. Also, the relationship between BW and MF may allow biologists to infer condition based upon BW.

Pup and adult Hb concentrations were in the upper range of values reported for free-ranging (Seal et al. 1975; Messier 1987; DelGiudice et al. 1991) and captive (Seal and Mech 1983; DelGiudice et al. 1987;

Pospíšil et al. 1987) Gray Wolves. In addition, we observed a correlation between Hb and BW and it has been suggested Hb concentration is a good indicator of physical condition (Franzmann and LeResche 1978; Messier 1987; Franzmann and Schwartz 1988). However, Harlow and Seal (1981) observed little change in Hb concentrations in food-deprived captive Badgers (*Taxidea taxus*). Perhaps, lower Hb concentrations in pups are indicative of a dietary difference due to social status. Seal and Mech (1983) observed low Hb concentrations during July and August in captive Gray Wolves. They also noted reduced BW during this period. Also, lower Hb concentrations in winter than in spring were reported by Thomas and Kittrell (1966) for German shepherds. Changes in Hb concentrations by season have also been observed in female Black Bears (*Ursus americanus*) (Franzmann and Schwartz 1988) and female White-tailed Deer (*Odocoileus virginianus*) (DelGiudice et al. 1992). However, our Hb data were unaffected by season and we observed comparable Hb concentrations in summer (18.6 ± 1.4 g/dL, $n = 5$). Franzmann and LeResche (1978) did not observe a seasonal effect on Hb concentrations in Moose. Perhaps, the reduced BW and Hb concentrations observed by Seal and Mech (1983) during summer can be attributed to a physiological response to greater summer heat in Minnesota. However, the elevation of Alaska Game Management Unit 13 lies above 1,220 m and the research conducted by Thomas and Kittrell (1966) suggested increased elevation resulted in increased Hb concentrations in German shepherds. Thus, perhaps, high Hb concentrations in south-central Alaskan Gray Wolves may have been due to higher elevation.

Thomas and Kittrell (1966) also observed increased elevation resulted in increased PCV levels in German shepherds. Perhaps, this explains why mean PCV in south-central Alaskan Wolves was greater than values reported by DelGiudice et al. (1991) in free-ranging Minnesota Wolves. Similar PCV values have been observed in free-ranging (Smith and Rongstad 1980) and captive (Gates and Goering 1976; Rich and Gates 1979) Coyotes (*Canis latrans*).

Franzmann and LeResche (1978) and Franzmann and Schwartz (1988) suggested PCV was a good indicator of physical condition. We also observed a seasonal effect on PCV. Autumn PCV (59.9 ± 2.0%, $n = 30$) was greater than spring (49.4 ± 0.8%, $n = 66$) and winter (49.4 ± 1.6%, $n = 23$). This suggests Wolves in Alaska Game Management Unit 13 were in their best physical condition in autumn. However, different seasonal patterns were observed by Thomas and Kittrell (1966) in German shepherds: lower PCV in winter than spring. Seasonal changes in PCV have also been observed in female Black Bears (Franzmann and Schwartz 1988), female White-tailed Deer (Bahnak et al. 1979; DelGiudice et al. 1992), and Moose (Franzmann and LeResche 1978). Female White-tailed Deer in Minnesota exhibited two peaks (February-March and October-November) in BW and PCV (DelGiudice et al. 1992). However, PCV levels in Michigan female White-tailed Deer reached their lowest levels in July through September when those animals reached slightly lower weights (Buhnak et al. 1979). Female Black Bear exhibited a decline in PCV during summer and, though not significant, an increase during autumn (Franzmann and Schwartz 1988). Franzmann and LeResche (1978) observed greater PCV during June through October in Moose.

TABLE 4. Mean characteristics ± 1 standard error by age for free-ranging Gray Wolves in south-central Alaska during 1976 through 1984. Sample size denoted in parentheses.

Characteristics	Age	Mean ± standard error (*n*)
Phosphorous (mg/dL)	Pup	5.8 ± 0.3 (54)
	Adult	4.4 ± 0.4 (69)
Calcium (mg/dL)	Pup	9.6 ± 0.3 (54)
	Adult	8.9 ± 0.3 (70)
Creatinine (mg/dL)	Pup	0.9 ± 0.04 (54)
	Adult	1.1 ± 0.1 (70)
Marrow fat (%)	Pup	79.6 ± 16.9 (64)
	Adult	87.0 ± 9.2 (44)

TABLE 5. Mean serum chemistry values ± 1 standard error for free-ranging Gray Wolves (season, sex, and age combined) in south-central Alaska during 1976 through 1984. Sample size denoted in parentheses.

Serum chemistry values	Mean ± standard error (*n*)
Iron (umol/L)	47.4 ± 4.5 (71)
Chlorides (mmol/L)	161.1 ± 4.0 (124)
Glucose (mg/dL)	118.7 ± 7.4 (122)
Lactic dehydrogenase (IU/L)	306.7 ± 22.7 (123)
Glutamic oxalic transaminase (IU/L)	226.5 ± 23.8 (120)
Triglyceride (mg/dL)	51.8 ± 5.8 (124)
Beta gobulin (g/dL)	1.0 ± 0.06 (93)
Uric acid (mg/dL)	1.3 ± 0.09(114)

Our SUN data was greater than or in the upper range of values reported for free-ranging Wolves (Seal et al. 1975; Messier 1987), captive Wolves (Seal and Mech 1983; Drag 1995), captive Coyotes (Rich and Gates 1979; Dunbar and Giordano 2002), and free-ranging Coyotes (Smith and Rongstad 1980). However, other studies have reported concentrations similar to this study. DelGiudice et al. (1987) reported average SUN concentrations of well-fed captive Gray Wolves between 37.5 and 44.4 mg/dL. However, during fasting those concentrations were reduced to a range of 12.0 to 19.8 mg/dL. Another study conducted on free-ranging Wolves ($n = 11$) in the Yukon-Charley Rivers National Preserve, Alaska (Constable et al. 1998), reported SUN concentrations (46.2 mg/dL) similar to our observations.

Higher dietary intake of protein is indicated by higher SUN concentrations as described for Dogs (Lane

and Robinson 1970; Bressani and Braham 1977), White-tailed Deer (Seal et al. 1972; Bahnak et al. 1979), and Pronghorn (*Antilocapra americana*) (Seal and Hoskinson 1978). We observed lower SUN concentrations in pups, suggesting a dietary difference, perhaps, due to social status. We also observed seasonal differences in SUN concentrations. Urea nitrogen was greatest during spring, intermediate in autumn, and lowest in winter, suggesting greatest intake of protein during spring. This may be indicative of increased Moose vulnerability due to reduced Moose group size and increased number of calves (Ballard et al. 1991b). Though sample size was low ($n = 5$), SUN concentration during summer was relatively high (41.8 + 6.1 mg/dL) which was comparable to well-fed captive Wolves (DelGiudice et al. 1987). Seasonal variation has also been observed in Black Bears (Franzmann and Schwartz 1988), female White-tailed Deer (Bahnak et al. 1979; DelGiudice et al. 1992), Santa Cruz Island Spotted Skunks (*Spilogale gracilis amphiala*) (Crooks et al. 2003), Santa Cruz Island Foxes (*Urocyon littoralis*) (Crooks et al. 2000), and Son Joaquin Kit Foxes (*Vulpes macrotis mutica*) (McCue and O'Farrell 1992). For each of these species, peak SUN concentrations appeared to coincide with the most productive seasons.

Phosphorus concentrations were similar to those reported for free-ranging (Seal et al. 1975; Messier 1987; Constable et al. 1998) and captive (Drag 1995; Constable et al. 1998) Wolves. Our analyses suggested pup P concentrations were higher than adults. Messier (1987) observed lower P concentrations in adults as well. Calcium concentrations were similar to reported values (DelGiudice et al. 1987 in addition to those cited above). However, no other Wolf study reported pup Ca values but we observed pup Ca concentrations were higher than adults. We also observed higher SAP concentrations in pups than adults. This has been observed in Gray Wolves (Messier 1987), Coyotes (Smith and Rongstad 1980), and Dogs (Pickrell et al. 1974). High SAP concentration is indicative of bone formation and osteoblast differentiation (Searcy 1969). Serum alkaline phosphatase was also correlated to age, P, and Ca. Interestingly, of adult SAP values, 11.4% (all male and sampled in different seasons) were above the lower 95% confidence interval for pup SAP values. High SAP concentration has been associated with mammary tumors in dogs (Karayannopoulou et al. 2003), mast cell disease in humans (Pardanani et al. 2002), pregnancy in animals (Stockham and Scott 2002; Bain 2003), healing of broken bones (Searcy 1969), and other diseases in Dogs (Cornelius 1980). Thus, SAP concentration may be used to identify injured or diseased individuals.

Conclusions

New patterns in physical condition, hematology, and serum chemistry were identified for Gray Wolves. Pups appeared to be under greater nutritional stress than adults as suggested by reduced MF, PCV, and SUN and Hb concentrations in pups. We also confirmed established differences in SAP concentrations between adults and pups. However, abnormally high SAP concentrations were observed in a portion of the adult male Wolves, perhaps, identifying injured or diseased individuals. High PCV in autumn suggested Gray Wolves of this population were in their best physical condition during autumn. High SUN concentrations in spring suggested these Wolves were under little nutritional stress during spring and appeared to be on a good nutritional plane during summer, as suggested by relatively high summer SUN concentrations. Also, high Hb concentrations and PCV in this population were probably a result of higher elevation.

These data, classified by season, sex, and age, provide a baseline physical condition, hematology, and serum chemistry for free-ranging Gray Wolves with a relatively high and increasing prey base in south-central Alaska. However, more information on yearlings and summer is needed to properly understand physical condition, hematology, and serum chemistry of this Gray Wolf population. Although we found several correlations among BW, Hb, PCV, MF, and several other variables, a number of measurements should be used to assess physical condition.

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